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ILC Research and Development Plan for the Technical Design Phase

Release 5

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ILC Global Design Effort

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1 Purpose of this Document

This document represents the 5th release of the R&D Plan for the GDE Technical Design Phase. The first release was in June 2008, and outlined the scope and top-level goals for the Technical Design Phase 1 and Phase 2. Release 2 through 4 followed at roughly six-month intervals. Release 5 comes at the midway point of the GDE's plans, and the end of TD Phase 1; as such it represents a review and re-structuring of the plans for TD Phase 2, which focus on consolidating the on-going R&D programmes and producing the Technical Design Report at the end of 2012.

The document is structured into two parts:

- A relatively short report which summarises the primary goals and schedule for the Technical Design Phases 2.
- A set of appendices, which contain detailed information on worldwide resources and the complete project work-package structure.

The front report matter is divided into X sections:

Section 1 Purpose of this Document: this introduction.

Section 2 Overview of Technical Design Phase 2: top-level management goals and milestones for the Technical Design Report.

Section 3 …

The appendices are structured as follows:

Appendix A: Summarises the estimated global resources available for the Technical Design Phase.

Appendix B: A description of the project work packages.

Appendix C: An overview of ILC-relevant activities (and resources) at other projects which have a strong synergy with ILC (for example the European XFEL and Project-X).

Appendix D: contains a list of institutes who are either participating or have expressed interest in participating in Technical Design Phase work.

2 Overview of Technical Design Phase 2

The Technical Design (TD) Phase of the ILC Global Design Effort will produce a technical design of the ILC in sufficient detail that project approval from all involved governments can be sought. The TD phase will culminate with the publication of a Technical Design Report (TDR) at the end of 2012. The key elements of the TDR will be:

- An updated technical description of the ILC in sufficient detail to justify the associated VALUE estimate.
- Results from critical R&D programmes and test facilities, which either demonstrate or support the choice of key parameters in the machine design.
- One or more models for a Project Implementation Plan, including scenarios for globally distributed mass-production of high-technology components as "in-kind" contributions.
- An updated and robust VALUE estimate and construction schedule consistent with the scope of the machine and the proposed Project Implementation Plan.

The report will also indicate the scope and associated risk of the remaining engineering work that must be done before project construction can begin.

The TD project structure remains essentially unchanged for Phase 2. The Project Management team leads and coordinates the international effort in the three regions (Americas, Asia, and Europe) needed to complete the Technical Design Phase (TDP) and deliver the TDR. The Project Management structure is summarised in Table 2-1. The project is divided into three Technical Areas sub-divided into Technical Area Groups (TAG). Each Technical Area has an associated Project Manager. The fifteen TAG listed in Table 2-1 are each coordinated by a TAG leader, who reports to the respective Project Manager. Each TAG comprises of a set of technical Work Packages (WP), which are summarised in Appendix B.

Table 2-1: TD Phase Technical Areas

	Technical Area		
	1. Superconducting RF Technology	2. Conventional Facilities & Siting and Global Systems	3. Accelerator Systems
Technical Area Groups	1.1 Cavity	2.1 Civil Engineering and Services	3.1 Electron Source
	1.2 Cavity-Integration	2.2 Conventional Facilities Process Management	3.2 Positron Source
	1.3 Cryomodules	2.3 Controls	3.3 Damping Ring
	1.4 Cryogenics		3.4 Ring To Main Linac
	1.5 High Level RF		3.5 Beam Delivery Systems

	1.6 Main Linac Integration		3.6 Simulations

TD Phase 1 activities placed emphasis on high-priority risk-mitigating R&D – most notably the Superconducting RF linac technology – and quantifying the scope for potential cost reduction of the current Reference Design (Accelerator Design and Integration, or ADI, activities)

A concise interim report will summarise the status of the critical R&D in TD Phase 1 (expected to be published at the end of 2010).

TD Phase 2 (2010-2012) will further consolidate the R&D, and finalise the updated baseline reference design on which the cost and design work for the TDR will be based. An additional critical component of TD Phase 2 will be the development of the Project Implementation Plan.

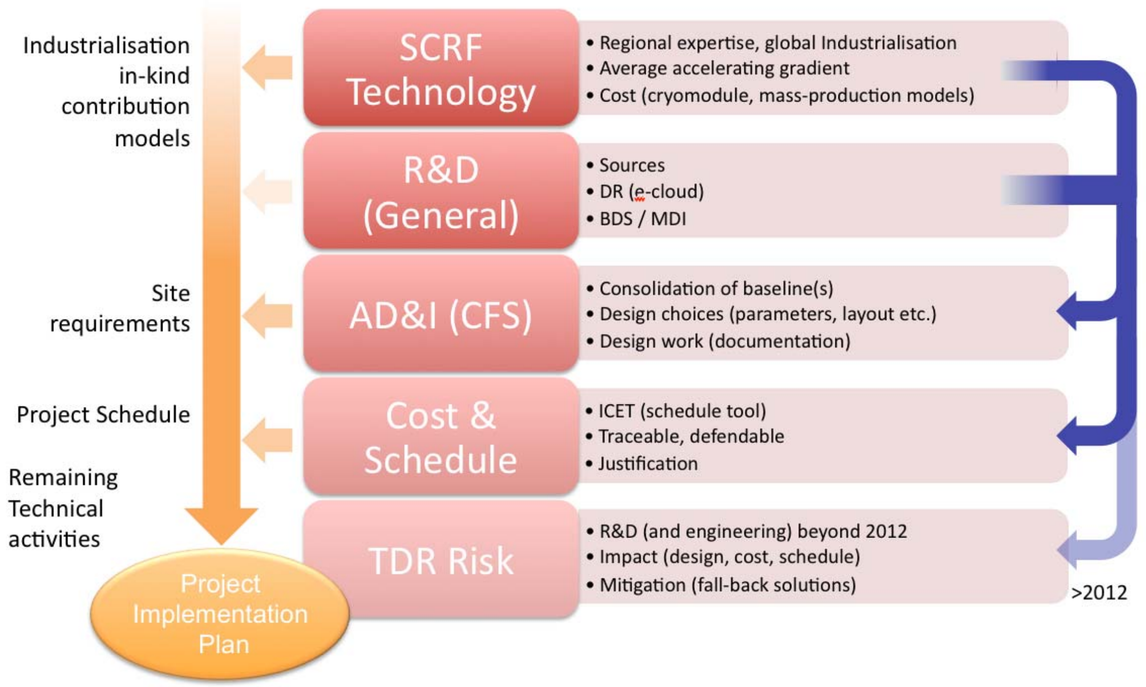


Figure 2.1: TD Phase 2 technical themes (scope of the Technical Design Report).

Figure 2.1 shows the five technical themes that reflect the scope of the Technical Design Report. How these five themes input into the Project Implementation Plan (PIP) is also indicated. It is these five technical themes (together with the PIP) than need to be successfully developed and brought to conclusion over the next two-years. The planning for these goals is the subject of this (updated) report. Figure 2.2 shows the schedule including top-level milestones for Phase 2.

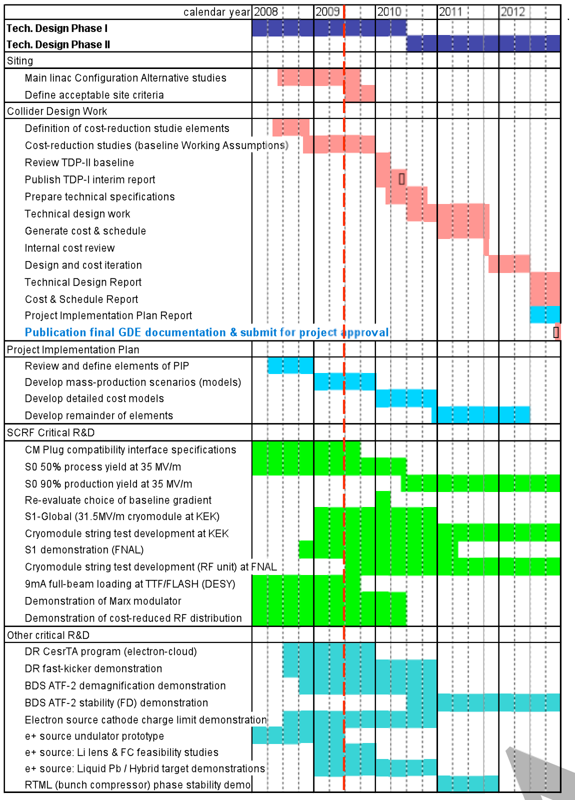


Figure 2.2: Top-level milestones for TD Phase 2

Guidelines for each of the sub-sections (level 2 heading)

Sections 3 & 4 (primarily R&D – not necessarily in this order)

1. Table of top-level milestones for each topic:
    a. Expected outcome and date (*each 'deliverable' should produce a written report*)
    b. Relevance of outcome to scope of TDR work (*impact: what decision will be based and/or supported by this R&D that affects a design decision, cost or schedule*)
    c. If 'beyond TDR' what are the ramifications (*similar to 1b but more 'remaining risk' orientated. Could also be labelled as 'further industrialisation effort'*)
2. Summary text describing the scope, relevance and outcome of the work associated with this part of the project (should be consistent with 1)
3. Some text referring to the existing situation, i.e. after TDP-1. *Note that this should not consume the section as this is not intended as a status report – that's what the interim report is for. It should supply only enough information as needed to support the forward-looking plans for TD phase 2.*
4. Possible something about risk; e.g. what is the fall-back if some planned R&D does not supply the desired result. *This needs some discussion.*
5. …

Sections 5 & 6 (Design and cost work): this should be similar to the above (table of milestones, scope text etc.) but clearly the emphasis is on producing the RDR-like part of the TDR. More top-down planning with clear milestones when information should be made available (for example) to the CFS group and costing-group in general. Documentation milestones should be provided consistently. *Note that this will almost certainly need to be iterated, both in level of scope (detail) and schedule, as our TAG leaders react to our proposal.*

Sections 7 and 8: Need to discuss what to put in this release of the plan. I would suggest we restrict these two couple of paragraphs each. Specifically for Risk where we need to discuss our approach more. These could be 'place-holders' for Release 6 (due December 2010).

3 Superconducting RF Technology [Akira]

3.0. Primary (SCRF) Goals

The primary R&D goals for the SCRF include:

- Cavity: High-gradient R & D with single-cell and 9-cell cavities for the material, mechanical forming, surface-preparation process, and vertical testing, with a goal to achieve a field gradient of 35 MV/m at Q0 = 8E9 (and 31.5 MV/m at *Q*0 = 1E10) with the production yield of ≥ 90%. Designated as S0.
- Cavity-integration: Plug-compatible cavity-package design and integration including tuner, input-coupler, He-vessel and magnetic shield, and the cavitystring test with an average field gradient of 31.5 MV/m in one cryomodule. Designated as S1 and S1-global program. The effort for preparing industrialization and mass production technology to be well investigated in the phase of TDP-2, in parallel to the continuous effort for the field gradient improvement.
- Cryomodule: Plug-compatible thermally-optimised cryomodule design and integration for cost-effective fabrication and operation.
- Cryogenics: System-engineering to realize cost-effective construction and operation. The coordination required to meet high-pressure vessel code/regulation in each region.
- High-Level RF: Development of cost-effective modulator and power distribution systems capable to support a spread of cavity field gradients within a linac RF unit (average gradient operation). As cost-effective designs in support of a single Main Linac tunnel design, the klystron Cluster Scheme (KCS) and Distributed RF System (DRFS) are to be investigated as part of the on-going cost reduction studies.
- Main Linac Integration: Optimization of layout and parameters of the linac unit with a cryomodule string, including cavity, diagnostic, and quadrupole and alignment tolerances. Beam dynamics aspects including wake-field and HOM calculations.
- SCRF-system with beam acceleration: System integration and test of cryomodules in with a suitable RF distribution system; quadrupole package at the centre of the 8-cavity cryomodule). Demonstration of an average accelerating gradient of 31.5 MV/m at Q_0 = 10^{10} in the cryomodule operation with full beam-loading and beam acceleration. Designated as S2 program.

The milestones for the TD Phase SCRF goals outlined in section 3.1.1 (notably the S0, S1 and S2 programs) are summarized in Table 3.1.

Table 3-1: Milestones for the SCRF R&D Program.

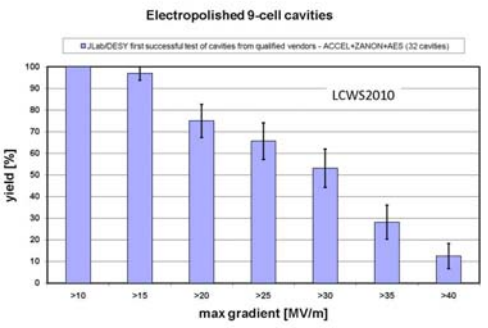
Stage	Subjects	Milestones to be achieved	Year
S0	9-cell cavity	35 MV/m, max., at Q0 ≥ 8E9, with a production yield of 50% in TDP1, and 90% in TDP2	2010/ 2012
S1	Cavity-string	31.5 MV/m, in average, at Q0 ≥ 1E10, in	2010

		one cryomode, including a global effort	
S2	Cryomodule-string	31.5 MV/m, in average, with full-beam loading and acceleration	2012

3.1 Achieving (assessing) the average accelerating gradient

Cavity Gradient Progress and A Tool for Evaluation

The tool for evaluating cavity performance, the ILC cavity database, has been successfully implemented, and includes cavity test data from all participating labs from the last few years and two standard yield plots. For the plots shown below, cavities must be from established vendors (ACCEL/RI, ZANON, or AES 2nd batch or later, as of June 2010), and made from fine-grain material. The cavities must have undergone one standard EP process at either DESY or JLab for the 1st pass. If the cavity does not reach 35 MV/m, it is assumed to need a 2nd pass, the details of which may vary depending on the performance; if the cavity reaches 35 MV/m it is assumed not to need a 2nd pass. All cavities reaching the 35 MV/m gradient specification also reached the Q0 specification; however no explicit Q0 cuts are made on the data. Cavities in the 2nd pass plot are defined to be a subset of the 1st pass plot; if a cavity has not yet received a 2nd pass though it should, it is not in the 2nd pass plot. Only cavity tests with cavity limitations (as opposed to test infrastructure limitations) are used. The cavity yield as a function of maximum gradient is shown in Fig. 3, and the raw number of cavities as a function of maximum gradient is shown in Fig. 4. The sample averages and standard deviations are shown as a function of the minimum accepted gradient in Fig. 3. These data samples shall continue to be updated periodically as additional test data become available.



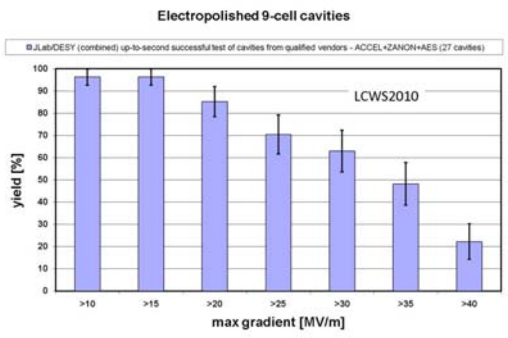


Figure 3: First-pass (left) and second-pass (right) yields as a function of maximum gradient. [To be replaced with updated data by June 30.]

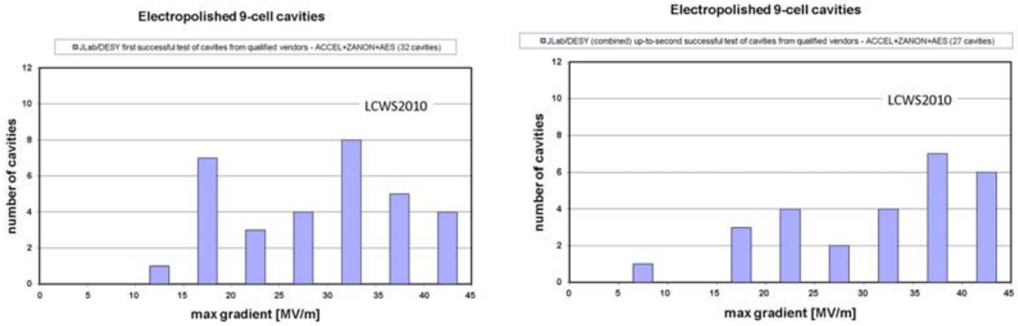


Figure 4: Number of cavities as a function of maximum gradient, for first-pass (left) and second-pass (right) data samples. [To be replaced with updated data by June 30.]

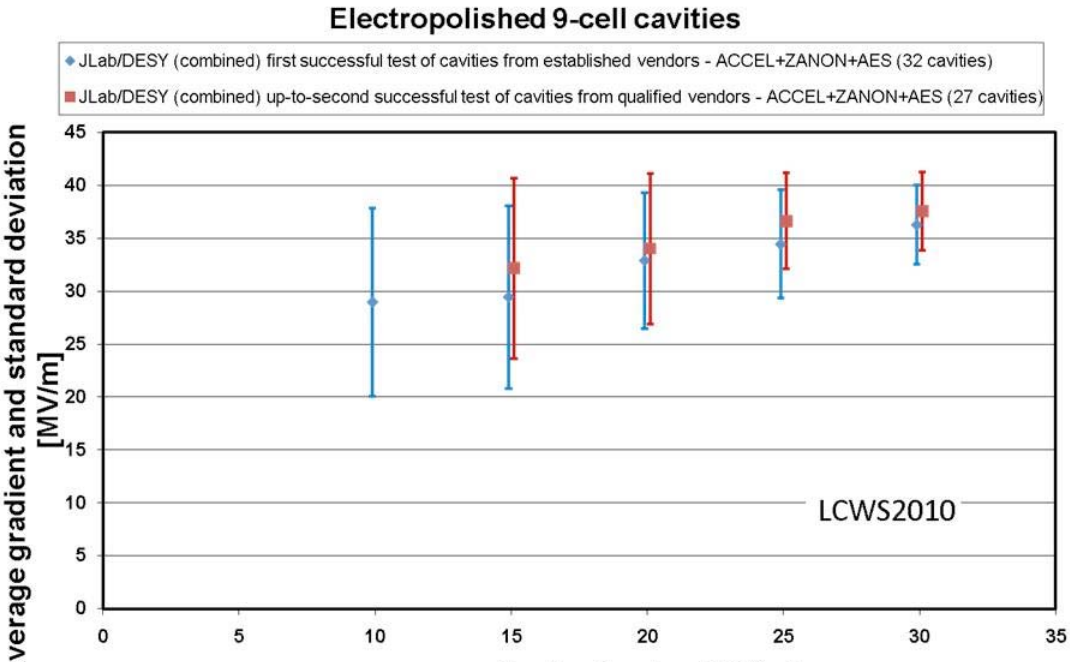


Figure 5: Average gradient (data points) and standard deviation (error bars) of the first-pass and second-pass data samples after excluding cavities which fail to meet the minimum gradient shown on the horizontal axis. The two data samples have been artificially offset from each other for clarity. [To be replaced with updated data by June 30.]

Toward the 1st Baseline Assessment Workshop to be held at KEK in September, 2010 in order to discuss the ILC accelerator cavity gradient, the key issues to address for cavity performance evaluation may be listed as follows:

1) Horizontal bin size to be reduced, if justified by gradient measurement error,
2) Cavity performance tracks/changes from vertical test to horizontal test to cryomodule test in current data samples, and
3) Cavity performance evaluation to be extended to 3rd pass process.

The primary tasks we plan to complete by the Baseline Assessment Workshop are:

1) To create a standard plot tracking cavity performance for new vendors, and
2) To study Q0 at the 31.5 MV/m operating gradient and Q0 at the 35 MV/m vertical qualification gradient for data in the first- and second-pass data selections, for cavities which reach these gradients. This requires the adoption of a common algorithm to interpolate between measurements. As a later step, we will include this information in the ILC database.

The production yield plot would be a useful probe to track the cavity gradient progress to recognize feasibility of the cavity manufacturing and industrialisation. The current statistics of 32 cavities in the 1st pass and 27 cavities in the 2nd pass in the production yield is to be much improved, by the end of TDP2, based on the numbers of cavities in procured with industries with more than 50 cavities in Americas, more than 20 in Europe, and about 10 cavities in Asia.

Superconducting Cavity R&D to improve the Gradient:

The main effort of the ILC cavity gradient R&D is to improve gradient yield and reduce gradient scatter toward the TDP-2 goal of reaching 90% production yield.

In R&D efforts of surface process in these several years, two post-EP rinsing methods, namely ethanol rinsing and ultrasonic cleaning with detergent, have been used in all major SRF facilities in three regions. The optimal detergent concentration has been found through trial cavity cleaning followed by cavity RF testing as well as sample cleaning studies. Alternative detergents are also found and now in routine use. EP processing procedures and cavity handling and assembly procedures at various SRF facilities have been improved. Simplicity and repeatability in optimal 9-cell cavity EP processing have been demonstrated. Focused surface R&D has revealed that the key contaminants on the electropolished niobium surface are sulfur and niobium oxide granules. These efforts result in significant reduction of field emission in 9-cell cavity RF testing, a major success of the globally coordinated S0 program. A gradient yield of 50% at 35 MV/m with a $Q_0 \geq 8\times10^9$ is being achieved up to a second-pass processing.

The success of field emission reduction has allowed us to unveil remaining gradient scatters caused by quench limit. A fraction of 9-cell cavities turn out to be quench limited at a rather low gradient of 15-25 MV/m. This causes the gradient yield dropping to 65% at 25 MV/m for the first-pass processing (as shown in Fig. 3). A top priority of ILC gradient R&D for TDP-2 is to raise the gradient yield and reduce scatter by overcoming quench limit below 25 MV/m in 9-cell cavities.

Temperature mapping and optical RF surface inspection have been routinely used in all major labs since 2008 in association with RF testing of 9-cell cavities. These efforts have provided new insights into the nature of the quench limit at 15-25 MV/m in 9-cell cavities. It is clearly shown that in most cases a local defect in only one cavity cell is the source of the quench limit. Other cavity cells when preferentially excited by pass-band modes show far superior capability equivalent to a gradient of 30-40 MV/m. Most defects responsible for quench limit around 20 MV/m are found to be sub-mm side geometrical defects, such as pits or bumps as revealed by optical inspection. Initial SEM studies of samples cut out from 9-cell cavities have shown complex 3D structure as well as foreign elements at quench locations. It is also fairly well established that re-processing for a second-pass electropolishing is not effective in raising the quench limit at 15-20 MV/m in 9-cell cavities. In comparison, as shown by recent successful experience with targeted grinding of 9-cell cavities, local defect removal results in significant gradient improvement. It has been even shown that it is possible to predict whether an initially observed feature will ultimately evolve into a gradient limiting defect in a 9-cell cavity. All the known facts about the quench limit between 15-20 MV/m in 9-cell cavities strongly imply that responsible defects have an origin from cavity fabrication and/or starting niobium material.

An increasing number of 9-cell cavities quench limited above 30 MV/m have been studied also recently using T-mapping followed by optical inspection. In this case, no defect (down to the spatial resolution of the optical inspection tools) is observable at quench location predicted by T-mapping. And a second-pass electropolishing is often time effective in raising the quench limit up to 40 MV/m. This implies that re-electropolishing remains a usable method for raising gradient performance from 25-30 MV/m to above 35 MV/m. Repeatability and reliability of electropolishing process is necessary for reliable gradient improvement by using a second-pass electropolishing (it is noted that sometimes the cavity gradient degradation occurs when a second-pass electropolishing is applied).

Based on the improved understanding mentioned above about the quench limit in electropolished 9-cell cavities, R&D paths are identified and should be pursued toward the realization of the ILC cavity gradient goal of 90% yield by 2012 and beyond.

Fabrication QA/QC and fabrication improvement and optimization

Fabrication QA/QC is expected to result in improved gradient yield. Production cavities for the XFEL project are unique opportunities in this direction, particularly in the context of cavity mass production. QA/QC tools such as optical inspection for production control should be improved and implemented. Despite the goal gradient of XFEL is different from that of ILC, overcoming the quench limit for 15-20 MV/m in the mass production context is a shared challenge. The European ILC-HiGrade cavities will be an integral portion of the XFEL cavity production and will be processed using the ILC-style recipe.

The established fabrication technology such as forming, machining and electron beam welding have room for improvement and optimization. New vendors have particular motivation and opportunities to pursue. KEK pilot plant is expected to play a unique role in this direction. R&D cavities should be built in collaboration with industry. R&D cavities should also be built in-house where expertise and facilities exist to allow inspection at intermediate fabrication stage. These R&D cavities should allow post-test cavity destruction for microscopic studies of cut-out samples from the known defect locations.

Alternative fabrication technology such as seamless cavity should be pursued. Seamless cavity technology eliminates weld prep machining and electron beam welding and hence offers a unique opportunity for improved gradient yield as well as potential for reduced cavity fabrication cost. Recent seamless cavity experience at DESY in collaboration with Jefferson Lab has shown very good 9-cell cavity results.

Material improvement and optimization

Improvement in the gradient yield is also expected from material improvement and optimization. Niobium of different Tantalum concentration as well as different RRR should be pursued through 1-cell cavity testing and basic material characterization.

Large-grain niobium material directly sliced from ingots eliminates intermediate handling steps as compared to the standard sheet material.

This alternative material offers opportunities for reduced defects introduced by rolling and forging steps. Excellent 1-cell cavity results are well demonstrated in all three regions. The level of effort for 9-cell large-grain cavities should be increased. Existing 9-cell large-grain cavities at DESY and JLab should be tested timely and new 9-cell large-grain cavities should be built particularly in the context of multi-wire slicing successfully demonstrated recently at KEK.

Post-fabrication improvement, optimization and remediation

Post-fabrication improvement and optimization are expected to provide expeditious improvement in the cavity gradient yield because this path offers improvement opportunities for cavities fabricated with the present standard fabrication technology and standard material.

Mechanical polishing prior to heavy EP eliminates weld irregularities. It reduces or may even eliminate the need of surface removal by heavy EP. A significant fraction of the near future 9-cell cavities should be mechanically polished prior to main electropolishing.

Post-fabrication heat treatment provides important material property improvements such as hydrogen removal and metallurgical recovery. There are presently three main recipes for cavity heat treatment in a vacuum furnace. Optimal heat treatment parameters should be investigated with cavity testing as well as material characterization.

Effort for cavity remediation such as targeted repair should be continued. This path not only offers a cost-effective solution for gradient recovery of under-performing 9-cell cavities but also provide knowledge about the nature of localized defects. Success of 9-cell tumbling repair at Cornell and the more recent success of 9-cell local grinding at KEK clearly show the value of cavity remediation. Success of 1-cell cavity local re-melting with laser beam and electron beam at FNAL and JLab respectively should be extended to 9-cell cavities.

The new ILC main linac baseline design allows some cavity gradient spread. Some cavities may need to be operated at very high gradients say over 40 MV/m. This increases the field emission risk. Effort should continue for further suppression of field emission in 9-cell cavities. From the linac operation point of view, dark current is an important issue. Efforts should start to quantify field emission during cavity vertical test and correlate field emission in cavity vertical test with dark current in cavity/cavity string horizontal tested and linac beam operation. Field emission measurements should allow direct comparison across SRF facilities. One possible way is to place X-ray detectors at suitable locations on the cavity outer surfaces or at locations inside the vertical dewar where no material (other than liquid helium) is present

The Cavity basic R&D to improve gradient in a period of TDP2 may be summarized in Table 2.

Table 2. Basic R&D effort to improve field gradient with the cost effective cavity fabrication in TDP-2.

Subjects	R&D themes	Actions planned
Fabrication	Improve tools for QC in mass production	XFEL and HighGrade Project (DESY)
Fabrication	Forming/machining EBW	Smart cups (FNAL-PAVAC) Forming & EBW with Pilot Plant (KEK) Destructible bare 9-cell cavities, (FNAL/JLAB/Cornell/Industry) Bare 9-cell cavities w/ in-house welder (JLAB)
Mechanical polishing prior to heavy EP	Eliminates weld irregularities, Reduce surface removal by heavy EP	Raw 9-cell mechanical polishing before chemistry (FNAL) 9-cell tumbling for cavity recover (Cornell)
Large-grain and direct slicing	Eliminate rolling	Large-grain cavities and multi-wire slicing (KEK), Processingand evaluation of 8 existing 9-cell large grain cavities,
Seamless cavity	Eliminate weld prep machining and EBW	Hydroform and test muti-cell cavities, (DESY-JLab) Hydroform and test multi-cell cavities (FNAL/Ind.)
Material improvement	Nb with low Ta concentration	Material characterization and 1-cell cavity testing (FNAL) Materila characterization and 1-cell testing (JLab)
Post heavy EP heat treatment	Engineering thermal and metallurgical properties	Local grinding (KEK) Local re-melting with laser beam (FNAL) Local treatment/re-melting with electron beam (JLab)
Post vertical test local treatment	Rapid quench limit improvement with small incremental cost	Local grinding (KEK) Local re-melting with laser beam (FNAL) Local treatment/re-melting with electron beam (JLab)
Field emission quantified	Additional information than unloaded quality factor	Correlation of vertical test FE with horizonatal test FE as well as dark current in linac beam operation, Comparison across facilities world-wide,

Justification of the ILC Accelerating gradient

Based on the R&D plans described above, further systematic design study need to be carried out to figure out a systematic balance of R&D target values and operational parameters. It should require reasonable difference between individual cavity/component performance and the system performance with beam acceleration. Table ** summarize how we need to update our system design in the field gradient in coming TDP-2 phase.

Table: Cavity gradient balance to be re-optimized in TDP-2.

	Consideration in RDR/SB2009	Re-optimization required in TDP-2
R&D goal: S0 - 9-cell cavity gradient	35 MV/m (≥ 90%)	35 MV/m (≥ 90 %): kept for forward looking
R&D goal: S1 - Cryomodule gradient w/o beam	31.5 MV/m in average	31.5 in average or higher to be optimized for reasonable cryomodule operational margin, inclusive
R&D goal: S2 - Cryomodules gradient with beam acceleration	Not specified	Likely to be the same as ILC operational gradient
ILC-ML design value: - Accelerating gradient	31.5 MV/m in average	31.5 in average or lower to be optimized for reasonable accelerator operational margin, inclusive

An appropriate balance should be re-considered with better definitions of milestones in R&D stage and specification in the Project Stage, and a set of specification for the SCRF cavity performance (for the project and not yet for procurement) should be well established.

A new guideline in TDP-2 may be proposed as follows:

- R&D goal for the 9-cell gradient to be kept at 35 MV/m at a production yield of 90 % or more,
- Project performance for the ILC accelerating gradient with allowing the spread;

Table ***: A possible balance of gradients in various stages in the ILC ML cavity production stage (to be studied and established)

Single 9-cell cavity gradient	String Cavity gradient in cryomodule w/o beam	String cryomodule gradient in accelerator with beam
35 MV/m, in average w/ spread above a threshold	33 MV/m, in average or (or to be further optimized)	31.5 MV/m, in average (or to be further optimized)

The following two specific subjects to be further studied in the TDP-2 as follows:

- How wide cavity gradient spread may be acceptable in balance of additional HLRF power source capacity and efficiency to be required?
- How large operational margins are required in the single cryomodule gradient (without beam), and in the accelerating gradieng in cryomodule strings in the ILC main linac (with beam) ?

The above studies are crucially important to optimize the ILC ML SCRF design in balance of the HLRF design.

3.2 Towards a global cryomodule design and plug compatibility

Cavity Integration:

The main R&D items of cavity integration area for the TDP term are;

(1) Tuner including integration with He jacket,
(2) RF input-couplers,
(3) Cavity assembly with plug-compatibility
(4) Preparation for industrialization.

There are three kinds of tuner design: lever-arm tuner, blade tuner, and slide-jack tuner. The lever-arm tuner is used for the FLASH cryomodule and XFEL cryomodule. It has a lot of experience and performance demonstration around 35MV/m operation. It is installed into the beam pipe location, so that the beam pipe length of the tuner installation side should have excessively longer length than ILC cavity design requirement. The blade tuner is designed to install in the middle of Helium jacket and with much consideration on the mechanics simplicity for cost reduction. The slide-jack tuner design has been done by the point of view of enough stiff structure to reduce piezo stroke for long life and reducing risk of failure. The performance experience will be accumulated in FLASH and XFEL pre-series cryomodules for the lever-arm tuner, in the project-X cryomodules for the blade tuner, and in STF phase2 cryomodules for the slide-jack tuner. In 2010, the S1-Global cryomodule experiment at KEK-STF supplies a good R&D opportunity to compare these three tuners in the same place and the same condition. During S1-Global test, frequency tuneablity including sensitivity, backlash, and stability, heat-load, maintenability will be tested and compared. For piezo actuator, performance of Lorentz Force Detuning compensation will be directly compared, together with frequency control sensitivity, performance of multiple pulse compensation action.

The R&D for the coupler will be done for the compatible design between tuneablity function, easiness of mechanical installation, and low heat load. The loaded Q control for each cavity is essential for the combination use of various Q cavities. The unification of Q control which is now done by both of three-stub tuner and input coupler control should be done in this TDP. The ceramics window R&D for less stress for thermal contraction, for more stable brazing and more short time RF processing are also considered. In S1-Global cryomodule, four of TTF-III coupler and four of KEK disk window coupler will be operated and compared their performance, in the same condition.

Cryomodule Assembly and and A Global Collaboration: S1-Global

The project of ‘S1-Global’ is in progress with aiming at to demonstrate the ILC accelerating field gradient with an international cryomodule composed of an 8 string of 9-cell cavities in one cryomodule. It has been successfully assembled at KEK, and is scheduled to have cold test from June 2010 to December 2010 at KEK-STF. The cryomodule consists of the two half-length cryostats which house 4 cavities in each. They are two DESY cavities and two FNAL cavities. Two DESY cavities install lever-arm tuner, two FNAL cavities install blade tuner, and four KEK cavities install slide jack tuner. As for the input coupler, DESY and FNAL cavities use TTF-III coupler and KEK cavities use KEK coupler which has double disc window. A half of cryostat and cold mass has been developed in cooperation with INFN and KEK and another half has been provided by KEK. The experiment items for these cavities are as follows;

Table R&D and subjects to be evaluated in S1-Global cold Test

Period	Subject	Contents	Contributed by	Notes
June 7 -	Cool-down	Alignment and Frequency deviation	KEK, IHEP, DESY	Cooling in day-time only,
June 16 -	Heat load		KEK, IHEP	Optical window open,
June 21 -	Low-power RF	Tuner (mortor and Piezo) test and frequency tuning	KEK	
June 28	Low-Power RF	Qt calibration HOM property Single pulse response to Piezo Tuner		
July 5 -	Low-Power RF	Piezo tuner exp.	KEK, FNAL, INFN	
July 12	Heat Load /Calibration	At 2K with Heater		No optical window
Aug. 23 -	Coupler againg			
Sept. 6	Re-cool-down			
Sept. 15 -	Heat Load at 4 K			
Sept. 20 -	High-power RF	High gradient test,	KEK, FNAL	
Oct.	Dynamic Heat Load	With High P. RF, 2K	KEK, FNAL	
Nov.	LLRF control/feedback			

Dec.	HLRF	DRFS	KEK	

(1) Evaluation of mechanical tuner and piezo tuner performance in low power
(June 2010 to July 2010; INFN team and FNAL team participation)
(2) Perform input coupler conditioning in room temperature and in cooled state
(August 2010 to September 2010; by only STF team)
(3) High gradient operation of each cavity to its maximum to check the maximum allowable gradient of each cavity.
(September 2010)
(4) High gradient operation with supplying the power to 4 cavities group, and with supplying the power to the all of 8 cavities from the 1 klystron.
(November 2010)
(5) Study of Lorentz detuning and its compensation control
(October 2010; with FNAL team participation)
(6) Static heat load measurement and dynamic heat load measurement of the cryomodules
(July 2010, November 2010 for static, and October, November 2010 for dynamic; with FNAL team participation)
(7) LLRF study on feedback performance, IF mixture method, adaptive feed-forward method, RF power fluctuation measurement
(November 2010)
(8) DRFS system test using 2 set of the system consist from one 750kW klystron with two cavities
(December 2010)

DRFS test in S1-Global

DRFS system in the tunnel to be tested is the basic system which consists of the HV-DC power supply and the modulation anode power supply that are connected to the two klystrons, together with LLRF control rack in the tunnel next to the cryomodule. The klystron will be connected to two cavities with the simple waveguide eliminating the circulators, and they placed in the aisle side of the cryomodule.

The end point of the S1-Global experiment is determined to the end of December, 2010, because of the STF phase-2 accelerator construction schedule will be started on January 2010, aiming of the injector part operation from October 2011. The cryomodule operation and the study must keep the schedule and should be done with efficient manner.

Cryomodule Design/Integration and plug-compatibility

As the R&Ds for the cryomodule integration, the following items are proposed from the previous studies and the present on-going S1-G cryomodule tests. The items are divided into three parts; cryomodule design for the stage S2 (i.e. STF-2 at KEK, and NML at FNAL and further) , assembly procedure of the cryomodule and thermal test plan of the S1-G cryomodule.

<u>1) ILC Cryomodule design (for the S2 and further)</u>

1-1. Thermal shield design

The proposed design of the ILC cryomodule in RDR has two sets of thermal shield of 5 K and 70 K as same as the TTF-Type-III and XFEL cryomodules. In the previous GDE meetings, the heat load by thermal radiation to 2 K region without the 5 K shield and the total cost including the operation cost of 10 years were studied, and the total cost without the 5K shield by optimizing the cooling scheme can be less than that with 5K shield. In the cryomodule design for S2, the cryomodule components need to be designed to make the study of this thermal concept possible, and the cryomodule cost should be re-evaluated with the 12 m cryomodule for S2 (STF-2 at KEK) .

1-2. Magnetic shield design

The magnetic shield design will be discussed in the cavity integration, however, the shield inside or outside of the cavity jacket has a big impact on the cryomodule assembly and the required man-hour outside of the clean room. The performances of two types will be compared in the S1-G cryomodule cold test. The overall cost including manufacturing shield components, assembly time and man-hour needs to be studied.

1-3. Plug-compatibility

The cryomodule for S2 should be designed for accommodating the “Plug-compatible” concept. In the S2 cryomodule design, the connection flange of the vacuum vessel, the size and position of cooling pipes, thermal shield shape and input coupler flange on the vacuum vessel should be considered.

The alignment process and the fiducial target of cavities and cryomodule should be discussed in designing the S2 cryomodule from the “Plug-compatible” point of view.

{note: the following part may be moved to the S1-Global section}

2) Assembly study of the cryomodule

The S1-G cryomodule consists of three types of cavities and two types of 6-m cryomodules. From the assembly experiences of these different components, the assembly processes and man-hours are able to be compared and reviewed. The data are necessary to estimate the assembly cost of the ILC cryomodule.

3) Thermal test plan of the S1-G cryomodule

In the cold test of the S1-G cryomodule, the thermal measurements of the static and dynamic heat loads of the S1-G cryomodule are scheduled; the static heat load measurements are in July and November 2010, and the dynamic load measurements are in October and November 2010. In the following, these study items are shown.

3-1. Heat load measurements

Static and dynamic heat loads of the modules are mainly measured by the mass flow rate of evaporated 2 K liquid helium. In order to attain the stable thermal condition, after setting the thermal parameters, it will be required two hours for one measurement. The calibration measurements by a heater will be performed, and the precision of the measurement will be confirmed.

The dynamic heat load of three types of cavities will be measured at its maximum operating field. Heat load of each cavity in the detuned condition will be measured in the same sequence of the dynamic measurement. In order to measure 8 cavities, the period of 8 days is scheduled. After the measurements of the individual cavity, the measurements of two sets of 4 cavities and all 8 cavities at the average field gradient of 31.5 MV/m are scheduled.

3-2. Measurement of temperature profile in the two 6-m modules

Temperature profiles of the components are measured with 201 thermal sensors. The measured profiles are compared with thermal calculations in order to evaluate thermal performance of the different types of the components.

3-3. Position deviation of cavities and GRP during the cold test

Positions and deformations of the gas return pipes are measured with 10 Wire Position Monitors (WPM), 4 laser position sensors and 24 strain gauges. Movement of the gas return pipe during the cold test will be measured with these sensors.

Eight WPMs are assembled on four KEK cavities, and the measured positions of cavities will be compared with the motion of the gas return pipe.

Preparation for Industrialization

As a good experience of an industrialization study, ILC will have a benefit from XFEL construction, that is, 4% cavity production of ILC. The other effort will be done in both of US region and in KEK, in collaboration with industry. Especially, KEK will construct the KEK cavity fabrication facility (KEK-CFF), where the cost-effective production technology will be investigated. The electron beam welder (EBW), press machine and trimming machine as well as chemical treatment room and various inspection tools will be installed during 2010-2011. The first production of 9-cell cavity without HOM coupler by partly using this facility will be done in 2010, before EBW machine delivery, as a start-up. The next cavity production from 2011 is expected to be installed in the STF cryomodule. The production technology development can be done in parallel for these cavities production during TDP. The KEK-CFF may be open to be used by Japanese Industries to study cost-effective manufacturing as well as to be used in cooperative study between KEK and other laboratories world-wide.

The cavity industrialization study has been also started and an international workshop on the cavity technology and industrialization was carried out as a satellite meeting for the 1st International Particle Accelerator Conference, held at KEK. Based on this workshop, the following observation/finding and subjects for further study are given.

(note: the following text, from part of close out given by J. Kerby, and to be further edited)

…….,

For cavity production, it was presented that a reasonable split would be 6 manufacturers, two in each of the three regions, each producing ~3000 cavities over the course of 5 years. Even with this split, each manufacturer is producing at a rate of ~5-6 times more cavities per year than the current world maximum expected in the upcoming 5 years. This level of production, though appearing large to our current vendors and the ILC community, is actually a mid-level to modern large scale production (cars, electronics…), and will be best served by flexible workshops and flexible cells of manual work.

However, the level of production is well beyond what industry sees as a sustainable level for business…meaning that the ILC will be treated as a 'project', not a 'business', such that plant costs associated with scale up and tear down will have to be born by the ILC.

The laboratory / industry interface was the subject of considerable discussion, both at a detail level as it relates to cavity and cryomodule production plans, but also in a more general sense as it pertained to other recent large science projects such as ITER, the XFEL, or the LHC.

Throughout all the discussions it was emphasized that involving industry as early in the process as possible was good, even in the development phase, however where industry excels in delivering the best value is when it can quantify the risk. Industry can add value particularly in areas of cost reduction, alternative methods, shortening production times, and technical performance when involved early. However, to do so the item and process should be relatively well understood. In places where research is ongoing, or the risk can not be well quantified, the laboratory should bear the burden of the effort. This is not to say that the boundary is fixed; on the contrary, as research progresses, it may be more and more possible for industry to assume the role—an example of this in cavity production is the current effort to move EP to industrial locations in Europe and now in the USA.

………..

There were several production models that have been developed, estimating the size and number of components in production facilities for cavities and cryomodules that had been developed in all three regions. It was agreed that cross checking such models would be beneficial, and further the cross checking the models with XFEL production experience will be extremely valuable in making better projections of the ILC needs.

It should be an important subject in further study for ILC management to review the existing RDR VALUE estimate with the information gained at this workshop to review both what production model is included in the VALUE estimate, and the R&D plan to see if the current ILC-industry relationship is the best possible under the time and economic constraints imposed on the TDP-2 phase but leading to a production ready stage for the ILC.

Cryogenics Design Study and R&D

Critical R&D for the TD Phase includes:

- Empirical determination of dynamic heat loads using test facilities
- Cryoplant engineering, specially for cryoplant design in mountain regions, as a subject not well experienced,
- Evaluation and comparison of pressure vessel regulations
- Design of non-main linac cryogenic systems

3.3 System integration testing ("string tests")

{Note; the following text, as prepared by M. Ross, June 25, 2010}

1) Motivation for System Test

Full performance of multiple cryomodules powered by a single klystron through the baseline RF power distribution system will be demonstrated as part of the main linac test system test, referred to as the 'cryomodule-string test' or 'S2'(http://ilcdoc.linearcollider.org/record/7056/files/s2_report_v6.doc). The test will include beam acceleration and beam handling.

The motivations of the cryomodule-string test are:

a) demonstration of ILC linac performance with beam acceleration,
b) demonstration of a number of cavities in operation showing repeatability of the production process and providing an estimate of reliability,
c) evaluation of realistic cavity performance as a test of the industrialization process, in order to prepare for industrialization.

Preparation for such tests are planned or underway at facilities built at DESY (TTF / FLASH), KEK (STF), and Fermilab (ILCTA-NML).

2) Goals of the System Test

Specific string test goals, listed in order of importance, include:

1. Demonstrate stable acceleration at nominal parameters. The nominal accelerating gradient specification is 31.5 MV/m, average, with 0.5% pulse to pulse RF amplitude stability / 0.5° pulse to pulse phase stability at any point during the ~1 ms RF pulse.

    a. The demonstration should include feedback and related controls to achieve stable phase and amplitude at nominal ILC beam intensity,
    b. Evaluation and demonstration of operational gradient margin budget and
    c. Demonstration of operation with a spread in cavity limiting gradients
2. Tests of basic system parameters
    a. demonstrate operation of a nominal section or RF-unit,
    b. determine the required power overhead under practical operating conditions,
    c. to measure dark current and x-ray emission, (this is to be used to establish precise radiation dose-rate limit vertical test acceptance criteria), and
    d. to check for heating from higher-order modes in order to determine the dynamic cryogenic heat load with full beam current operation
3. Tests and optimization of operational and logistical strategies
    a. developing RF fault recognition and recovery procedures,
    b. evaluating cavity quench rates and coupler breakdowns,
    c. testing component reliability,
    d. performing long term testing of cryomodules, (including thermal cycling), and
    e. assembling the string an actual tunnel to explore installation, maintenance, and repair issues.

The ILC main linac performance requirement is 9 mA peak beam current with 2625 bunches and 0.1% energy stability, rms, with 5 Hz pulse repetition rate. Current studies, underway at DESY (TTF / FLASH), have demonstrated 7 mA peak beam current operation with 0.13% rms pulse to pulse beam energy stability and 0.5% peak to peak energy deviation within a 2400 bunch train. As described below, the TTF / FLASH test linac was neither constructed using ILC-performance cavities nor was it laid out in the nominal ILC Reference Design 'RF unit' configuration. Current study results were done with cryomodules operating with a limiting average gradient of 23 – 27 MV/m.

Feedback and feed-forward control of the RF unit accelerating-field vector sum over all cavities is the most challenging aspect of full power, full gradient linac system tests. If the vector sum control is properly optimized, then the required operational gradient and HLRF power overhead will be minimized and the main linac baseline can be established accordingly. Three elements dominate controls development: 1) Lorentz Force detuning (LDF), 2) cavity input power and coupling (P_k, and Q_ext) under nominal beam loading conditions and 3) pulse-driven vibration or microphonics. These effects are strongly dependent on beam current and peak gradient.

Our strategy for accomplishing the goals depends on the infrastructure limitations and schedule constraints at each of the three main linac test facilities (see x.4, below). It is important to note that the strategy relies heavily on experience gained at 1) injector test facilities, such as PITZ (Desy/Zeuthen), FNPL (Fermilab/A0) and Quantum Beam (KEK), 2) high-power cavity 'horizontal test facilities', such as Checchia (DESY) and HTS

(Fermilab/Meson) and 3) cryomodule test facilities, such as CMTF (DESY). This critical test infrastructure has allowed development of the technology required to produce ILC-like beam and to control and stabilize the superconducting linac accelerating RF. In many cases, equipment developed in these smaller test facilities is subsequently directly deployed in the System Tests.

3) Global Competence and Diversified Strategy

It is important that each region implement a full superconducting linac system, including the cryomodules, the beam generation and handling and the RF power source and distribution systems to integrate the accelerator technology and gain sufficient experience in that region. However, even with the planned three-fold regional string test infrastructure redundancy, no one of the test linacs will match the final baseline reference design RF unit within the TD Phase time scale. This is partly due to institutional commitments to support parallel projects as well as more fundamental conventional facilities infrastructure limitations. Also, the baseline design itself will evolve as R&D results become available. It is foreseen, however, to address the essential technical aspects of the technology by globally developing suitably complementary programmes to obtain sufficient R&D results in preparation for the Technical Design Report.

4) Main Linac Technology Test Facilities

a) TTF / FLASH (DESY)

1) Background and Goals for operations

The 'TESLA Test Facility / FLASH' linac at DESY is a 1.2 GeV linac based on the same technology as that planned for ILC. The linac is by far the oldest and best established facility based on ILC technology, having started operation in its present configuration in 2005. FLASH operates as a VUV – FEL user facility for roughly 6000 hours each year. Time available to develop key technologies needed to demonstrate the above includes nominally allocated FEL machine development time since that program has several key goals which are the same as those of the string test. Extended FEL operations using long bunch trains (1 MHz bunch rate with 0.5 nC bunches at 10 Hz linac repetition rate) will begin in 2010.

2) Anticipated Beam Parameters

The TTF/FLASH linac has:

a. Nominal ILC beam current with 2400 bunches (90% of nominal)
b. Seven cryomodules with 56 cavities powered by 4 klystrons (3x5MW and 1.3 MW) and accelerating gradient limited to 30 MV/m average for two of the 7 cryomodules (95% of the ILC nominal). The spread in limiting gradients for these two cryomodules is 21 – 39 MV/m, about 2 times larger than the limiting gradient spread under consideration for the updated ILC baseline.
c. RF units of two cryomodules and ~ 6 MW power sources.
d. Cryogenic and power infrastructure capable of 10 Hz operation.

2) Development plans

The cryomodule string test at TTF / FLASH is referred to as the '9 mA' experiment. The objectives of the 9 mA experiment are closely aligned with the goals listed above. Studies and development activities in support of 9 mA experiment include:

a. Modeling of the cavity / HLRF/ power distribution / LLRF control system, including 'Lorentz Force detuning' and microphonics
b. Development of LLRF controls
c. Integration of high – power linac machine protection systems
d. Studies of needed RF power and cavity gradient overhead
e. Studies of long - term RF stability
f. Studies and demonstrations of ILC bunch compressor RF stability

Work on each of the above is proceeding in parallel and is supported largely by the DESY / FLASH expertise. Initial modeling results have provided a phase and amplitude stability tolerance budget to guide technical strategy and prioritization:

Error Source	Required Amplitude Stability	Required Phase Stability
LFD	.2	.2
P_k / Q_ext match with nominal beam current	.2	.2
Microphonics	.2	.2
Static detuning	.1	.1
Beam loading variation	.1	.1
Calibration	.1	.1
Linearity	.1	.1
Noise	.02	.02
Residual error	.1	.1
Long term Drifts	.1	.1
Quadrature sum	.4	.4

In order of priority, the TTF / FLASH 9mA program implementation will be based on

- improvements to the machine protection system that minimize the impact of beam off/on and RF off/on transients. These allow the steady high power beam operation, a pre-requisite for controls studies. The most important transient is beam off / on in the SCRF cavities that are tuned for nominal high current operation. The successful completion of the study requires adjustment of P_k and Q_ext for each cavity to match the 9 mA beam current. (For some of the TTF / FLASH cavities, P_k control cannot be done remotely.)
- adoption of a cavity frequency tuning and Q_ext adjustment procedure that provides 'flat' cavity amplitude and phase during the beam pulse and maximum sustainable (below quench) gradient. The procedure must include feed-forward compensation for Lorentz Force detuning using piezo-electric cavity tuners. In preparation for the 9 mA studies, LFD control will be demonstrated and evaluated using the S1 Global cryomodule (KEK) and HTS (Fermilab).
- adoption of nominal gain vector sum feedback with the integral gain required to flatten the accelerating gradient during the beam pulse. The feedback primarily compensates for variations in beam current.

3) Issues with operation and schedule

Dedicated ILC 'cryomodule string test' operation of TTF / FLASH is expected to be around 250 hours per year. Since performance achieved in late 2009 is quite close to the goal performance for the 9 mA experiment, we expect to deploy the above changes, and take full advantage of long-pulse FEL operation, to achieve the intensity and stability goals in early 2011.

b) Superconducting Test Facility (KEK)

1. Background and Goals for operations

STF development during TDP2 will be on the injector construction and operation, and on the first ILC-type cryomodule construction and operation. The injector, which includes an L-band copper cavity RF gun and two 9-cell cavities in a capture cryostat driven by the one DRFS klystron will be operated for the "quantum beam experiment" for one year from October 2011 to July 2012. It will then become the injector for the STF accelerator. In the end of 2012, the first ILC-type cryomodule will be assembled and installed in the tunnel. STF RF and beam operation will begin in 2013.

2. Anticipated beam parameters

Beam parameters of the "quantum beam experiment" is 162.5MHz bunch repetition rate within a 1ms RF pulse with 62pC bunch charge. The beam loading, 10mA is similar to ILC. For STF phase 2 operation, the injector beam parameters will be changed to 3MHz bunch repetition and 3.2nC bunch charge within the nominal 1ms RF pulse by changing the laser system for the photo-cathode.

3. Development plans

The photo-cathode RF gun is now under development collaboration with FNAL for cavity part and Institute of Applied Physics (Russian Academy of Science, Nishni-Novgorod) for the ILC type laser part. RF processing is now underway and the laser system is ready for use. For the "quantum beam project", the laser system will be replaced to the 162.5MHz one which has already been purchased and tested. Two 9-cell cavities and the capture cryomodule have already been ordered and will be delivered in early 2011. Nine 9-cell cavities, intended for the first ILC cryomodule are now in fabrication as part of a 3 year fabrication plan. The design of the first ILC cryomodule will begin later this year. For the second ILC cryomodule, the plan is to include cavities from additional Japanese vendors and cavities produced in the KEK pilot plant. Procurement for these cavities and for the cryomodule will start in 2011 and be completed by the end of 2013.

The ILC type cryomodule will be driven by DRFS klystrons in the tunnel. The klystrons and the power supplies are constructed in two years, (2011- 2012). The LLRF system will also be installed in the tunnel.

4. Issues with operation – including system limitations and schedule

The "quantum beam project" assignment must finish by the end of JFY2012. The beam operation and its X-ray generation experiment should finish by the summer of 2012, after about one year operation, starting in October 2011. Due to budget constraints, the ILC cryomodule will be assembled in-situ in the STF tunnel, without the construction of a new vertical shaft large enough for full length cryomodules at the very end of STF tunnel.

> For this construction scheme, the cavity-string cold-mass assembly is divided in two parts, i.e. two 4 cavity strings. Each string is brought into the STF tunnel separately and joined there as part of the final cryomodule assembly.

Within the TDP2 time frame, the STF contribution to the cryomodule string test ('S2') task operation will be limited to one cryomodule with ILC beam loading.

c) New Muon Lab (Fermilab)

1. Background and goals for operations

The Fermilab-based 'New Muon Lab' facility is under construction, in two stages. The facility will produce 450 MeV ILC-like beams by the end of the Technical Design Phase with 2 cryomodules. In 2013 – 2015 the facility will expand to 6 cryomodules and a beam energy over 1 GeV. To facilitate development of needed technology and expertise, the injector single-cavity cryomodule is operational and under test for stabilization and cryogenic system testing.

2. Anticipated beam parameters

The NML injector has been developed in collaboration with KEK and DESY and is based on more than a decade of experience at FNPL (A0). It uses a 1 ½ cell copper L-band RF gun with a capture cavity. FNPL equipment will be re-deployed at NML in 2011 and full ILC beam parameter operations with two cryomodules will begin in USFY 2012.

3. Development plans

As part of the general lab expansion funded through the 'American Recovery and Reinvestment Act of 2009', the New Muon Lab building is being extended to accommodate the installation of 6 nominal – length cryomodules. Construction is expected to be complete in late 2010. The Fermilab group has developed specialized controls for controlling and minimizing the impact of Lorentz Force detuning. This system will be applied to control pulse-driven microphonic instability and will be tested at NML, HTS (Fermilab), TTF/FLASH and S1 Global.

4. Issues with operation – including system limitations and schedule

In 2013 and 2014, approximately half of the scheduled linac operation (2000 hours/year) will be dedicated to demonstration of the cryomodule string test objectives. The system will be complete and operational for RF unit testing during USFY 2014.

3.4 Development of High-Level RF solutions

{note: The first part of the following text is that for R&D plan (Release 4)}

The main focus of the TD Phase High-Level RF R&D program is to develop and test a Main Linac section or RF Unit which meets ILC requirements and has an estimated cost significantly lower than that of the RDR RF unit. Specific targets for cost reductions are the modulator, the klystron and RF power distribution systems.

Modulator

The RDR baseline modulator is the Fermilab “Bouncer Modulator”. A transformer-less design based on Marx-generator circuits is under development. The Marx-based design is being pursued because of potential cost savings and reliability improvements over the Bouncer design. The projected cost savings assume a lower component cost and a significantly less labour-intensive manufacturing process. A prototype Marx modulator is being developed at SLAC in order to show proof-of-principle and to establish a design that would allow a credible cost estimate. Current projections would make it possible to develop a cost estimate by mid-2010 and hence allow the adoption of the technology as part of the re-baseline to be used in TD Phase 2.

Power Distribution System

The RDR baseline is a linear distribution system with individual tap-offs, circulators, and 3-stub tuners for each cavity. An alternative design using a semi-branched system (two cavities per tap-off) with variable tap-offs is under development and may make it possible to eliminate costly circulators. A critical aspect of the power distribution system activities is to develop low-cost implementations of key RF components such as the variable tap-offs, phase shifters, and loads. An additional focus for the power distribution system is to provide sufficient flexibility and adjustability to compensate for variations in cavity gradient, allowing the total gradient for each linac RF unit to be optimised. Recently, two new proposals have been under investigation as alternative design configuration: a klystron cluster scheme (KCS) and a distributed RF source scheme (DRFS). Further investigation and R&D are under discussion in combination with a single tunnel CFS design, as it is discussed in the Section 4.

TD Phase-1 Milestones:

- Demonstrate operation of Marx modulator powering a baseline multi-beam klystron
- Demonstrate performance of key distribution system components – variable tap-offs, phase shifters and loads

TDP Phase-2 Milestones

- Perform a demonstration of an integrated RF system (modulator, MB klystron, power distribution, cryomodules, LLRF, controls). The goal is to perform this test at NML, (Fermilab) and at STF, (KEK). Related testing of critical aspects will also be done at TTF/FLASH, (DESY). Beam operation is required to demonstrate regulation and control.
- Perform R&D efforts for KCS and DRFS to figure out the most cost effective RF system design.

Klystron Cluster Scheme R&D

Current program:

- Pumpdown of 10 m large circular waveguide
- Cold test of CTO’s
- Transmission test through CTO’s and 10 m waveguide
- Resonant test of evacuated CTO and 10 m waveguide up to ~300 MW traveling waves.
- Resonant test of (2 bar absolute) pressurized CTO and 10 m waveguide

Follow-up plans (2011):

- Design and build bends for large waveguide
- Cold test bend between CTO’s.
- Incorporate bend into assembly with large waveguide and repeat high power transmission and resonant tests
- Obtain more large waveguide (~80 m) and add to assembly
- Make 3rd tap-off to test tap-off function and combining function.
- Perform tests.

Further plans (2012):

- Design and build directional coupler?
- Make resonant ring w/ tap-off/tap-in assembly (w. WR650 circ., dir.cplr. & phase shifter)?
- Test at full travelling wave power?

Distributed RF System R&D

The following subjects need to be studied:

- Design and demonstration of medium power (- 750 kW) klystron for DRFS,
- Design and perform two-cavity circulartor-less RF system for DRFS at KEK, and demonstration at S1-Global HLRF test,
- Design of HV charger system for DRFS,
- Value engineering,
- Installation into single tunnel,
- Maintenance, and upgrade-work ability,
- MTBF and replacing scenario,
- Long term operation with quantum beam project as a demonstration and technology verification,

-

3.5 Main Linac integration

Main Linac Integration design work and development in the TD phase includes:

- Integrated beam dynamics simulation (including tuning and feedback modelling) and wakefield calculations to establish tolerances for linac component initial alignment and specifications of beam-based alignment procedures
- Development and testing of the linac quadrupole and dipole magnets and key linac beam instrumentation

The primary R&D efforts are required for the quadrupole magnet package design and prototype development in the TD Phase. A new technical approach is being investigated to design the quadrupole magnet with conduction cooling. It enables to assembled the quadruple separately from the cavity string assembly in clean room environment.

{note; the following text prepared by J. Kerby, June 17}

Fermilab has started design and development of a splittable quadrupole design. The advantages of this design are that it can be assembled around a beam tube, so it can be added to the cavity string outside of the clean room in the cryomodule assembly process. The quadrupole is also conduction cooled, and designed to occupy the same space as the baseline quadrupole design, so integration into the baseline cryomodule design is relatively straighforward.

To develop the design this year Fermilab will design, construct and build a first model of a splittable quadrupole and prepare it for test in VMTF at Fermilab in US-FY11. This test will allow us to measure the basic magnetic properties of the quadrupole, though not the full features needed as when it will be assembled into a cryomodule. In addition, we will make a 2nd iteration of the design, which would incorporate more of the functionality required for operation in the ILC. Furthermore this year we will do an analysis of the various test station options such that the 2nd model can be tested more thoroughly with respect to the ILC requirements.

Although not in the ART region funding at this time, should further funding be available in FY11 the program would be extended to procure the parts and assemble quadrupole #2, and develop a test stand or dewar and associated equipment so the 2nd magnet can be tested in conduction cooled mode, and detail measurements of the magnetic stability taken.

4 Accelerator Systems R&D (including BTF) [Marc]

4.1 Damping Ring electron cloud mitigation (CesrTA)

4.2 Final Focus demagnification and stabilisation (ATF2)

4.3 Electron and positron source R&D

4.4 Damping Ring systems R&D

4.5 RTML R&D

4.6 BDS R&D

5 Accelerator Design & Integration (AD&I) [Nick]

5.1 Parameters

5.2 Baseline consolidation (layout)

5.3 CF&S

5.4 TDP-2 Documentation

6 Updating the VALUE Estimate [PHG?]

6.1 Superconducting RF

6.1.1 Producing mass-production models

6.1.2 …

6.2 CFS

6.3 Other Accelerator and Technical Systems

6.4 Developing the construction schedule

6.5 …

7 Developing a Risk Assessment for the TDR [TBD – Ewan?]

8 Producing the Project Implementation Plan [TBD – Mike?]

9 Global GDE Resources [TBD]