August 9, 2004

Review Committee Report of the 3rd CNGS Review
28-30 June 2004

THE CHARGE TO THE REVIEW COMMITTEE:

To review the progress made since the 2003 Review and to assess the overall schedule of work until the start of the CNGS facility in 2006. In particular, to analyse critically the proposed solutions for the target and horns systems, the beam monitoring in the target region, the muon detection system as well as the preliminary installation and commissioning plans. To comment on issues concerning project management and cost to completion, if any.

EXECUTIVE SUMMARY

Progress: The CNGS project has made excellent progress in many areas since the last review, which was held in April 2003.

On the construction side, the civil effort is concluded. The beam absorber and decay pipe, both major items, have been successfully installed on schedule. The decay pipe has been demonstrated to be vacuum tight.

On the technical side, impressive work has been done for example on the target design, such that final drawings and construction of most of the system can proceed. A complete horn has been assembled, and the measured vibration when excited with the CNGS design double-pulse matches predictions. Prototype tests have been done for the target and beam monitoring systems. Plans for outfitting, installation, monitoring and many other areas are proceeding in a smooth, highly competent way.

The project team members are to be strongly commended for these successes!

Technical Issues: The prospects for successful technical completion of the project are excellent. Several problems highlighted at the previous review (target and windows being able to withstand the impact of the beam, and safety in case of decay pipe vacuum window failure) have been essentially resolved. The committee has identified only one serious technical risk: the kicker does not meet the project specification. The details will be covered in the section on primary beam, however we call attention to the importance of beam time scheduled this fall to test a possible solution to this problem using the damper system.

Recommendation: Carry out beam tests this fall to make sure the damper system can compensate the effect on the second beam batch of the kicker tail from extracting the first batch.

Schedule: The project reports that it is overall on schedule to meet the May 2006 completion date. Indeed, the committee finds that the project has done very well staying on schedule thus far, with the exception of resources to calculate beam heating and residual radiation levels.

The present installation schedule is building on recent experience in the installation of TI8. It looks convincing and it should be successful if needed equipment is there in time to be installed. Careful planning is needed to avoid installation conflicts with LHC efforts.

However, the committee feels that without increased manpower, the most challenging target hall components (the horn/reflector systems, target system, and hot handling equipment) will most likely drive project completion late.

Recommendation: Vigorous efforts should be make to substantially increase the manpower working on the target hall component systems. A coordinator and significantly more engineering resources are required.

Management Issues: The project is to be commended to have nominated a schedule coordinator and an installation coordinator.

Radiation protection is a very broad and demanding issue for the project, for which the manpower situation has been exacerbated by the retirement of Graham Stevenson.

Recommendation: There is immediate need for full time effort from a radiation protection specialist to do calculations and complete necessary documentation.

Costs: More than 70% of the funds for the project have now been spent or committed. Great care has been taken to contain scope increases, and careful oversight and documentation of the civil construction has limited claims from contractors. The highly successful completion of the civil work has left the project with contingency funds at a reasonable level for the remaining project tasks.

Services like ventilation, cooling, and electricity have been correctly assessed and a margin of 15% minimum has been foreseen. Thus, there should not be any problem for primary services.

Although some necessary uses of contingency are now identified (crane, cooling contracts, horn modifications), the project appears to be in good shape financially.

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ACKNOWLEDGEMENT

The review team thanks Jos Engelen (CERN Chief Scientific Officer) for providing us with this opportunity to learn about the CNGS project.

We wish to express our appreciation for the excellent set of presentations and the hospitality provided us by the CNGS team. We believe that the effort that went into the presentations will be highly useful to the CNGS team in its own understanding of the project, and that the review was a valuable experience for the committee members as well.

Respectfully submitted,
The members of the review committee:

Sam Childress (FNAL),
Nancy Grossman (FNAL),
Alain Herve (CERN),
James Hylen (FNAL) (Chair),
Tadeusz Kurtyka (CERN),
Jacques Lettry (CERN),
Kazuhiro Tanaka (KEK),
Wolfgang Weingarten (CERN)

COMMENTS ON INDIVIDUAL SYSTEMS

Proton Beam

Excellent progress has been made on many fronts for the proton beam.

Two beam optics studies were carried out. The first shows the extraction line has the capability to increase the beam spot size on target from $\sigma = 0.53$ mm to $\sigma \sim 0.75$ mm, but not beyond. This increase in spot size may be required to reduce target stress. The second was an alignment study to eliminate coupling between planes for horizontal bends aligned with vertical slope.

On magnet production, the dipoles are near completion, quad problems are resolved with production to complete in 2004, and corrector production is underway with completion also expected in 2004.

For the vacuum system, it is now planned to have an ion pump every half-cell, instead of every 2nd half-cell. This provides a large improvement in pump down capability and resolution of possible electron cloud bias effect for alternate half-cell BPM's.

Two instrumentation improvements were made. An intermediate profile monitor was added for targeting lineup, to give improved targeting precision and reliability in that relatively high radiation area. In the BPM electronics design, a 2nd "de-phased' log amp was added to reduce inherent non-linearity. Instrumentation readiness is good for 2005 installation.

Significant improvement has been made to the extraction kickers – flat-top pulse length has been increased to approximately the required 10.5 μsec, and the rise-time now looks good - but pulse fall-time is still far from meeting specs. For the CNGS double-fast-extraction, this means that kicker ringing from extracting the first batch will affect the second batch. The current kicker waveform gives an unplanned deflection to part of the second beam batch of 8-10% of the extraction path waveform, compared to a specification of 1%. It is very challenging technically to meet the kicker specification directly. A plan is in place to use SPS transverse dampers to stabilize the 2nd beam batch within the 50 msec between extractions. Near term beam tests are planned, and are essential!

For installation, planning & installation coordinators are in place. There is strong experience with very similar LHC transport line installation. It is planned to track LHC installation efforts in parallel, as it is important to identify and respond to installation resource conflicts.

Machine development tests are planned for September 2004. The tests will check extraction of CNGS beam, check extraction kicker parameters and use of SPS damper, verify the capability for base CNGS intensity, and investigate the option for future higher intensity. Doing the tests this fall is very important as there will be no SPS beam in 2005 and CNGS start-up is in 2006.

Protection interlocks are required to protect components from beam induced damage when a major problem signature is detected. Design of an integrated system for protecting both LHC and CNGS is well along, and will be ready for CNGS. The system allows for both fast (able to preclude extraction of 2nd batch) and slow (software generated, thus essentially able to inhibit subsequent pulses) inputs. Loss monitors can provide fast inputs detecting scraping along the beam line. A fast input for detecting off-center beam would be useful for target and TBID window protection, but it is not clear how to generate such a signal.

There is good first stage level of development of commissioning plans, for equipment readiness checkouts, and commissioning with beam.

In summary, overall the extraction and proton beam show solid progress and are well on track for Spring 2006 commissioning. The beam tests in September 2004 are extremely important.

Recommendation: Carry out the planned machine development tests (September 2004) to verify the solution for meeting extracted beam stability requirements, and intensity capability for CNGS operation.

Windows in the Beamline

The work on CNGS windows has progressed well during the last year and this progress is in line with the recommendations of the 2003 Review.

At the last review, questions about beam windows were conditioning the progress of design in at least three areas vital for the project: the primary beam vacuum system (TT41 vacuum system exit window), target station (He/vacuum windows of the Target Units), beam diagnostics (upstream and downstream Target Station beam monitors). In all these cases the outstanding issue was what material can be used for the windows? Titanium windows, used as the standard SPS solution, 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. Vigorous studies were recommended to clarify the temperature rise and strength estimation for various window materials vs. Ti, and in the case of choice of beryllium, failure analysis should be made with the aim to minimize the risk connected with Be contamination.

The status as of this review can be summarized as follows. Ti windows have been excluded upstream and including the Target Station as non-withstanding the requirements, replaced by Be windows, equipped in the case of the exit of proton beam line with a protective carbon-carbon membrane. Ti windows have been retained for the beam line downstream Target Station (TBID monitor, He tank).

For the exit window from the proton beam line, there is a baseline design of a standard (commercial) Be window, but equipped with an additional, separate carbon-carbon membrane to avoid Be contamination upstream in the beam-line in the case of window failure. An alternate option has been proposed, a novel type of Be window with an integrated carbon-carbon membrane ("Reinforced Captive Window").

Recommendation: The Reinforced Captive Window option is an interesting alternative and its further development is encouraged. It should be thoroughly tested (mechanical tests, beam tests) before use.

For the Target Station, the design is standard Be windows welded to stainless steel (entry window) or Al flanges (exit window).

For the TBID monitor immediately downstream of the target, the baseline is a standard CERN monitor which has two windows made of low grade Ti. High intensity running may destroy these windows; the project position is that this device is most useful during commissioning, and having it fail after commissioning is acceptable. Replacement of this window with a better grade of Ti may extend its lifetime at modest cost, and is worth considering.

The design of the Helium tank window appears to not have been finalized yet.

Recommendation: As the baseline Ti window may be destroyed if the beam misses the target, it seems advisable to replace at least the central section of the Ti window with Be.

Structural analyses (thermal shock, dynamic stress) supported by experiments are required to validate the new design proposals and new materials (e.g. new Ti grades).
In view of limited CNGS staff resources, the question who should do the R&D for these new design solutions becomes important. A possible solution is to "subcontract" to other CERN units.

Target Station

The recent major technical problem for the target design was that with better analytical tools applied to the double-fast extraction calculation, the baseline CNGS target design was predicted to have unacceptably high stress.

The re-survey of options for the target configuration / target rod material has been successful in that one reasonably safe option has been identified for nominal intensity, at only a modest decrease in neutrino event rate relative to the previous baseline. (See table; some interpolation is required since calculations were done for 0.8 mm radius beam, while the primary beam optics limits this to of order 0.70x0.75 mm). The increased operational reliability of the "safe" design is very attractive, as the downtime for even one exchange of a target magazine per year could cost more events.

	Baseline design	"Safe" design
Protons per double pulse – Ultimate (Nominal)	2x35 Tp (2x24 Tp)	2x35 Tp (2x24 Tp)
Beam size	Radius = 0.53 mm	Radius = 0.8 mm
Target element (graphite)	Diameter = 4 mm	Diameter = 5 mm
Worst Stress / beam 1.5 mm off axis – Ultimate (Nominal)	38 MPa (26 MPa)	22 MPa (15 MPa)
Stress limit, including fatigue	19 MPa	19 MPa
Relative neutrino event yield	100 %	97.2 %

From the table, it appears that even the "safe" design has no margin for the ultimate intensity. The committee has the impression that the way the stresses from the two spills were added together for this calculation is conservative, so that it is not clear whether the target will fail or not.

Two further studies of graphite are planned, and may help clarify this:
• ~1 Mcycle fatigue tests at 1000º are proposed (2 month / stress oscillations before damping).
• The effect of off-axis irradiation will be measured in October in TT40; the analytical simulation of the stress generated by the 1 mm SPS beam instead of the 0.53 mm CNGS beam would be an asset.

The target magazine has five target units that can be rotated onto the beam-line; this provides enough flexibility that the target strategy can and should be frozen now so that construction and testing can be completed in time for installation. The committee endorses the project's concept of loading the magazine with a mix of units along the lines of:
1.Graphite target with baseline geometry under helium; (best understood target with highest neutrino yield, but subject to failure due to stress at high intensity)
2.Carbon-Carbon target with baseline geometry under helium; (the low coefficient of thermal expansion eliminates the stress problem, but the rate of radiation damage is not known)
3.Graphite target with baseline geometry under vacuum; (addresses a possible concern of stress cycling on the Be window from thermal cycling of gas)
4.Graphite target with 5mm diameter rods under helium (for use in conjunction with increase in the beam size – the "Safe" target condition in the table);
5."Safe" target based on the knowledge available in 2005 (graphite target with 5mm diameter rods in vacuum?).
Boron-Nitride has been excluded as a target material following a 100 k-cycle fatigue test at 700º.

Recommendation: At least one target unit in the magazine should be the larger diameter style graphite, and the capability to produce the larger (~0.75 mm radius) beam spot should be preserved, as this is the only configuration known to be safe for nominal intensity.

Thermal expansion due to beam heating of the target cave has now been estimated to cause up to a 1 mm vertical displacement of the target magazine. If nothing else, this would cause shifts in the muon monitor signals. The muon information should be kept as clean as possible, to be used for diagnosing target and horn failures; that dual function will be confusing enough. The thermal motion of the target can be reduced, for example, by supporting the target on low expansion material (like Invar) tubes to the floor through the shielding.

Recommendation: Reduce the motion of the target due to thermal expansion of the supports.

The target magazine holder, bearings and tangent screw are currently specified as pure stainless steel, which may result in excessive friction.

Recommendation: Check for auto lubricating materials for the moving contact parts.

For the target area, it was shown that if the top shielding is in position, the remnant dose rates are low enough for maintenance like replacing the motors on the outside of the shielding to be carried out. However, all possible human interventions needs description, timing and training during 1st quarter 2005.

Marble shielding immediately down stream of the target has had to be removed from the design because it would overheat. It is important to know how this affects the horn. Since ~250 kW of beam heat is dissipated in the target, horns and shielding elements, the heat flow should be modelled more globally.

Completion of the detailed drawings for the target system is expected in September 04, and testing should occur in the first quarter of 2005. The schedule is deemed very tight but not in the critical path.

In summary, for the target system
• Clear path towards completion
• No show stoppers thanks to the flexibility of the chosen approach
• Impressive amount of work ahead under a tight schedule.

Horn System

I. Progress

Since the last review, the inner conductors for the horn and spare horn have been constructed, and one complete horn has been assembled and delivered to CERN by IN2P3-LAL/Orsay. The horn has been pulsed 65,000 times, and measured vibration amplitudes and frequencies agree well with predictions. This bodes well for the mechanical lifetime of the horn inner conductor.

Substantial improvements have been made to the design of the Fast Coupling System that provides for connection/disconnection of the stripline to the horn in the high residual radiation area, and a prototype of this system was used while test pulsing the horn.

II. Resources

There has been a significant setback for the horn system in that all the personnel who were previously working on the system at LAL have left the project, and a new group is taking over the system. The continuity has been lost, and the new team is still on the learning curve as far as understanding the target hall environment.

There is a substantial amount of design work left to produce a robust system that is operable and maintainable in the high radiation environment. Prototyping and debugging the hardware are an important part of this. Systems which need work include

- The stripline fast connection, which must be iterated until it is fast and robust
- The stripline from the horn to the transformer, where calculations of heating and thermal expansion are needed for the detailed design
- The radioactive water system, which is mostly at a conceptual stage right now
- The remote water connection, which has not been designed
- The horn body, where Stephane Rangod (CERN) has identified a list of 20 issues to be addressed
- The hot handling procedures and any special equipment for this
- Air flow cooling issues, which depend on calculating the beam heating
- The horn foot support system, which is being iterated

The LAL group has one physicist (who has a detector rather than accelerator background), one full time engineer and one part time engineer, and has to address these issues serially. CERN has 0 FTE physicist and less than 1 FTE engineer on this system, to address hot handling, system specifications, integration, testing and QA. The committee's assessment is that it is highly unlikely that a robust well-tested system will be in place in time for beam turn-on unless significantly more resources are made available soon. We emphasize that having a robust well-tested system is critical, as the high residual radiation after beam turn-on will make it extremely hard to correct problems later.

Recommendation: Management should urgently address the issue of increasing manpower for the horn systems as a top priority, as the schedule risk is high.

III. Radiation Physics Input

CNGS is being designed for an order of magnitude more beam than the previous CERN neutrino facility WANF. This crosses a threshold so that every component downstream of the target ought to be examined for beam heating, and a solution engineered for each. Further, radio-activation becomes severe enough that operations that previously could be done with a very fast manual access must be done remotely.

Without the critical inputs of beam energy deposition and residual radiation, the engineering of the target hall components and the plan for hot handling is guesswork. Thus the number one recommendation from the last review was to increase the resource for the radiation calculations. Now, 14 months later, although calculations have been done for the target, there is still no calculation of the residual rates or energy deposition at the horn. These numbers are still urgently needed.

The dilemma for the project, stated in a simplified fashion, is that all parts should be arriving at CERN by the end of the year for test assembly (and in fact the first horn has been delivered already), but the estimate presented to us was that the radiation calculations needed as input to their design will only be completed by December. At this point, essentially the radiation calculations will be used to verify that the designs are OK, or that re-design and re-fabrication will need to be done.

Recommendation: The project should obtain a clear commitment for enough Fluka support to complete the radiation calculations on an accelerated schedule; failing that, contract out the calculations to experienced MARS physicists (as NuMI did with IHEP).

IV. Horn Technical

Recommendations:

- The project should consider whether it makes sense to take advantage of the downstream passageway next to helium pipe cave to store hot components – this would save development of the hot handling cart which would have to remotely navigate changes in slope and direction; it simplifies hot handling as that area is under the same crane coverage as the horn cave.
- The committee suggests the project consider commissioning a second horn power supply so that horn testing can continue as the main supply is moved to the "target hall".

- LAL should be provided with the thermal environs, (so for instance they can allow for expansion of the horn base), and the specifications to them should reflect the ultimate intensity rather than the nominal intensity.
- The committee supports implementing the CERN list of horn system modifications we were provided, with the comment that of the two materials suggested to replace ARCLEX for the drain insulator, alumina ceramic is the better choice as MACOR may not be radiation hard enough.
- The temperature of the strip-line near the horn should be calculated including both electrical and beam heating.
- The current horn cave design is like an oven. Given that results of radiation calculations may still be sometime off, the project might consider pre-emptively changing the design to force air in the bottom and exiting at the top of the cave, and direct an air stream at the downstream stripline where there is both beam heating and electrical heating but no water cooling.
- The tendency of the horn outer conductor to "banana" with temperature difference between top and bottom should be examined.
- A good scheme for remote connection of the horn water lines should be developed
- To provide continuity and support during operation, a younger staff member should overlap with the CERN horn engineer (will retire about the time the beam is commissioned). In general, the significant number of retirees from the CNGS project increases the importance of good documentation practices.

V. Helium Tanks

The design of the helium tanks is maturing. There is one helium tank before and one after the reflector. The sections of each helium tank are bolted together such that any future attempt to install horns at different locations is likely to be very difficult. To prevent this loss of flexibility would consume significant engineering and construction expense.

The tank windows are addressed in another section of the report.

Reccomendation: The area of the helium tank should be examined for any problem due to overheating.

Diagnostics for Targeting and Secondary Beam

At the 2nd CNGS review, the committee summarized the activity of the construction team on the beam monitors at the target area as follows;

- Proposed conceptual scheme of the beam monitors, i.e. locations, species and performances etc. etc., seems reasonable including the preparation of spares and/or redundancies.
- Design work should be shifted to the quantitative (realistic) one.

Now at the 3rd CNGS review, the committee observed great progress on the realistic preparation of monitors near the target in the past 14 months. On both the target-upstream and downstream monitors, we believe essentially no problem can be seen at present. On the target-downstream monitors, however, small recommendations will be made to augment the muon monitor.

I. Upstream Monitors

On the target BPM (BPKG), the species of the monitor was reconsidered and a BPM (stripline Beam Position Montior) operated in air was selected instead of a SEM (Secondary Emission Monitor). This eliminates the need for windows and active elements in the beam, as well as the need for vacuum. Testing of BPM operation in the air has already been performed in 2004, and encouraging results were accumulated in that the stripline difference signal correlated well with beam position. Significant noise on the individual output signals due to the air ionization effects (?) were seen and the external magnetic field did not improve the performance. However it seems the BPM in the air should be adequate after some further R&D, especially since a beam scan across the target monitored by the muon monitor and target BLM monitor would appear to provide a backup for the BPKG function. The integration scheme of both the monitor itself and the signal cables seems realistic, reasonable and sufficient.

For beam profile monitors, the CNGS team decided to employ OTR (Optical Transition Radiation) foil monitors with TV camera readout and graphic digitiser, labelled BTVGs. Two possible candidates of the OTR plate are selected, i.e. 12 micron Ti foil and 100 micron Carbon foil. Anyway two foils can be mounted in the BTVG monitor stand at the same time and replaced by each other during beam tuning. The important progress is that the location of the third BTVGs has been selected to be very close to the target. Though the strong radiation from the target will not allow the BTVG to be operated for long time, this third one can work as the direct beam profile monitor on the target at the initial most serious stage of the beam tuning as well as a redundant monitor of the system. One possible problem is the short life time of the TV camera which views OTR, since CID and/or CMOS cameras are normally preferred. A beam irradiation test will be performed by using the primary proton beam of the PSI. A possible replacement is the visicon camera whose radiation life is long enough, although the light sensitivity is one third of the CID/CMOS cameras.

II. Downstream Monitors

The project proposes to use some extra BLMs (ionisation Beam Loss Monitors) to increase the number of downstream monitor systems from two (TBID and muon) to four (adding target BLM and target hall cross hair BLM at very little extra cost).

The Target Beam Instrumentation Downstream (TBID) monitor is the secondary-electron emission monitor (SEM) right after the target. By preparing several SEM foils with special figures, multiplicity, beam halo, and transverse tails, etc. etc. will be measured. The possible problem is the short life time of the TBID due to the irradiation from the target. The CNGS team states this TBID monitor will be a temporary one and its function will be taken over by the muon monitor after commissioning beam tuning is performed with the TBID. It means that the muon monitor would have been the only downstream monitor of the target after the "death" of the TBID. This could cause a serious situation for the CNGS experiment. With some (small?) probability the muon monitor could be broken and, especially given the limited access to the area the muon monitor is in, it could take a somewhat long time to replace/maintain it. We believe the muon monitor should not be the only downstream monitor of the target. Two options to improve this situation have been presented by the project. One is to give "longer life" to the TBID, which may be realized by preparing the vacuum windows of the TBID with pure (high quality) Titanium foils. The other is to add the target BLM, which appears to be a more permanent solution.

The CNGS team also proposes to add a Cross Hair at the reflector exit or/and decay tube entrance, monitored by a BLM. With a target-out beam scan across the Cross Hair, the direction of the proton beam can be confirmed with high accuracy over a macroscopic distance. Given the damage to the decay pipe that misalignment of the primary beam might do, this is a very prudent investment of effort.

For the muon monitor itself, we believe the hardware is now almost ready and the ion chamber (LHC type loss monitor) tests at the PS-Booster are in good progress. Linearity and reproducibility of the ion chamber may have some small problems. However those are not serious for the relative calibration of each ion chamber. The absolute calibration of each ion chamber is not very important at the beam tuning stage. Determination of the muon centroid, which monitors the neutrino centroid, is essential and the relative calibration is enough for this purpose. The absolute calibration can be performed later if physicists required the absolute neutrino flux of the CNGS facility. For the discovery of the tau neutrino events at the Grann Sasso, the neutrino flux density has less importance since the CNGS is an appearance experiment.

Recommendations:

- The muon monitor should not be the only downstream monitor of the target. The committee endorses adding the target BLMs as a solution to this.
- It appears worth while to look at extending the TBID life by preparing vacuum windows with high quality Ti foils.
- The Cross Hair monitor at the reflector exit or decay tube entrance is a prudent addition, and should be implemented.

General Safety

Findings and comments:

The committee acknowledges that ionizing radiation safety and general safety hazards were addressed since an early stage of the project and that appropriate solutions were envisaged. Among these were topics such as protection of workers against ionizing radiation, the consequences on personnel of the window of the decay tube breaking, the definition of the evacuation paths from the target chamber and muon detectors, and the fire hazards in the service gallery.

However, as a consequence of many other pressing important technical issues, and lack of important data, for example on activation, the respective solutions for these safety hazards could not yet be completely tackled and presented during this review. The tools for assessment are available and validated. The main issue being radiation protection, the results obtained with a new method using FLUKA matches well with experimental data. Important results on intervention dose estimates were obtained, but are not yet complete. Missing manpower impedes a faster progress (presently slightly more than 1 FTE is available).

To obtain a formal approval of the project, both externally and internally, safety documents and working procedures must be finished in the near future. In view of the first beam planned for May 2006, the report to be provided to the INB authorities is due in September 2004. It is nearly ready except for the part dealing with ionising radiation.

Other documents are those needed for the formal approval in a preliminary safety review by the CERN Safety Commission before beam will be delivered to the target.

(Non exhaustive) list out of which the topics for this preliminary safety review may be chosen are:
• Alarm and evacuation issues,
• EMC issues with regard to safety alarms,
• Electrical and fire safety for the transformer and capacitor banks,
• Mechanical safety in the design of target, horn, reflector, and target and decay tube entrance windows,
• Mechanical safety with regard to stress in the support frames following the temperature increase by particle impact,
• Failure mode analysis of mechanical and transport tools in general, and during remote operation, with special regard on lubrication issues,
• Detailed planning of scenarios in case of major problems, including replacement of components, such as the horn,
• Optimisation and limitation of dose with regard to ionizing radiation for maintenance and handling work,
• Operational safety in consequence of a misaligned or mis-focused beam,
• Radiation hardness, fatigue and chemical and structural stability of materials,
• Environmental impact of the whole project, including activation of water and air, and the disposal of its main elements after dismantling.

As to the safety organisation of the installation work, there was a coordinator appointed, who is assisted by a safety coordinator working on behalf of AB department for both the SPS shutdown and the CNGS installation work. This situation was considered by the project management as very satisfying.

Recommendations:

- A risk analysis should be performed for one of the major operations of component replacement. A well-established and documented technique such as HAZOP, etc., should be applied.
- Additional manpower is urgently needed during a restricted period (about 1 year) for simulations of radiation fields and preparing the documentation that is requested for the approval of the project.
- A Preliminary Safety Hearing should be held at the end of 2004 that shall be supplemented by follow up hearings and by a formal approval procedure before the beam will go on target in 2006. Environmental and waste disposal aspects shall be included as a major part of these hearings.

Radiation Safety & Radioactive Component Handling

Findings:

RADIATION SAFETY: CNGS has benefited from the LHC need for a new fast interlocks design. It is somewhat complicated by the new central controls location for CERN for which CNGS will be the first user.

Release of activated air to the environment was well addressed in the past and has not been recently revisited. Similarly radioactive water calculations were done in the past and need to be revisited.

The last review recommended a vigorous effort be made to increase resources to calculate beam heating and residual dose rates. A fellow has recently (February 2004) been added full time to work on this. The remnant dose rates and beam heating for the target region have been determined. These dose rates have been used to get a rough first pass estimate of personnel dose for changing out of several target area elements. The geometry in the horn area is now being added to the simulation in order to determine heating and remnant dose rates in this region. Thus the recent progress has been very good. Due to the delay in the start of this progress, though, the project has had to precede on some design issues without waiting for the Monte Carlo simulations to better optimize the design. The simulations were done for an instantaneous rate of 8E12 protons/second and the "ultimate" intensity is 1.17E13 protons/second. Depending on the calculation (heating versus residual dose rates), this may or may not be appropriate.

RADIOACTIVE COMPONENT HANDLING: The radioactive component handling details have been slowed greatly due to the fact that the person in charge of this is also responsible for the horns and stripline. The horns and stripline, being provided by LAL, were envisioned to be mainly an oversight task. Recently this has been shown not to be the case.

RADIATION SAFETY DOCUMENTATION: A preliminary safety document is to be provided to INB in September of 2004. It is not clear where the resources will come from to address the radiation section of this document or other documentation tasks needed for radiation safety requirements and project success.

Comments:

The use of the new fast interlock system for minimizing the number of poorly extracted/targeted beam pulses when the CNGS beamline is not working optimally is encouraged. This will minimize remnant dose rates and the likelihood of component damage.

Release of activated air to the environment should be revisited to ensure that these calculations are still applicable to the current design. Activation of the cooling water in the target area needs to be re-estimated and the manner in which to sample and change out this water determined.

A more detailed evaluation of changing out of elements in the target area and the resulting dose to personnel needs to be completed. The detailed analysis of the horn area using FLUKA to estimate remnant doses and heating must be done. This is needed to specify and evaluate the process and design for changing out of elements in that area. The number of protons per second to be used for the various calculations needs to be determined by the project in conjunction with the FLUKA experts. The late start of this recent simulation work may lead to changes being required later in support elements or radioactive component handling elements after these elements have been built. Fast-tracking of critical calculations such as the energy deposition near the beam in the horn and transmission line area should be done.

More resources are needed to work on radioactive component handling as there are still several items that need to be designed and more detailed handling procedures that need to be developed soon.

Providing documentation of radiation calculations and the corresponding documents that are needed for CERN and the INB could be a very large task, depending on the reviewers. It is not clear where the resources are to do this.

Recommendation: Obtain resources at the level of one full time experienced person for at least 6 months to work on the remaining issues of radioactive component handling (procedures, dose rates needed, etc.), overseeing the verification and completion of the remaining radiation calculations needed and their documentation, and preparing the documentation needed for Radiation Safety for CERN and the INB. This may, perhaps, be 2 people at 50%. It is critical that this manpower be provided now, as it is already too late to efficiently make some changes that may be needed.

Management / Manpower Needs Summary

To be ready in 2006, several important projects (horn, reflector, target, radio protection issue & INB report) have still to be completed. The creation of a coordination position with LAL and injection of supplementary manpower in the various projects seem mandatory to reach the goal. The following summarizes the manpower needs – please note it duplicates recommendations in other sections.

Recommendations for additional manpower (summary):

- An experienced beam physicist to coordinate the target hall component efforts, review and transmit specifications, and identify and handle integration issues would be a tremendous asset to the project; in any case it seems mandatory to create a position at CERN for coordination and follow-up of LALs important contribution of the horn system.
- Enough engineering resources need to be added to be able to attack the horn sub-systems in parallel rather than serially. In particular, as a consequence of the re-orientation of work by LAL, the engineering tasks for S. Rangod at CERN, to define horn, reflector and services, will increase and help will be needed.
- Logistic help will be needed by L. Bruno to complete detail design and organize procurement of the target systems.
- Radiological protection issues and preparation of INB report and associated documentation will require one full time equivalent.
- The determination of heat deposition is urgently needed to complete engineering design. The FLUKA team may need help to complete this important task in time.

On the management side, since the remaining time to complete correctly the horn, reflector and target is short:

Recommendation: CNGS management should introduce and monitor Milestones in the horn and target systems engineering schedules. This will allow a follow-up of the critical items.