Technical Division Memorandum

November 15, 2000

To: V. Bharadwaj

Cc: E. Paterson, L. Klaisner

From: LCLS LLRf Review Committee
M. Browne, J. Frisch, R. Humphrey, K. Jobe, R. Larsen (Chair), H. Schwarz

Subject: Design Review of LCLS LLRf Proposal

1. Committee Charge: Today we reviewed the technical proposal of the LLRf group. The agenda, charge and list of presenters are attached. Our charge is to comment on the necessity of the approach(es) presented, and if necessary, gauge the potential of the system or systems presented for meeting LCLS requirements. The following is a brief summary of our findings.

2. Proposed System(s): The presenters gave a picture of the LLRf requirements based on (a) a parameter sensitivity analysis by P. Emma in which an overall tolerance budget was developed that, if met, would hold the beam phase, amplitude and time precision to desired tolerances; and (b) a large number of parameter measurements made on the existing S-Band linac by R. Akre, as well as calculations to establish likely errors accruing from performance of the existing machine. In addition, an overall architecture was shown by P. Krejcik, followed by a suggested list of R&D projects including upgrades to a number of existing and proposed components, including a new phase reference line, new oscillator or VCO decoupled from the existing main drive line to avoid issues with operation of PEPII, new solid state sub-boosters, and upgrades to components such as MKSU, PIOP, PAD, etc. A presentation of impacts on machine controls by M. Ortega contained a more or less identical list.

3. It was clear that there is not one firm proposal at this time, in that measurements are continuing and the architecture that was described does not demonstrate a complete understanding of requirements or a firm implementation plan. For example, it seemed clear that short-term stability measurements and calculations demonstrate acceptable performance of the present linac over short time periods (~ 2-17 seconds), or performance that was close enough to acceptable to indicate that slow feedback loops around each linac section might be able to achieve the required long term stability. At the same time, the thrust of the R&D proposal seemed to assume that such overall loops will not work and therefore a large number of separate sections of the instrumentation would have to be improved simultaneously to make all parts of the machine inherently stable enough to operate without overall feedback. The range of work required between these two assumptions is more than an order of magnitude.

4. The Committee understands that beam diagnostic observations in real time (CSR bunch length, BPM energy) might be transformed into effective orthogonal engineering control parameters for overall feedback. The technical alternatives in order of preference then appear to be:

A. Overall feedback with the present hardware, provided it can be demonstrated that parameter tolerances can be maintained over each linac section via a feedback model, which in turn implies that the parameter measurements necessary can be made rapidly enough to correct amplitude and phase within the natural stability of the system(s).

B. Overall feedback but with additional corrections required within each loop in order to maintain the inherent stability within capture range. This implies some improvement of existing hardware or additional shorter feedback stabilization of certain parameters.

C. If overall feedback does not work at all because the parameter space cannot be captured in a feedback algorithm with sufficient accuracy or speed, then the full scale development or improvement of all intervening components has to be undertaken, more or less as proposed in the presentations.

5. Priorities for R&D: The Review Committee sees these alternatives on an increasing scale of difficulty, and therefore as a logical prioritization of further R&D. The *first priority* should be further theoretical work on development of an overall feedback model, coupled with a continuation of machine measurements that so far have covered a limited set of the total area of interest. In particular phase and amplitude measurements should be carried forward during times when diurnal variations are changing more rapidly. If this model is successful, very little new R&D is needed. The key is to demonstrate that beam diagnostic measurements can be orthogonalized to the Rf control parameters sufficiently rapidly to achieve control. The *second priority* tasks should be undertaken only if it is demonstrated that further stabilization is needed, either via internal loops augmenting the overall feedback, or via component improvements. The *third priority* tasks likewise should be undertaken only if overall feedback is shown to not work at all, in which case exhaustive work to improve each and every component is needed, the largest and most expensive of the three alternatives. Depending on the time required to make the measurements necessary to stabilize each section, if drifts are moving out of range faster than measurements can be made, the scheme may not work at all. Comparisons with the NLC may prove useful in this study.

6. Other Technical Issues: The separate phase stabilization line that is required for the LCLS is a major concern. This was described as either a single uninterrupted cable run with a power amplifier driving it in a resonant stabilization scheme, or a segmented line with separate booster amplifiers at each sector in which case the resonant scheme does not work, and further noise and phase stability concerns arise. Neither of the concepts described has been demonstrated so continuation of work to find a solution is critical. A less critical but very important problem is to

work out the scheme by which PEPII and other experiments will continue using the timing system and Rf for beams while LCLS operates in tandem. The details are sufficiently complex that this area needs serious work.

7. Costs and Schedules: Since the range of options is large so are the potential ranges of effort and capital costs. Some of the presentations stressed making component improvements for the sake of improved reliability or maintainability. The Committee comments that these are secondary issues compared with the basic stabilization issues, because the reliability of the linac as it stands seems quite adequate for LCLS requirements. Such parts of the proposal should be argued on their own merits, and not as an essential part of solving the phase, timing and amplitude stability problems. As far as making inputs to a CDR description, some aggressive work on evaluating the overall feedback model might yield an optimum model at minimum cost. The Committee notes that effort on the second and third priority tasks will require additional LLRF engineering personnel - a resource that is currently in short supply and high demand in this laboratory.

8. Conclusion: The Charge to the Committee was as follows:

   Assuming that the required LCLS RF tolerances are valid, the Review Committee will determine whether the proposed LLRF upgrade is necessary (i.e. are there other solutions that should be investigated instead). Assuming that an upgrade to the LLRF is necessary, the Review Committee will determine whether the proposed upgrade will fulfill the required LCLS needs.

   The Committee concurs that as far as can be reasonably determined the stated tolerances are valid, but the required scope of modifications and upgrades cannot be determined without further investigation as outlined in Sections 5-6. The short-term performance of the present system appears adequate to meet specifications, and optimistically may work long-term if overall feedback based on beam diagnostics of pulse length and energy is successful. Significant additional work will be needed if overall feedback cannot work without component redesigns and/or stabilization loops. In the worst case, overall feedback could be ineffective and all components would have to be re-engineered for optimum stability. The Committee proposes attacking the problems in the order stated, and from the data presented believes that the LLRf stability requirements should be achievable.

   Respectfully submitted,

   LCLS LLRf Design Review Committee
   M. Browne, J. Frisch, R. Humphrey, K. Jobe, R. Larsen (Chair), H. Schwarz
   Attach: Committee Charge & Design Review Presentation Schedule

Technical Division Memorandum

Attachment:

LCLS LLRF REVIEW

The LCLS places demanding tolerances on the RF phase and amplitude stability of the SLAC linac RF systems. As part of the LCLS project it is proposed to upgrade the linac Low Level RF system to accommodate this. A design for upgrading the LLRF exists. There will be a semi-formal review of this upgrade on Wednesday November 15th 2000.

Review Committee

Mike Browne
Joe Frisch
Rusty Humphrey
Keith Jobe
Ray Larsen (Chairman)
Heinz Schwarz

Charge to the Committee

Assuming that the required LCLS RF tolerances are valid, the Review Committee will determine whether the proposed LLRF upgrade is necessary (i.e. are there other solutions that should be investigated instead). Assuming that an upgrade to the LLRF is necessary, the Review Committee will determine whether the proposed upgrade will fulfill the required LCLS needs.

AGENDA

08.30	Executive Session (Review Committee only)	Ray Larsen
09.00	Agenda & Charge to the Committee	Vinod Bharadwaj
09.05	Introduction & Overview	Patrick Krejcik
09.20	Beam RF requirements and tolerances	Paul Emma
09.30	Measurements of the present linac performance	Ron Akre
10.10	Proposed architecture for a new phase reference system	Patrick Krejcik
10.25	Key RF components	Ron Akre
10.45	Design Implications for the Control System	Mario Ortega
11.00	Recap of planned R & D	Patrick Krejcik
11.05	Discussion and questions	
11.30	Executive Session (Review Committee only)	Ray Larsen