May 12, 2003

Review Committee Report of the 2nd CNGS Review
28-30 April 2003

THE CHARGE TO THE REVIEW COMMITTEE:

To assess the progress made so far, including design changes. To assess proposed milestones and schedules and their validity and practicability. To consider whether any technical or management issues may require more attention. To look for possibilities of cost reduction, considering the budget situation.

EXECUTIVE SUMMARY

Progress: The project has made very good progress over the last year! Highlights include: the tunnel excavation is complete and finishing of the tunnels is well under way; delivery of horns is expected soon; magnet production is underway (12 series MBG magnets already received); the contract for the decay pipe construction and installation is signed; studies of extraction optics are complete; conceptual design of target is done; primary beam monitoring is defined; aluminium cooling blocks, graphite blocks, and iron shield blocks for the hadron stop are all in mid-acquisition.

Design changes that have been made appear well motivated.

Schedule: The civil construction is on schedule, and the enforced delay due to the one-year CERN accelerator shutdown considerably reduces schedule concerns for the technical components, which otherwise would be very tight. It is none-the-less urgent to address the radiation calculation issue described below, without which it will not be possible to finalize designs.

Management Issues: We are very pleased to see that the project now has a full time deputy project leader. In general, manpower appears to be at a sufficient, though certainly not generous, level. A few specific areas deserve comment.

A larger FTE will be needed soon for installation coordination, installation and handling of beam monitoring equipment, and transport.

There is concern that the high priority PS magnet problem may impact resources available for the CNGS work.

Now that the CNGS team has momentum, it is important that the team stay intact, and not be siphoned off for other work. This is especially important since the retirement of several staff members will already be disruptive to project continuity.

The most significant manpower problem, in the opinion of the committee, is the resource for calculation of heating, radiation dose, and residual radiation induced by the beam. Significant design changes in the target station could be required when alignment requirements will be confronted by thermal expansion effects. Similarly, the stripline connection to the horn may have to be redesigned when beam thermal effects will be added. The Radioactive Handling Working Group must have residual radiation calculations as input to make sensible decisions. We have been told that 1/4 FTE is starting to work on providing these calculations. Given the number of issues to be addressed, and also the fact that some iteration with design changes induced by the initial calculations will likely be necessary, 1/4 FTE is not sufficient.

Recommendation: Vigorous efforts should be make to increase the resource for calculation of beam heating and residual radiation in the near term.

Technical Issues: The issue of safety in case of decay pipe window failure during beam operation has recently been identified as a non-trivial problem, which the design team is aggressively confronting, looking for the most cost effective solution.

The design team is also struggling with several issues related to having a very small intense proton beam spot size, namely the likely failure of a titanium window if used at the end of the primary beam pipe, the inability to measure the spot size near the target due to the likely failure of the TBIU monitoring chamber, the likely failure of the TBID target multiplicity split foil monitor if the beam wandered off the target, possible excessive stress on the target rods if struck off-center by the beam, and perhaps failure of helium tube windows if beam wandered off target. It could be possible that all of these issues could be avoided by the adoption of a factor of two larger spot size on target, with perhaps a modestly larger target, at the cost of a small reduction in neutrino rate. The cost savings for equipment due to such a change may be relatively modest; more important is probably the easing of R&D burden on the project and the ability to finalize designs.

Recommendation: We suggest that the design team examine the option of increasing the beam spot size to see if it makes sense.

Costs: Over the last year, the CNGS team has worked hard to contain costs. Savings due to design simplifications and obtainment of favourable contracts have roughly balanced cost increases in other areas, so that estimated cost to completion has not changed, and use of contingency is minimal. This is commendable.

There are several outstanding issues that indicate possible need for use of contingency. Examples are that equipment cost for hot handling is likely underestimated, claims from the civil construction are outstanding, and the recently realized ramifications of a failure of the decay pipe window may require remediation. The review team notes that contingency is tight, especially with the budget reduction last May, but that is not different than other projects at CERN now.

In view of the tightness of the contingency, perhaps some of the radioactive handling tests and similar costs may properly be placed on an operating budget in 2005 rather than as a direct cost to the project, if needed.

The review team looked for places where a cost savings could be realized, without finding any good candidates (other than perhaps the above described increase in beam spot size).

TABLE OF CONTENTS

ACKNOWLEDGEMENT

The review team thanks Director Wyss for providing us with this opportunity to learn about the CNGS project.

We wish to express our appreciation for the excellent set of talks presented to us. We believe that the large amount of work that went into the presentations will be valuable to the CNGS team in its own understanding of the project. Certainly some of the reviewers learned things that will be valuable to their projects as well.

Respectfully submitted,
The members of the review committee:

Michel Chanel (CERN),
Alain Herve (CERN),
James Hylen (FNAL) (Chair),
Tadeusz Kurtyka (CERN)
Jacques Lettry (CERN),
Dave Pushka (FNAL),
Kazuhiro Tanaka (KEK)

COMMENTS ON INDIVIDUAL SYSTEMS

Management Issues

Findings:

Since the 1st review the management structure has been strengthened with the appointment of a full time Deputy Project Leader. A technical group is meeting frequently to oversee progress. The presence of a person in charge of the 'Master Installation Schedule' is commended.

An earned value analysis will be rolled out in May; compilation of the work units to be tracked has already been completed. Schedule items are not linked to each other (predecessor-successor) but estimated costs, actual costs, planned schedules and actual schedules are included.

Comments:

Management staffing appears to be adequate for the design phase. 'Radiation and General Safety' will have to be properly covered after the retirement of G. Stevenson. The integration of the CNGS project inside the AB Division structure may also need strengthening.

The project is commended for using EDMS for documents needing approval, or which have to be available in the future.

CNGS QA is handled inside the general LHC QA plan. However it is felt that some aspects should be directly linked to the CNGS EDMS structure to allow an efficient and direct oversight by the Project Leader. This could be the case for handling 'Major Non-Conformities' and 'Survey Operations' for example.

For Earned Value Reporting, monthly progress updates require real, measurable effort from each project engineer or manager. Where work is performed under umbrella contracts (electrical installations), effort to load each identifiable activity and with costs will allow the EV system to report useful information. For large contracted jobs (e.g. the decay tube installation), the committee suggests requiring a cost loaded schedule from the contractor; and using a one or two activity placeholder in the EV system until the contractor submits the schedule.

The project is moving fast towards the installation phase, starting with the Hadron Stop. Installation of the proton beam line is nearly standard, however installation in the decay tunnel will be difficult. Access is limited and operations will have to be carried out in the proper order, and in the proper time window to mitigate technical and financial risks. Extensive handling tests will also have to be accommodated in the installation schedule.

Recommendations:

The Committee recommends the appointment of an ‘Installation Coordinator’ also in charge of driving the ‘Master Installation Schedule’ which should be the guide for all technical groups.

Proton Beam

Findings:

BEAMLINE DESIGN. The design number of protons per year on target has not changed since 1998. The optics of the line has not changed since 2002.

Since the 2002 review, calculations have been made to verify that the effects of different types of errors (extraction, dipole field, quadrupole displacement, etc.) can be compensated by the foreseen correctors, and that the position measurement pick-ups are sufficient. This calculation allowed the removal of two correctors (generating cost savings), and indicated that the remaining needed correctors will be powered to about one third of their maximum strength. One pick-up station has been added. Whereas previously it was planned to instrument only one plane per BPM, now both the x-y planes of each BPM will be equipped with electronics to avoid unseen π-bumps (at extra cost of 120kF). The maximum orbit excursion and the RMS orbit are then reduced by a factor of about 5.

The effect of different fluctuations from shot to shot on the spot at the target has been analysed. They are mainly due to the extraction fluctuations and are computed to be less than one sigma of the beam. This seems reasonable as far the beam is well contained on the target dimension (radius =4 sigma’s), but modest mis-steering can induce forces on the target (see the section on the target station). A collimator will be installed in front of the target to protect the horns in case of large mis-steering of the beam.

MAGNETS. All seems to be going well as far as the quality and schedule for magnets are concerned. The main problem is the resource available for the magnet group as they are involved in other projects and in addition the renovation of the PS magnets, which came recently on top of the foreseen work.

VACUUM SYSTEM. The technical work is well in hand. Some contingencies can be foreseen due to delays. The main problem is that the exit window may need to be made of beryllium, where toxicity is a problem in case of window failure.

INSTALLATION. The extraction systems in the SPS and the line TT40, which are common to LHC extraction, are now installed and will be commissioned by the fall of 2003. The TT41 line will be installed during the second semester of 2005, and the coordinator is now nominated. A detailed installation plan has yet to be issued.

Comments:

The instrumentation in front of the target is sufficient for determining the profile and for alignment control. The possibility to add another pick-up position monitor after the reflector has to be seriously considered.

The availability to the project of resources from the magnet group is a problem of general management at CERN, which has to be followed up seriously.

Recommendations:

If mis-steered beam on target would endanger the target, we recommend studying the possibility to reduce the magnification factor between injection and target errors, although a better option may be to ensure the target is robust to such mis-steering.

If a Be-window is chosen, add protection to avoid contamination of the whole TT41/TT40 lines in case of window failure (a fast valve or an upstream titanium window?).

Windows in the Beamline (near the target station)

Findings:

This issue is addressed separately, as it is estimated to be conditioning the progress of design in at least three areas, vital for the project:

1. Primary beam vacuum system - TT41 vacuum system exit window,
2. Target station (air/He windows of the Target Units),
3. Beam diagnostics (upstream and downstream Target Station beam monitors).

Although not presented, the upstream helium tube windows could presumably also be problematic.

In all these cases the outstanding issue is: what material can be used for the windows? The standard SPS solution of titanium windows cannot withstand the high intensity, small spot, fast extracted CNGS beam. Thus, unless a drastic solution of increasing the beam size is considered, the feasible solutions are to consider beryllium or novel/exotic materials windows that are tentatively estimated as fulfilling the requirements. However, these tentative results presented during the Review are not yet conclusive.

Recommendations:

Vigorous studies should be continued to clarify:

- Limits for titanium windows as a function of the beam size,
- Temperature rise + strength estimation for various window materials vs. Ti,
- Choice of the window material,
- Cost / schedule implications.

In the case of choice of beryllium, that may preferred for its precedent use in HEP installations (with good and bad experiences in this respect - e.g. see FNAL experience), failure analysis should be made with the aim to minimise the risk connected with Be contamination. As mentioned in the proton beam section, segmentation of the vacuum line with a fast valve or an additional (titanium?) window is worth considering.

Target Station

Findings:

The strategy adopted starts with the design of a target unit. The unit consists of the elements that are the beam target, an almost thermal-dilatation free CfC composite support to keep the elements aligned, and a tube to contain an encapsulating inert gas atmosphere and any radioactive contamination that may be produced by the target elements being struck by beam. Five such target units are mounted in the target assembly, forming a sort of five shot revolver, such that a new unit may be rotated into the beam when one unit fails. This also provides the possibility to have differently optimised units on tap, with various balances of neutrino yield and level of stress in the target elements. The cooling is done by force air, which involves no moving parts in the target hall.

The materials chosen are Be or C-Si composite for the unit windows, helium for the inert gas, and graphite for the target elements. The graphite has grain size10μm, and V= 2.4 mm/μs so that the 10.5μs beam spill time is close to the radial relaxation time.

Comments:

The strategy adopted is excellent. The committee is especially intrigued with the idea that one could easily in a short time back off to more conservatively designed elements if for instance the first target failed rapidly or if proton beam positioning stability were somewhat below specifications. (Beam positioning in X direction is projected to have one-sigma variation of 0.36 mm, as compared to the 0.53 mm nominal beam size).

The target material will mainly lead to ^{22}Na and ^{8}Be; activities should not be a waste disposal issue. The exception could be that Be windows would be mixed waste.

The cooling strategy is also commendable, since all parts with reasonable likelihood to fail are in the target service gallery rather than the high radiation target hall.

Recommendations:

Fatigue tests on single graphite elements are recommended to validate the lifetime of an element and its support under longitudinal and radial oscillation modes as found in off-axis irradiation.

The overall alignment incertitude should be estimated. The actual status leads us to recommend a study of the target response to a systematically misaligned beam.

A low intensity proton scan across the target with TBID readout should allow one to centre the beam on the target, and monitor it. However, we were told the survivability of the TBID is in doubt because of the small intense beam spot size. The use of the TBID (or a replacement) and/or the muon detectors to diagnose the status of the target thus has to be clarified, as this is a critical function.

The installation, alignment and removal should aim at a fully remote controlled handling in view of (i) the unknown delay required between turning off the proton beam and first access (ii) the unknown dose rate at the maintenance work place (iii) the announced increased radiation protection safety requirements. If the project will instead rely on human intervention, for instance to connect or maintain the motors on the marble wall in the current design, this must be justified by the presentation of calculations showing that the dose from such operations will be acceptably low.

Energy deposition and estimation of dose rates within the target area are mandatory to complete the design. Energy deposition through the entire support assembly will need to be estimated in order to understand the effects on alignment of thermal expansion.

Horn System including Power Supply

Findings:

Horn construction is well under way, with deliveries to CERN soon. Power supply capacitors are about to be ordered. Thyristor switches are purchased and tested. Transformers have been recuperated and modified. A reasonable testing period is available before installation. Water supply cooling system has yet to be designed.

A spare horn will be constructed, but no spare for the reflector.

Comments:

Progress in general appears very good, and very significant cost savings have been achieved with the power supply system.

Given the budget situation, the committee believes the decision to not build a spare reflector is a correct balance of risk versus impact.

Recommendations:

While horn and power supply are at an advanced (construction) state, the stripline connection and hot handling appear to be in the design phase. Some concerns with the stripline connection to horn as presented:

(i) The entire stripline from floor to horn is a rigid structure, which may not have enough flexibility to allow for thermal expansion due to beam heating of the stripline. (Note WAMF for example of a flex joint). The first step to study this is a Monte Carlo calculation of beam heating of the stripline.

(ii) The remote clamping of the stripline to the horn, while an interesting design, will likely need revision once dose rate to the person loosening/tightening bolts is calculated. (The connection for the horn feet may have similar concern). The design should be done in close cooperation with the Radioactive Handling Working Group.

(iii) The bolt heads to be loosened in case of horn horizontal position adjustment are in too awkward a location.

(iv) The permanent stripline fingers at the floor appear very difficult to repair if they get damaged in a horn changeover or develop some other problem. A repair scheme, or else at least a risk analysis, should be presented.

Vacuum Decay Tube Windows

Findings:

An existing, un-used, 2mm thick titanium window has been recuperated for use in CGNS as the upstream decay tube window. It is identical to one used in WANF for full vacuum service. Calculations on the existing window have been made and indicated that it is appropriate for the service. No special cooling is required. An X-ray inspection of this existing window is planned.

A 50 mm thick carbon steel plate with active cooling is being planned for the downstream window of the decay tube. Stresses from vacuum and thermal loads have been calculated to be satisfactory in a model where beam misses the target.

A hazard analysis of the effects of a catastrophic failure of the decay tube upstream window has been performed. Results indicate that high wind velocities represent the greatest hazard to people. Designs of a safety barrier have not been made nor budget assigned.

Comments:

Appropriate engineering analysis of the windows appears to have been performed. Inspection of the existing window is scheduled with sufficient lead time that over one year is available should the existing window prove flawed. Decay tube ends represent little cost or schedule risk.

The window failure hazard analysis does not include the mitigating effects of the volume of the temporary construction shaft. The project should continue to pursue the design of a safety barrier to protect people upon entry of all of the spaces, especially ECA4.

Recommendations:

Beam heating for the case with beam hitting the target should also be checked in determining the energy deposition in the windows and resulting thermal stresses.

Vacuum Decay Tube

Findings:

A contact for fabrication, delivery and installation of the decay pipe has been signed and is consistent with the budget. The contract includes provisions for contractor performed quality control steps (radiography, ultra-sonic, and leak-tightness testing). CERN intends to use an independent testing agency for quality assurance.

Comments:

The temporary end caps the contractor will use for vacuum testing should be evaluated for safety before use.

Quality assurance for the alignment of the decay tube both before and after concrete placement should be evaluated by the project.

Recommendations:

None.

Hadron Stop

Comments:

The design is estimated as sound, the work well advanced, the installation scenario seems to be carefully prepared and the costing reliable.

Comments on design solutions are restricted to one item, namely: in the cooling system, flexible metallic hoses have been chosen as connection elements "to minimise the installation work in the tunnel, to absorb thermal expansion of various system parts and to absorb vibrations". The latter issue, of the vibrations of the cooling system, may require additional attention, and it should be noted that such flexible hoses might suffer themselves from hydraulically induced vibrations.

Recommendations:

Therefore, if not checked yet, it is suggested to calculate/estimate the vibrations of the cooling system and their possible influence on fatigue life of the hoses and of the remaining parts of the cooling system. This seems to be essential in view of accessibility and radiation constraints.

Primary Proton and Secondary Muon Beam Diagnostics; Aiming of Neutrino Beam

Comments:

Designs have progressed since the first review of CNGS; the specification of the primary beam monitors seems reasonable and no serious problem is found.

Good progress has been made on the monitors near the target. The proposed scheme of beam monitors, i.e. locations, species and performance etc., seems reasonable including the preparation of spares and/or redundancies. Now the design work should be shifted from the qualitative (conceptual) to the quantitative (realistic).

Several problems have already been pointed out by presenters on the actual specifications of the beam monitors near target. One of the most serious problems is the heat deposit to the foils and/or wires of monitors by the very sharply focused beam near the target, the same problem that affects the vacuum windows. A traditional Titanium foil cannot survive the large heat deposition. Beryllium is being strongly considered as the window material. Then should Beryllium foils be used for beam monitor electrodes also? The technical difficulty of Beryllium because of its chemical toxicity leads one to search for other possible options. Silicon Carbide and/or Carbon rod/wire can be candidates for the electrodes. The radiation hardness of those materials may be obtained from several European laboratories with high intensity (low energy) beams such as PSI and RAL. They have already constructed SEMs by SiC and/or C fibers. Foils for entrance and exit windows of the beam monitors may be Beryllium. It would be very generally useful to the field if other materials can be found. Modest enlargement of the beam spot size on the target also should be considered seriously if it can reduce the heat deposit sufficiently with acceptable reduction of neutrino yield. The small spot size makes everything difficult.

Another important "realistic" problem is the replacement and re-alignment of monitors near the target where very high residual radiation is expected. Quick and automated alignment by employing a plug-in system should be necessary. Connection and disconnection of signal cables and high voltage cables should be made by quick connect devices. Cables and connectors themselves should be radiation resistant near the target. Adjustment and/or the check of the monitor positioning should be made from an isolated/distant location by means of a long tong and/or a remote manipulator. CERN has considerable experience with them. In any case, the maintenance scenarios of the devices near the target should be established as a part of their specification. For this purpose a map of the expected residual radiation level is essential. The maintenance scenario is completely different according to the length of allowable human occupancy for maintenance/replacement, i.e. 1 hour (no problem), 10 minutes (quick disconnect?), 1 minute (plug-in?) or 1 second (full remote manipulation/maintenance free).

Some kind of small lead coffin may be necessary to transport used monitors to other places for maintenance. Another option is to prepare a graveyard for monitors near the target.

For the muon monitors, the scheme of using loss monitors is almost the same as for the previous review. Results of a study of the performance of the loss monitor at high intensity were presented. The data indicate that the non-linearity of the loss monitors may be a serious problem. The determination of the centroid of the muon (and by inference the neutrino) beam can be made by "non-linear" monitors. However if one wishes to compare the muon (neutrino) profiles and muon (neutrino) intensity to Monte Carlo Simulation, the non-linearity has to be understood quantitatively, i.e. high voltage dependence, reproducibility etc. The muon monitor is the only device which can indicate the neutrino profile and neutrino intensity at the CERN site. Thus the muon monitor is the only tool to validate the aiming of the neutrino beam to the experiments at Grann Sasso.

The committee endorses the project position that both muon monitoring stations are required to be instrumented, given the lack of other monitoring systems for the secondary beam.

Recommendations:

Produce a map of expected residual radiation for use in evaluating hot handling schemes, and include the maintenance scenarios in the specifications of the monitors.