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A REVIEW ON ACCELERATOR OPERATOR TRAINING

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Abstract

Operators of accelerator facilities have to be trained in order to safely operate their machines. While the amount of training varies between the different types of accelerators, many best-practices could be applied to the training of operators for a variety of different facilities. The aim of our study is to survey the best-practices for operator training for a larger number of accelerator facilities. The results may provide useful insights to advance the training-plans for operators of particle accelerators.

INTRODUCTION

The successful operation of a particle accelerator requires well trained operators; trained in many aspects from basic accelerator physics to control systems [1]. The actual amount of knowledge needed to be able to safely operate an accelerator can vary significantly for different types of facilities and even with the quality of the operator interface [2].

The PSI operation group runs three accelerator based user facilities: the High Intensity Proton Accelerator, the Swiss Light Source and PROSCAN, a facility for tumor treatment with protons. A forth facility is planned: a Linac based X-ray free electron laser. It is foreseen to go into operation in 2017. In order to prepare for this future challenge we wanted to evaluate the way operator training is handled at PSI.

Little has been published about the specific organisation of operator training at accelerators. Publications on "Operator Training" either deal with the design of tools to reduce training time [2–4], or highlight the importance of training for the operation reliability [5]; they rarely explain best practices or organisational aspects.

The authors aim to get an overview of the best practices for operator training by conducting a survey on how it is currently organised at different accelerator facilities. We wanted to collect good ideas from a large number of facilities and identify some with the potential to enhance the operator training at PSI.

METHODS: THE SURVEY

A survey with 21 questions was send to 20 organisations that operate accelerators. The questionnaire has been answered by the following people: A. Andersson (MAX-lab, Lund), M. Bieler (DESY, Hamburg), R. Flood (APS, Argonne), J. Friedel (DELTA, Dortmund), L. Hardy (ESRF, Grenoble), D. Johnson (FNAL, Fermilab), G. Johns (SNS, Oakridge), V. Kempson (Diamond, Oxford), J.F. Lamarre (Soleil, Saclay), M. Lamont (CERN), A. Lüdeke (PSI, Villigen), R. Müller (BESSY2, Berlin), M. Pont (ALBA, Cerdanyola del Vallès), P. Sampson (BNL, New York), N. Smale (ANKA, Karlsruhe), M. Takao (SPring8) and V. Toma (ISAC at TRIUMF, Vancouver).

The questions were grouped in four categories: about the facilities, the operation group, the training organization and the opinion of the answering person about operator training in general. The questions are listed below.

Questions about the facility: If there is more than one facility, please answer the remaining facility questions for each facility.

1. How many independent accelerator facilities are operated by your institute?
2. Please describe in a few sentences how difficult are these facilities to operate, taking into account the complexity of physics, the quality of beam diagnostics, the level of automation and the diversity of operation modes.
3. How many changes in the operation mode you have per year that require a set-up and some tuning by the operator? (Just give a rough estimate: 40, 200, 1000?)
4. Roughly how many fault recoveries are handled by the operators per year? (Please neglect automatic recoveries)

Questions about the operator group: If you have more than one operation group, please answer the questions of this chapter independently for each group.

5. Is the operation group dedicated to one accelerator facility or to more than one?
6. What is the education level of the operators (rather craftsman or academic degree)?
7. How many operators are on shift (per group)?
8. How often are the operators on shift? (Estimate $<$20%, 20%..50%, $>$50%)
9. Are the operators all educated to the same level of knowledge, or do you have different types of operators, e.g. students for night shifts and experienced operators for day shifts?
10. If the operators on shift cannot identify the cause of a problem, is there an on-call service to support them, e.g. is there a machine expert or an accelerator physicist on call?

Questions about the operator training: If you have more than one operation group, please answer the questions of this chapter independently for each group.

11. How long does it take on average to train an operator to safely operate the facility?
12. Is there formal training for operators, like on accelerator physics or the control system? If yes, please describe briefly the main topics and estimate the total hours an operator spends during his education period in the training for each topic.
13. Is there reserved beam time in the facility operation schedule for hands-on operator training on the accelerator, where the trainee can actually work with the beam under supervision?

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If yes, please estimate the total hours an operator spends in this training during his education period.

14. Is there a possibility for the operator to train on an accelerator simulator? If yes, please describe the capabilities of the simulator in a few sentences.
15. Do you have formal exams for the operator as part of the education period? If yes, please describe in a few sentences the course of the exams: what is tested and how?
16. How much man-power is spend per year to organize operator training for your group? How is the man-power split between: documentation, preparation and actual training?
17. How much training material do you have for an operator trainee to read, as part of his education? Just give an rough estimate in "number of A4/letter pages if printed in normal text sizes (11pt)".

Questions on your opinion: Please express your opinion in a few sentences for each question.

18. Do you think that training-on-the-job is sufficient to train operators or do you rather think complementary formal operator training or dedicated beam time for hands-on training is necessary?
19. Do you think that operators should have a comprehensive understanding of the accelerator or do you rather think it is sufficient for them to be able to fix problems by following standard procedures?
20. Are you satisfied with your current way to train your operators or do you consider ideas in order to improve it? If yes, please describe the ideas.
21. Do you have additional comments on operator training, that you would like to add here?

RESULTS

The survey covered a large variety of very different accelerator institutes (See Table 1). Most institutes are operating one accelerator facility, consisting of several accelerators. But seven institutes do operate a number of accelerators for independent applications.

Table 1: Summary of the questions about the facility

	Q1 facility count	Q2 operation complexity	Q3 mode changes	Q4 fault recoveries
APS	1	easy	15	49
ALBA	1	easy	20	120
ANKA	1	medium	100	20
BESSY II	2	medium	10	<100
BNL	5	mixed	700+	950
CERN	9	mixed	3000+	3000
DELTA	1	easy	20	unknown
DESY	4	mixed	300	650
Diamond	1	easy	3	100
ESRF	1	easy	20	80
FNAL	1	medium	special	>2000
ISAC	4	complex	300	647
MAX-lab	2	mixed	28	56
PSI	3	mixed	730	1470
SNS	1	easy	50	4200
SOLEIL	1	easy	36	700
SPring8	1	easy	30	40

Table 2 summarizes the questions concerning the organization of the operations group. It is striking that only two institutes are operating more than one facility by the same operators, although seven institutes have several accelerator facilities. For the latter often a single operation section is organized in independent groups, each responsible for the operation of only one accelerator facility.

Table 2: Summary of the operation group questions

	Q5 facilities per group	Q6 edu. level	Q7 staff in CR	Q8 shift duty	Q9 training level	Q10 24h on-call physicist
APS	1	BS	3	>75%	same	yes
ALBA	1	BS	1	60%	same	yes
ANKA	1	Craft	0-1	special	same	no
BESSY II	2	mixed	2	10-40%	same	yes
BNL	1	BS	2	70%	varia	yes
CERN	1	mixed	7	60%	same	yes
DELTA	1	mixed	2	≤20%	varia	yes
DESY	1	Craft	4	25%	varia	yes
Diamond	1	Craft	1	60%	same	yes
ESRF	1	Craft	1	80%	same	yes
FNAL	1	BS	4	>80%	same	yes
ISAC	1	mixed	2	75%	same	no
MAX-lab	1	BS	2	>50%	varia	no
PSI	3	Craft	3	65%	same	partly
SNS	1	mixed	3	80%	same	yes
SOLEIL	1	BS	2	>50%	same	yes
SPring8	1	Craft	4	60%	same	yes

The data shows that all facilities have mainly on-the-job training. Only less than half of the institutes have a formal operator training at all. Those who organize a formal training mostly have formal exams for the operators, too. About half of the institutes have dedicated beam time for hands-on training of the operators. Those who do not have formal training often name man-power limitations as a reason; very few are satisfied not to have it. Hands-on training is sometimes not possible due to beam time restrictions; very few consider it unnecessary. Three facilities have simulators or training accelerators for simple "hands-on" training. Several others are working on simulators or plan to develop such a tool. Table 3 shows a summary of the operator training questions.

Table 3: Summary of the operator training questions

	Q11 training in month	Q12 formal train.	Q13 reserved hands-on	Q14 simulator	Q15 exams	Q16 train. manpwr	Q17 train. material
APS	18-24	yes	yes	no	yes	40 h	140+
ALBA	6-9	yes	yes	no	yes	170 h	480
ANKA	3-4	no	no	no	no	0	0
BESSY II	3	no	no	WIP	no	0	100+
BNL	12-36	yes	yes	yes	yes	2 FTE	2000+
CERN	3-4	yes	yes	no	no	100 h	100+
DELTA	12	no	no	no	no	0	0
DESY	6-24	no	yes	no	no	180 h	35
Diamond	3	no	no	WIP	no	0	wiki
ESRF	6	no	no	no	no	0	50
FNAL	18-24	yes	no	no	yes	1 FTE	2000
ISAC	36	yes	yes	test stand	yes	varies	500
MAX-lab	≥12	yes	yes	no	no	?	50+Book
PSI	3-50	yes	yes	no	yes	174 h	450
SNS	6-12	yes	no	yes	yes	300 h	a lot
SOLEIL	6	no	yes	no	no	0	1000
SPring8	3	no	no	no	no	0	0

Most answers suggested that the training should be mixture of on-the-job, hands-on and formal training to get the best results. The majority considered it important that the

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operator has a comprehensive understanding of the accelerator and does not only follow given procedures. Only half of the people were fully satisfied with the current state of the operator training at their facilities. Table 4 summarizes the answers on the opinion questions.

Table 4: Summary of the opinion questions

	Q18 best practice	Q19 comprehensive understanding	Q20 satisfied with current training
APS	mixture of all	yes	yes
ALBA	mixture of all	yes	no
ANKA	On-the-job	no	yes
BESSY II	mixture of all	yes	no
BNL	mixture of all	yes	yes
CERN	mixture of all	yes	partly
DELTA	On-the-job	no	yes
DESY	On-the-job&hands-on	yes	no
Diamond	On-the-job&hands-on	no	partly
ESRF	mixture of all	yes	no
FNAL	mixture of all	yes	partly
ISAC	mixture of all	yes	yes
MAX-lab	mixture of all	yes	yes
PSI	mixture of all	yes	no
SNS	mixture of all	yes	yes
SOLEIL	dedicated beam time & mix	yes	yes
SPring8	mixture of all	yes	no

DISCUSSION

Only half of the people are satisfied with the current state of the operator training at their facilities; and even most of the others strive to improve it. This suggests that a collaboration on best practices and the enhancement of operator training could be of great value for the community.

No facility mentioned a collaboration on operator training material with others, although many facilities report a shortage on man-power to build and maintain the training material. Again this could be addressed by a collaborative effort on shared training material for accelerator operators. Laurent Hardy from the ESRF expressed the idea to set-up a collaboration on on-line video lectures in the style of modern massive open on-line courses (MOOC) [6], and Dan Johnson from Fermilab is looking into MOODLE.org [7] for operator training, a free software to create on-line video lectures.

Three facilities have simulators or training accelerators for simple "hands-on" training. Several others are working on simulators or plan to develop such a tool. While a simulator is often very specific to the type of the facility, a coordination of these efforts and an exchange of the experience could be fruitful for the whole community.

It would be interesting to know how the different facilities organize their "typical hands-on" training. At the SLS we use a tool to create random faults of the accelerator. What approach is used elsewhere? Unfortunately, we did not ask the right questions in the survey to gather this information.

The evaluation on the answers revealed some more problems of the survey. In question 4 we've asked how many fault recoveries are handled by the operator. We failed to specify the exact meaning of a fault and obviously there are very different views on what a fault is; therefore the numbers of the different facilities are not comparable.

Some answers suggested that the amount of formal training depends on the number of new operators that have to be trained each year. This number was mentioned for some facilities and varied considerably. Unfortunately we failed to include this question in the survey either.

CONCLUSION

The amount of publications about the topic of operator training is rather small. In particular new facilities could benefit a lot for their design of the operator training if a catalogue of best practices would be available. A large number of accelerator institutes strive to improve their operator training further; that suggest that there is a large potential for collaborations on operator training. Many facilities do currently suffer from a shortage of manpower to organize and enhance their operator training; collaborations could help them in many aspects: shared on-line courses, shared simulation tools or a catalogue of best practices would allow to get the best results with a minimal effort.

OUTLOOK

The SwissFEL facility at PSI will go into operation in 2017. This will give us some time to organize the training of the operators for this complex facility. We plan to participate in the creation of shared on-line operator courses, for example based on moodle [7]. We will contact other FEL facilities to collaborate on the operator training and we will explore in some more details how hands-on training is handled at other accelerator facilities.

We intend to use the upcoming Workshop on Accelerator Operations [8] as a platform to encourage other laboratories to publish more about their operator training, and to join in a collaboration to develop this topic further.

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