EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE

CERN - PS DIVISION

PS/DR/Note 2001-047

LONG TERM CONSOLIDATION PROGRAMME

FOR THE PS COMPLEX

- 2002 to 2016 -

J.Gruber

In order for the PS complex to completely cope with its different functions over the next few years, and above all its role as pre-injector for the LHC, the necessary consolidations must be planned and achieved. The aim of this note is to give a full inventory of the consolidation activities that are required in the long term, so that the PS complex continues to run at its current performance levels, and thus define a consolidation project for the next five years.

Geneva, Switzerland
18 October 2001

1. Consolidation of the PS complex, past, current and future situation

1.1 Consolidation during 1992 - 2001

i) Taking account the growing needs of the overall maintenance of the different accelerators in the PS Complex and above all the ageing equipment, consolidation since the 1990's has become a necessary activity: the maintenance of the equipment's functionality with a minimum of breakdowns and interruptions is a major objective of the Division.

Two separate budgets have financed the consolidation over the last few years:

- the consolidation project (PS/D-082) which is allocated yearly to the Division and since 1993 amounts to 1 MCH per year.
- a specific amount (called "PS Subvention") which since 1993 is taken each year from the exploitation budget of the Division and is devoted to financing necessary consolidations: an average amount of 1 MCHF was allocated up until the 1999 budget year.

ii) The budget restrictions that have been applied successively over the last few years, have severely reduced the exploitation budgets: the budget for PS has been reduced by over 50 % since 1993. The direct consequence of this budget reduction has been on consolidation: since 2000, the allocated amount has been less than 240 kCHF, which is no more sufficient.

The financial policies for consolidation over the past few years have allowed us to maintain - in the medium term - the PS complex's performance levels which are still satisfactory, but without allowing for a satisfactory **consolidation programme for the long term.**

iii) Nevertheless the detailed examination of the statistics of the faults of these two last years shows increasingly many failures, and signs forerunner of breakdowns (Annex 3: fault statistics since 1996). To maintain the performances we must absolutely continue a sufficient consolidation.

1.2 Consolidation for the future

The decision to use the PS complex as an injector for the LHC for over 10 years, due to start in 2006, implies the necessity for a longer term consolidation. The renovation project of the PSB and PS for the LHC (PS-9514 Project, 1995-2000) should be considered as a first stage of consolidation, that concerns the energy increase of the PSB and the improvement of the beams for the LHC. A second stage leads us to defining **a core consolidation for the long term**.

Consolidation is important for the future, not only for the performance levels and to be in phase with technology, but also due to a reduction in staff, and we must have a complex that is more effective and reliable as we will have less staff to ensure its operation.

1.3 For these different reasons, it has been decided to establish a complete and detailed consolidation programme for the future. This note has two sections:

- **a general consolidation programme for the long term (2002- 2016)**,
- **a defined consolidation project for the next five years,** focusing principally on the priorities for the LHC and analyzing in detail the necessary resources.

2. Strategy: definition and priorities

2.1. The equipment that needs to be consolidated is split into 3 categories based around the running-in of the LHC:

- category 1: 0 - 5 years (2002 - 2006) before the start of the LHC
- category 2: 5 - 10 years (2007 - 2011) after the start of the LHC
- category 3: 10 - 15 years (2012 – 2016) " " " " (long term)

2.2 The classification of the equipment into the 3 categories was carried out at each group level, taking into account the conditions set out below.

i) The consolidation concerns all of the equipment of the accelerators and the experimental zones, that are the direct responsibility of the PS division. For the warm magnets and the vacuum, the SL/MS and LHC/VAC groups have been consulted, to determine what should be included in the project: the estimations are given in the different tables.

The questions concerning civil engineering, electricity distribution, water, ventilation and security have not been included in this analysis.

ii) The consolidation is based on the replacement of equipment (on a one for one basis) and a certain number of criteria have been defined to encompass the specific priorities:

- old equipment: > 35 years for static hardware elements
  15 - 18 years for electronic equipment
  (in general, maybe less for the control modules)
- equipment that no longer meets security standards,
- equipment subjected to radiation, with a limited lifetime,
- equipment showing a noticeable increase in faults or a lack of reliability with the risk of long term breakdowns,
- equipment that has problems with the supply of reserve parts,
- equipment that has a maintenance workload that is too expensive,
- equipment that could be replaced with "new family": the consolidation should strongly encourage the standardization of equipment.

The above list is not exhaustive and some criteria could be combined to reinforce the priorities and justifications.

iii) To help set up the consolidation project for the next five years, the priorities have been defined as follows:

- on the one hand the priorities that deal with the accelerators and beams:
  LHC : priority 1, SPS and PS Fixed Target : priority 2, Isolde : priority 2
- on the other hand the priorities that relate to specific equipment:
  high priority or medium/low priority

2.3 The priorities were finalized within the Division, taking into account the different factors mentioned above, the human resources and the projects of the Division.

3. Long term consolidation programme (2002-2016)

Table 1 summarizes the different activities that are shown in detail in annex 1, and gives an indication of the necessary investments - for material - in the long term:

- category 1 (next 5 years), is the busiest as it deals with the necessary consolidation for the start of the LHC: this has been studied in detail to help define the consolidation project,
- for categories 2 and 3 (2007-2016), we have some indications of the important jobs in particular those that must be budgeted for as early as possible:
  - replacement of the PS main magnet power supply : 10 MCHF
  - renovation of PS main magnets and other magnets : 3 MCHF
  - renovation of the figure of 8 (PS main magnets): cost after evaluation study
  - the other jobs are financially less important , but still necessary
  - vacuum (VAC-Group, LHC Division) : 4.1 MCHF (request by VAC Group)

		Foreseen investments (kCHF)			
	Areas needing consolidation (Group)	**Category 1 (2002-2006)**	**Category 2 (2007-2011)**	**Category 3 (2012-2016)**	**TOTAL**
1	Accelerators and experimental areas (PS/AE) and magnets (in collaboration with SL/MS)	1240	1000	1000	3240
2	Beam diagnostics (PS/BD)	2580	450	200	3230
3	Controls (PS/CO)	2250	1200	500	3950
4	Operation (PS/OP)	280			280
5	Power (PS/PO)	6020	11245	3750	21015
6	Particle production (PS/PP)	1150	1140	130	2420
7	Radio frequency (PS/RF)	1980	930	600	3510
	TOTAL PS	**15'500**	**15'965**	**6'180**	**37'645**
	Vacuum (LHC/VAC)	2960	2385	1710	7055
	GRAND TOTAL PS + LHC-Vacuum	**18'460**	**18'350**	**7'890**	**44'700**

Table 1 : Long Term PS consolidation - foreseen investments for material

4. Consolidation project for the next five years : detailed analysis

A detailed inventory of equipment to be renewed is shown for each of the groups in a table that gives the following indications for each job: financial estimation, staff estimations and industrial support, yearly planning (specifying the time periods) and specific comments (justifications, major downtime of the beam in case of breakdown).

The financial resources with details for each year are summarized in Table 2.
The staff requests and the need for Industrial Support (available or foreseen) are shown in Table 3.

Annex 2 shows the tables established by the different groups.

Main needs of consolidation in the different areas of PS during the next 5 years :

4.1 **Accelerators and experimental areas (AE)**

After investigations and review of the needs, most of the proposed consolidation work concerns magnets :

i) For the PS main magnets it is proposed to start with an evaluation study on one magnet, possibly during the next shut-down, with the aim to define a complete renovation programme that could be set up and spread over 12 to 15 years (6 to 8 magnets upgraded per year). The evaluation study requires little resources, but the complete programme, once evaluated, may require large amounts, more in terms of industrial support than material.
The same is valid for the PSB magnet, with lower priority.

ii) Construction of spare magnets, already started for MNP23, but awaiting financing for Q120, is vital to ensure that test beams and physics in the East Area do not suffer major stops in the future.
This work will have to be carried out under SL/MS responsibility and therefore requires that the team involved is able, not only to cope with the induced workload, but also to prepare the required documentation (which may need significant resources).

This consolidation does not include a consolidation programme for the AD, as this should be a dedicated project beyond 2006, as it was launched for ISOLDE.

4.2 **Beam diagnostics (BD)**

For the consolidation and rejuvenation required in the different beam diagnostic domains to be ready for LHC era, two different cases have to be considered :
- systems for which the existing technology is still valid and a straightforward reconstruction is convenient,
- systems technically obsolescent for which a reconstruction benefiting from new technologies and industrially available components can reduce the preventive maintenance work load as well as the time needed for tuning and fault fixing.

i) Into the first category falls the renovation of the PS tune-meter, the replacement of TT2 wide band pick-up electronics, the replacement of the PSB closed orbit electronics and the construction of spares for the multi-wire proportional chamber (MWPC) used in the East Hall and in the AD Hall (second priority)

ii) In the second category four systems are considered:

- The electronics and computer interfaces of the PS beam transverse position observation and measurement system, which will be completely rebuilt using new technologies to simplify and increase its robustness as well as its performances for the observation of protons and ions for LHC.
- The electronics and computer interfaces of the beam profile measurement systems of all the machines of the PS complex which will be redesigned and rebuilt after a revue for a rationalisation of its use.
- The TV screen observation system with its associated in/out screen controls, camera remote diaphragm control and frame grabbers including the introduction of a commercial digital transmission and multiplexing system to replace the old obsolete analogue transmission hardware. This will provide a powerful tool for machine set-up and data logging.

- The reconstruction of the stepping motor control interfaces used for slits, tuners, wire beam scanners, etc. to replace obsolete present interfaces by commercially available systems.

4.3 **Controls (CO)**

i) The "SOS Video" system is essential for the operation team, allowing among other things to visualize the beams on scintillator screens. This system is 20 years old; the hardware is completely obsolete and only one single person in CO has still some hints on how the related software works. It is also the last part of the control system which is hardwired between the TV cameras and the observation displays in MCR. Collaboration with BD is part of the project since BD handles the mechanical part of the system (screen movements, and camera controls).

ii) The CAMAC control of PSB and AD (lower priority) power supplies is also a legacy system for which competence is fading away and for which the hardware is no more part of the standard equipment of the PS control system. The replacement of this control system by MIL 1553 is linked to the replacement of the power supplies themselves. It is handled in collaboration with PO.

iii) nAos is an observation system for the analogue signals coming from accelerator equipment. It is indispensable (i.e. more than 99.5 % availability needed) to adjust the machines, mainly to synchronize precisely all the pulsed elements. The system is still fully operational but the 2 main VXI modules (crate controllers and oscilloscope modules) are no longer available, and no equivalent modules are being produced. Within a timeframe of a few years the spare modules will all be in operation and a progressive seamless replacement with an other technology will have to be started.

4.4 **Power Converters, Kickers, and Septa (PO)**

The PO group is responsible for a large variety of different equipment that needs to be consolidated to remain exploitable in the near future:

i) There is still much outdated electronic equipment to control, monitor and protect power supplies for magnet, kickers, and septa for which no spare parts are obtainable and systems with archaic controls interfaces that are no longer maintainable. Renovation of this equipment is of prime importance and concerns PS power supplies and mainly kicker systems for fast ejection and Continuous Transfer of protons from the PS.

ii) A large contingent of dissimilar power supplies required to power Pole Face Windings, Dipole, Quadrupole and Multipole magnets for Linacs 2 and 3, PSB, PS and the transfer lines need urgent consolidation or replacement in order to cope with short term requirements and to be ready for the LHC start-up and exploitation.

iii) The beam slicing septa used for the continuous transfer is a very delicate device, because it has to resist large radiation doses. A new bakeable electrostatic septum, that can be quickly replaced, must be constructed to replace the existing fragile septum.

iv) The entire Continuous Transfer fast ejection kicker system is completely outdated. Both the different pulse generators and the electronics control system need total renewal. However, the PS division has not yet clarified whether a

new, entirely different transfer scheme will be used. Either way, new equipment or heavy renovation is required.

v) The Motor-Generator set of the PS main power supply (MPS) was put in to service in 1968 with a lifetime of 35 to 40 years. This time limit will be reached at LHC start-up. Although, according to the yearly revisions, the pulsed rotating machines seem actually in reasonable shape, its future replacement must be planned - a mayor breakdown could easily lead to many months of interruption of physics at CERN. A preliminary study proposes to substitute the motor generator set by a direct link of the PS MPS to the power grid. This requires a new transformer of 400/18 kV, with a 50 Mvar reactive power compensator, an upgrading of the MP6 cable link from the Prévessin to the Meyrin site and a further 40 MVA transformer of 18/6 kV. A 6 kV substation with switchyard to permit rapid commutation of the PS MPS from the Motor-Generator set to the new installation and the corresponding building and infrastructure are also needed. A new power converter (12 phase system, 6000A/10 kV) must be also foreseen.
A solid collaboration between PS and ST divisions and the Services Industriels de Genève is indispensable for the achievement of a serious study (year 2004-2005) and the final execution of this necessary and essential project to CERN.

4.5 **Particle production (PP)**

i) The two Linacs will both serve as LHC particle sources. Linac 3 is relatively new. As to Linac 2, quite a few items - including magnet coils (SL/MS), Linac 2 ventilation (ST/CV) and electrical switchboards (ST/IE) - need renovation after 2006, but there is no item under direct PP responsibility asking for consolidation until 2006. Equipment under the responsibility of PO and RF groups will have to undergo consolidation during the coming five years. Replacement of a leaking drift tube - each is unique - could result in a down time without beam of up to one month or much reduced Linac 2 performance.

ii) By definition, ISOLDE has lower priority than LHC. The scenario underlying PP's proposal foresees the fabrication of a 3rd front-end (second Chinese copy) so as to dispose of a spare by mid 2002. Then the new-type front-end would be designed, built, and made available by 2005. These items are not part of the "ISOLDE Consolidation Project" approved recently. Note that running ISOLDE without a spare front-end may lead to a loss of up to 150 shifts per year in case one of them breaks down (as happened in 2001).

4.6 **Radio frequency (RF)**

Main needs of consolidation of RF equipment during the next 5 years :

i) The RF equipment of the proton Linac (Linac 2) has been designed and built during the 70's, and the major part of the low level electronics requires an important effort to be upgraded into a satisfactory state for its vital role as the source of protons for LHC. The heavy ion Linac (Linac 3) needs a similar effort, because many parts have been simply copied from Linac 2 or even recuperated from Linac 1. The renovation of the interlock systems has started in 2001 and must be actively pursued in 2002 and 2003. The study of renovation of the low level RF using modern technology should begin in 2002 and be implemented in 2003 and 2004.

ii) The performance of the PS ferrite cavities system still needs to be improved over the next 5 years, especially concerning the impedance seen by the beam (RF feedback). The gap short circuit relays are also an important source of concern, because they age fast and require frequent maintenance with a single supplier left in the market: effort is required quickly to develop spare solutions and implement them.

iii) Beam synchronization is a delicate operation that takes place at every transfer of particles between synchrotrons, and the capabilities of existing analogue electronics limits the reproducibility of performance. Development of new equipment based on DSP technology is needed to help guarantee the beam characteristics at the standard of the LHC era.

4.1 **Other activity linked with the PS : Vacuum (LHC-VAC Group)**

For the PS Consolidation Project, a new analysis of the vacuum equipment used in the PS Complex has been done in August 2001. Approximately 600 ion pumps, 300 valves, 210 turbo molecular pumps, 250 primary pumps, 12 cryo-pumps and 300 vacuum gauges are currently used in the various vacuum systems of the accelerators. The most important criteria for the exploitation of these components is the limited lifetime, which was given previously (PS/DI/Note 97-09).
In order to guarantee the exploitation of these systems over the next 15 years, vacuum equipment has to be changed and regularly maintained depending on the age and performance. During the next five years, highest priority must be given to change approximately 10 % of all ion pumps, 15 % of the valves, 30 % of all turbo molecular and primary pumps and 30 % of all Penning/Pirani gauges.
The estimated budget does not take into account manpower, industrial support, spares and replacement of vacuum chambers, items which should estimated and included in the LHC/VAC consolidation project.

5. Resources for the next five years: summary

5.1 Budget request for material

For the next 5 years, the consolidation project for the PS equipment amounts to 15.5 MCHF for material, which represents a yearly average of 3.1 MCHF, although this becomes 1.9 MCHF if only the priority 1 jobs are considered.

As was explained in the introduction, the amount allocated to the consolidation over the last two years amounts to 1.2 MCHF/year due to a reduced PS exploitation budget.

For the consolidation of the vacuum, a total amount of 2.96 MCHF appears to be necessary during the next 5 years: the requests of the different divisions will be examined at the sector level.

5.2 Industrial Support

Industrial support represents approximately 10-11 man-years, per year, over the first three years: some of the industrial support is already working on the consolidation in progress (approx. 4-5 man-years). So the consolidation project needs an extra 6 man-years, which represents an additional budget of 500 kCHF/year, which is not included in the requested budget for material.

If only priority 1 jobs are considered for the next few years, an extra of only 4 man-years industrial support are needed, or 330 kCHF per year.

5.3 Manpower requirement

The PS staff needed to ensure the consolidation project is on average 12 to 15 man-years, per year, over the first five years. The estimates of the staff that are currently working on the consolidation projects shows us that we need to increase the staff levels by 40 - 50 %. The number in this document have been taken in account in the manpower plan of the Division.

6. Conclusion

The total cost of the consolidation project for material and industrial support amounts to 3.6 MCHF / year during the next 5 years.

The consolidation programme has largely been discussed within the division (at the PSMB of 26 September 2001) and the priorities were fixed with the boundary conditions recommended in the Medium Term Plan for the most urgent renewal of equipment to maintain the reliability and the performances of the PS complex for the start up of the LHC.

The proposal is to shift the jobs in priority 2 to the next slice (2007-2011), and in this case the required total amount is 2.2 MCHF per year, for the next 5 years.

After that time, the delayed jobs must be done, and will represent an increase amount of the annual budget above 3 MCHF / year.

The request will be presented at the Sector management level.

Acknowledgements

This note is a short summary of the great amount of work done in the different groups in the PS, LHC and SL Divisions; the author wishes to thank all the group leaders and other experts. The advice and comments of B.W.Allardyce, J-P. Delahaye and K. Schindl were also very useful.

Annex 1 : Long term consolidation programme 2002-2016
Annex 2 : PS consolidation project for the next five years
Annex 3 : PS complex : fault statistics since 1996