Low Level RF and Controls

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Scope

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- VTS
  - Cavity testing with automation - stand alone PLL (TD)
- HTS
  - Dressed cavity testing - Simcon based,
- HINS
  - Fast Ferite Vector Modulator - 325 MHz, SNS/LBNL/FNAL
- Coupler conditioning
  - 1.3 GHz and 3.9 GHz - rack and stack
- RF Unit
  - Cryomodules, RF distribution, regulation, reference line, automation - Simcon followed by FNAL design (compare and contrast)
- Photo injector for beam tests
  - Beam based calibration, beam loading, dynamic response, cryomodule stability, full system test
- Control system for control, automation, data acquisition

R&D issues in LLRF for SCRF

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- RF Field Regulation
  - Maintain Phase and Amplitude of the accelerating field within given tolerances to accelerate a charged particle beam to given parameters
    up to 0.5% for amplitude and 0.03 deg. for phase
- Minimimize klystron Power needed for control
  - RF system must be reproducible, reliable, operable, and well understood.
  - Active Piezo tuner feedback system
  - HINS- Fast Ferite Vector Modulator control
- Other performance goals
  - build-in diagnostics for calibration of gradient and phase, cavity detuning, etc.
  - provide exception handling capabilities
  - meet performance goals over wide range of operating parameters

Challenges for RF Control

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- Topics
  - Vector-Sum Calibration (Ampl. & Phase)
  - Operation close to performance limits
  - Exception Handling
  - Automation of operation
  - Piezo tuner lifetime and dynamic range
  - Optimal field detection and controller (robust)
  - Operation at different gradients
  - Defining standards for electronics (such as ATCA)
  - Interfaces to other subsystems
  - Reliability

R&D issues Controls for SCRF

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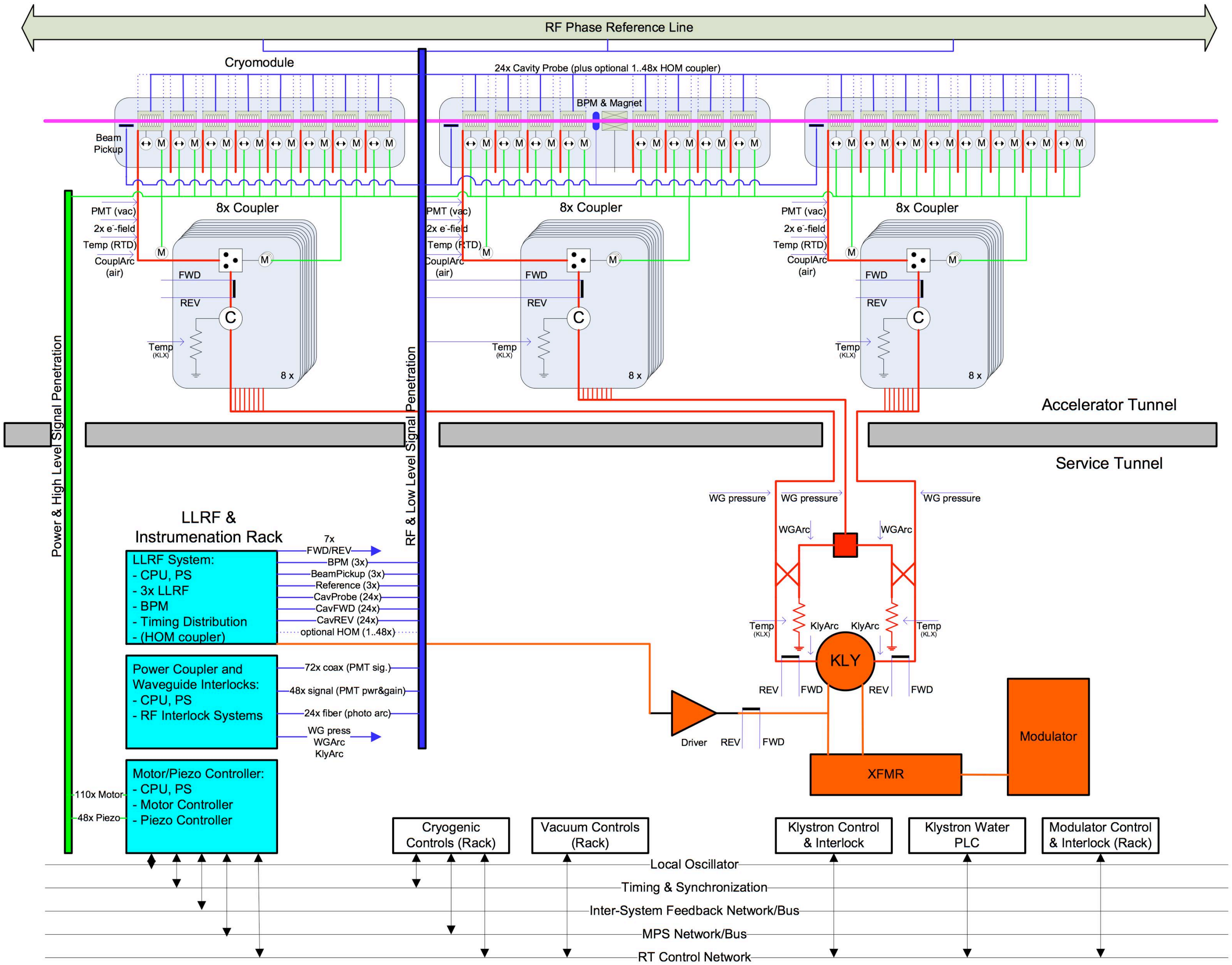
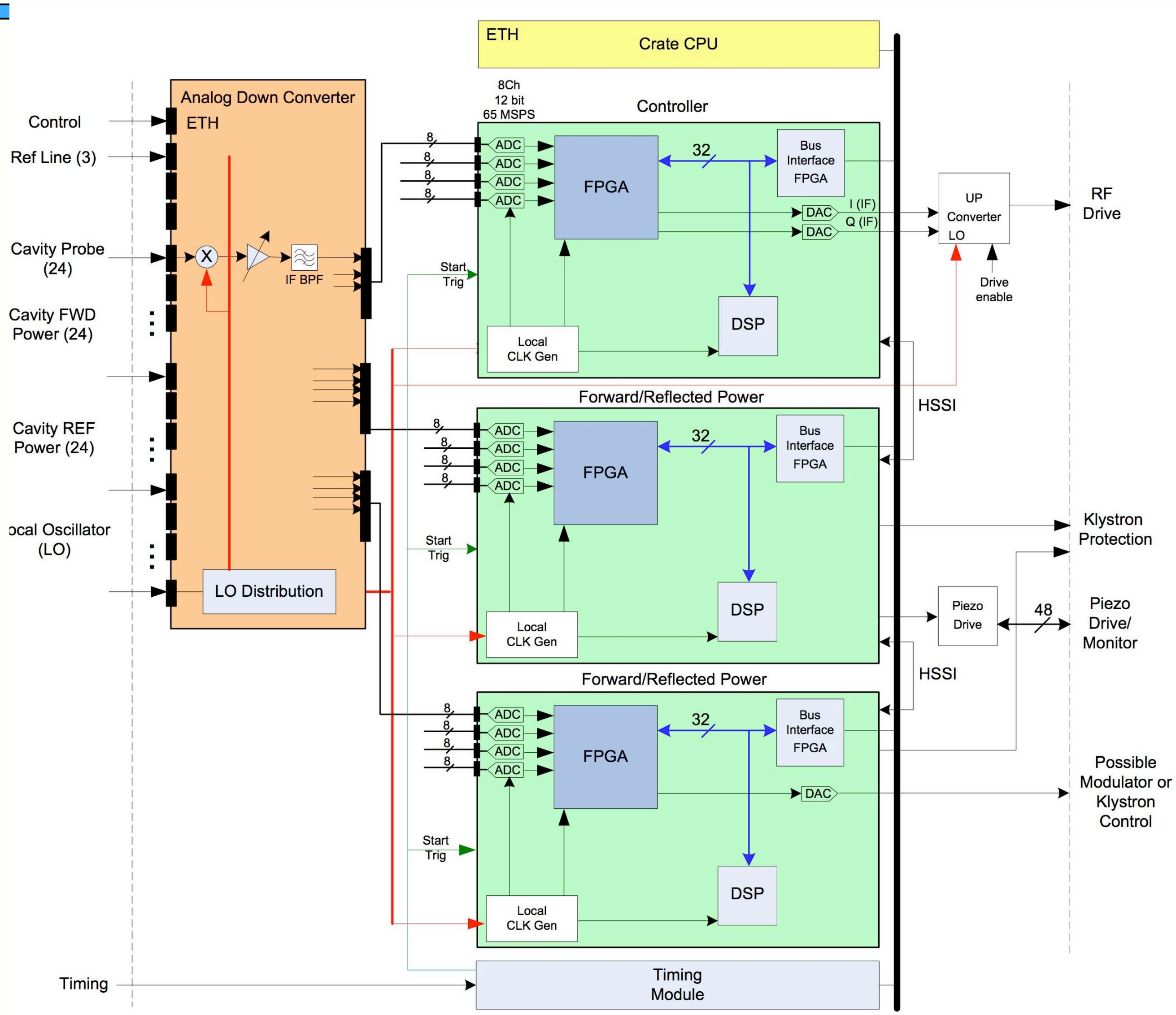
- **Short term development work needed**
  - **Multi-system**
    - **Provide a controls system infrastructure that can readily integrate components developed at collaborating institutions. E.g., DESY brings equipment with DOOCS interfaces, INFN with Labview, ANL with EPICS, etc.**
  - **Timing**
    - **Develop a timing and clock system that are required for first beam operation.**
- **Longer term R&D goals**
  - **High Availability**
    - **Evaluating ATCA (emerging high availability standard) as a middle layer and/or instrumentation platform**
    - **Evaluating middleware software techniques including such as service objects architectures for controls systems middleware.**
  - **Scalability**
    - **R&D needed to configure/control/monitor a control system as complex as the ILC.**
  - **Remote operations**
    - **Provide a framework which is supportive of remote operations R&D such as locking devices that are needed for autonomous operations.**
- **Requirements document** is currently under construction and a first draft can be found at : http://docdb.fnal.gov/ILC-public/DocDB/ShowDocument?docid=325

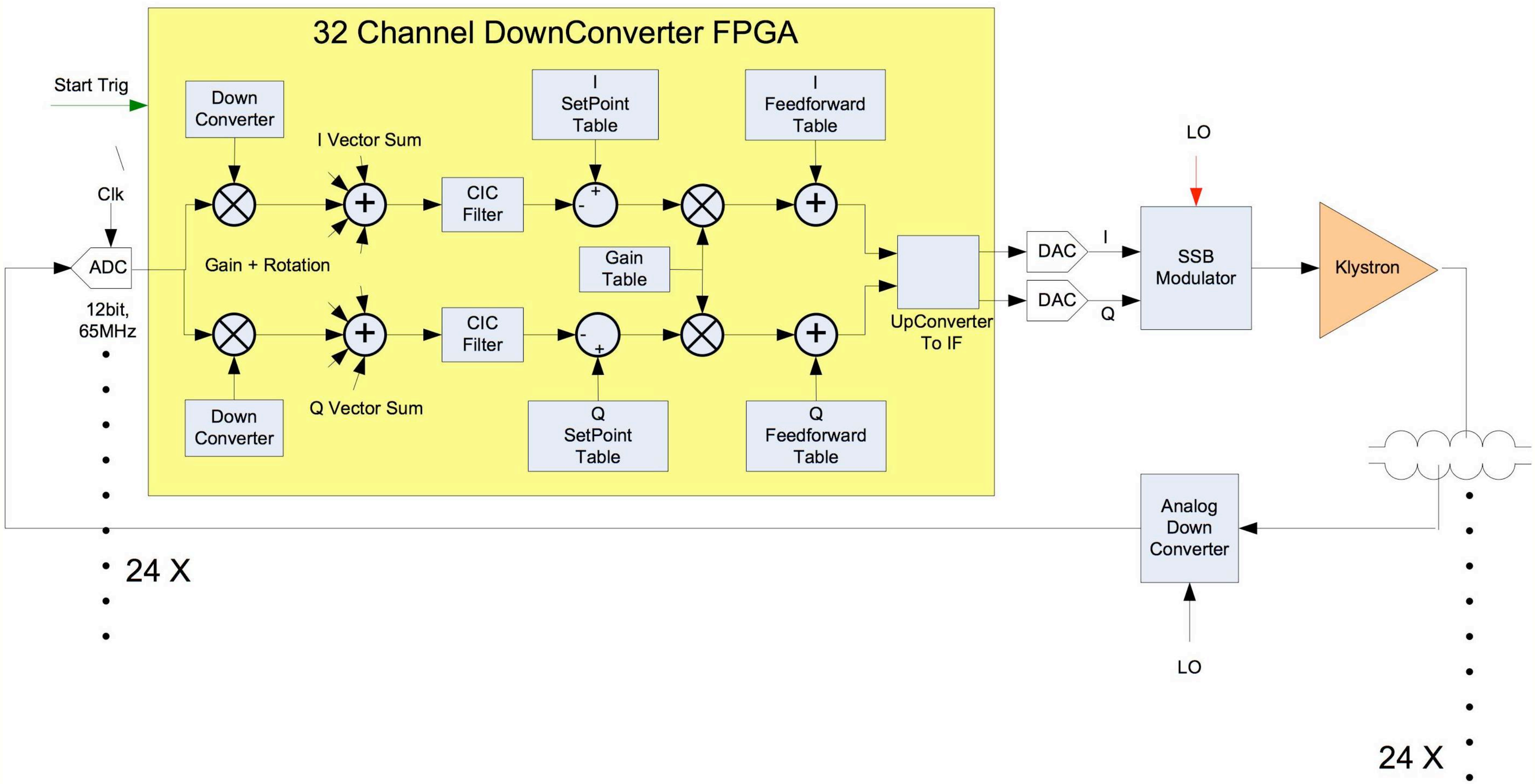
RF Station with 3 Cryo-modules



LLRF Rack Detail



3 Cryomodule Field Controller



Sources of Perturbations

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o Beam loading	o Cavity dynamics
- Beam current fluctuations	- cavity filling
- Pulsed beam transients	- settling time of field
- Multipacting and field emission	
- Excitation of HOMs	o Cavity resonance frequency change
- Excitation of other passband modes	- thermal effects (power dependent)
- Wake fields	- Microphonics
	- Lorentz force detuning
o Cavity drive signal	
- HV- Pulse flatness	o Other
- HV PS ripple	- Response of feedback system
- Phase noise from master oscillator	- Interlock trips
- Timing signal jitter	- Thermal drifts (electronics, power
- Mismatch in power distribution	amplifiers, cables, power
	transmission system)

Phase Reference Chain

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- Master Oscillator drives fiber reference(650,1300,3900MHz)
  - Close in phase noise from MO is coherent across all systems and does not matter to first order
  - Relative phase is critical!
- Local phase distribution repeats fiber signal without narrow band filters
  - Filtering is done in the phase measurement process in the LLRF receiver
  - Narrow filters have problems with drift and microphonics
- Narrow band PLL filtering is used in the generation of the LO which is phase locked to the reference RF
  - LO noise will be driven to the cavities by the LLRF system
- Absolute phase of the reference line relative to the LO is measured over 1 ms before the RF pulse
  - Absolute phase in the LO is not important as long as it is stable over the time frame of phase measurement and the RF waveform ~ 5 ms.

Real Time Cavity Simulator

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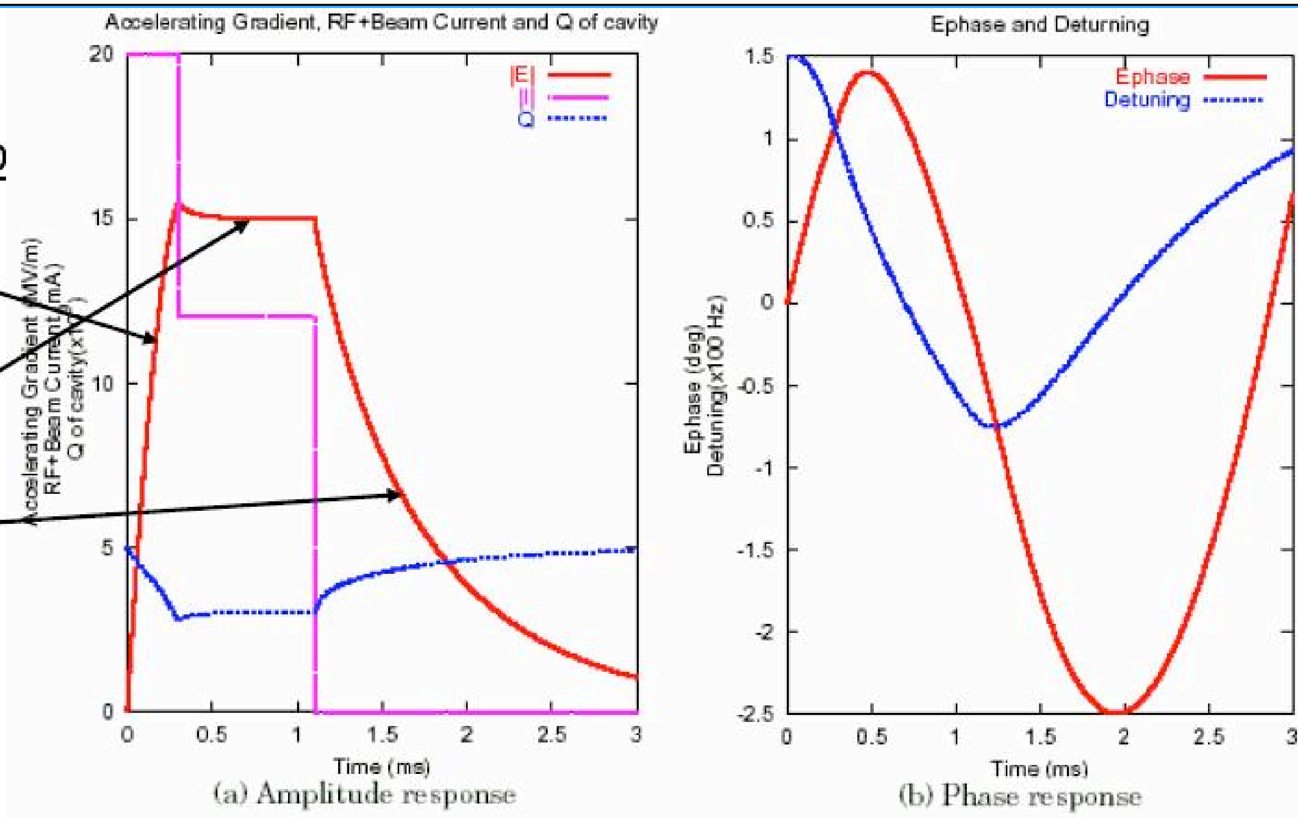
Test run of ILC Cavity Simulator (no beam)

1)fill: 0 - 0.3 ms at 20 mA (full power)

2)flat-top: 0.3 -1.1 ms at 12 mA

3)cavity emptying, decay curve shows high Q of cavity.

Compare with TESLA cavity measurements:
Shapes are similar, model is working.



(a) Amplitude response

(b) Phase response

IF in these simulations is 50 MHz.

Justin Keung, UPenn

Controls and LLRF Collaboration

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- FNAL(CD,AD,TD), DESY, Warsaw ELHEP, KEK, ANL, LBL,SNS, SLAC, JLAB,University of Pennsylvania
- Controls: FNAL, SLAC, ANL, and possible UofI
- Weekly telecom for Controls
- Weekly telecom for LLRF
- Weekly telecom for HLRF
- Major design efforts underway for XFEL and test string at FNAL
  - Several high performance controllers being developed
  - Master Oscillator and distribution
  - Real time Cavity Simulator

Staging LLRF and Controls

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- LLRF and Controls may be staged along with other key components
  - BUT…nothing will operate without some version of these systems.
- LLRF and Controls R&D are manpower intensive rather than M&S intensive
- Reducing manpower below some critical level will seriously hinder progress
- LLRF and Controls are tasks that require sustained long term effort for the final system to be meet design goals and be cost effective
- Training new people in the field is critical to the success of any large SCRF project

Cost

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- Spreadsheet here

- Make sure your estimates agree with infrastructure document

Conclusions

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- New technologies in industry allow for the development of the next generation Controls and LLRF systems
  - These next generation designs will be very flexible and will apply to light sources and other new machines
  - Control systems need green field projects to advance the state of the art
- We need these systems to achieve the stated goals of SCRF R&D here at Fermilab
  - The performance of these systems directly affect the performance of the accelerator as a whole.
- Now is the right time to be developing these systems
  - Up front R&D will pay off big in the lifetime of any project
- LLRF and Controls are on track to support the current program given the present budget profile