international linear collider

ILC-Americas
FY10 Work Package
Technical Progress Report

Laboratory: FNAL
Work Period: September 1, 2009 to March 31, 2010

Introduction

The mid-year FY10 Fermilab ILC/ART funding is $11,321K. Funding is divided into $3,618K of direct SWF support, $4,008K of direct M&S support and the respective overhead charges. The budget is distributed over twenty three distinct tasks including those associated with ILC global involvements and cavity & cryomodule work. In addition, there was $1,116K of carryover from FY09. This carryover was associated with specific tasks that were delayed due to technical considerations as well as a late year conversion of labor budget to M&S budget to compensate for the inability of these tasks to gain the originally budgeted labor. Since this carryover is already targeted to specific, planned work or for additional contract labor, it does not materially affect the FY10 work plan. The FY10 ILC/ART funding did increase slightly during the year due to additional support provided for the split quad work.

The total budget available in FY10 is $12,437K (including the FY09 carryover). The six month year to date Obligations plus Requisitions in Process totaled $6,356K (~51% of the budget). Work in FY10 includes support for:

- Main Linac Accelerator Physics
- Conventional Facilities Systems (CFS)
- Global Systems such as LLRF, Instrumentation, and Cryogenics
- Cavity & Cryomodule
  - ANL/FNAL Joint Processing Facility
  - VTS and HTS testing of cavities
  - Cavity Dressing
  - Cryomodule Components & Assembly
  - Cavity Coordination , R&D, and Data Management
  - Two cavities for S1 Global
- Program Management (travel and salary support to attend GDE meetings)

FNAL ILC Program Management (WBS 1.1.2.1)

The FNAL ILC Program Office plans and manages the FNAL ILC/ART work packages and provides an interface to the ILC Americas Regional Team (ART) Director and the global management team (ILC Project Managers). The FNAL ILC Program Director works directly with the ART Director to establish the Program and report on its progress. Travel expenses include those associated with attending ART/GDE meetings and maintaining a presence in global ILC activities. Program Management is also the work package that temporarily holds the M&S required for contract labor. Once the need for additional contract workers is established, the budget is moved to the appropriate task.

Accelerator Physics @ FNAL (WBS 1.5.1.1)

Accelerator Physics (AP) work at Fermilab includes both Main Linac and RTML studies. A number of critical studies for ML/RTML were started in FY09 and continued in FY10.

- Design of the single-stage bunch compressor (SB2009 baseline) is complete.
    - Beam physics studies were done for the nominal bunch length 300 micron. The results of these studies demonstrated that performance of single-stage compressor is comparable with the baseline 2-stage design for the nominal misalignments. Consistent with the AAC request, we have studied the limitations of a single-stage compressor to produce shorter bunches. The minimum bunch length achieved for the current design is 220 microns.
- Design of the extraction line after single-stage compressor is complete.
    - The general specifications for key beamline components were generated.
- Preliminary design of the RTML lattice in central area is finished. Additional information from other areas involved in the central region (damping ring, electron and positron sources, BDS) was requested to assure consistency.
- Re-evaluation of the emittance budget in the RTML in ML is in progress.
- Experimental studies of the phase and amplitude stability in a bunch compressor on the FLASH facility at DESY (9mA program) was postponed to late FY10.
    - Analysis of the data from Sept 2009 run is in progress as a part of preparation for stability studies.
- Dark current studies for the ILC are in progress.
- Design, prototyping and evaluation of RTML/ML components is in progress:
    - Prototype of the ILC cold BPM
    - Split-able SC magnet with conductive cooling
- Within the framework of the ILC-CLIC collaboration
    - Design of the sub-micron resolution BPM for CLIC Main Linac is in progress. Prototype of the BPM and electronics are under construction. Tests will be performed at the CTF3 facility at CERN
    - Simulation of the dark current in CLIC Main Linac is complete
    - Design/optimization of the spin rotator sections of CLIC RTML is complete

Many of these studies will continue in last half of FY10. Participation in the ATF2 collaboration will also continue with the goal of gaining experience with code benchmarking and simulation tools useful for the NML beam facility. The second ATF2-related task is to study stray magnetic fields at Fermilab site and especially phase-correlation the sub-harmonics of line frequency (60 Hz) vs. distance between points of measurement.

CFS In-house (WBS 1.7.1.1)

CFS work in FY10 will focus primarily on the completion of the Accelerator Design and Integration (AD&I) effort and continuing cost reduction efforts with respect to the conventional facilities design. The continued investigation of a single tunnel solution for the ILC Main Linacs utilizing two alternative High Level RF Systems, the Klystron Cluster and Distributed RF, will also be a major effort during the rest of the year. Three major milestones have been established for the CFS Group in FY 10:

- Complete the single tunnel Surface Configuration Study at access and equipment shaft locations
- Complete the single tunnel Americas Life Safety Study
- Update criteria for the Baseline Design for Technical Design Phase II (TDP II)

During the first half of FY 10, the CFS Group focused most of its attention on the AD&I effort which culminated in a review by the ILC Accelerator Advisory Panel (AAP) in Oxford, UK in January 2010. The Americas CFS Group developed the first complete revised baseline layout that incorporated the alternatives described in the AD&I Proposal Document. In addition, initial studies were completed to assess the impact of these proposed changes to the CFS mechanical and electrical design solutions using both HLRF alternatives. Development of the TDP II baseline machine layout will continue to be the central focus of the CFS Group in FY 10.

- Updating the baseline machine layout to changing technical criteria
- Focus on the single tunnel solution
- Develop a more detailed layout for surface buildings at access and equipment shafts
- Refine the design criteria for the Interaction Region and Detector support
- Complete a computer model analysis in support of the Life Safety and Egress solution for the single Main Linac tunnel configuration

The CFS Team continues to maintain strong international collaboration with Asian and European CFS Groups as well as the various Area and Technical Systems representatives worldwide. In addition, efforts will be made in the second half of FY 10 to identify contact points with the Machine Detector Interface Group and both working Detector Collaborations.

CFS Outside A/E Services (WBS 1.7.1.2)

Work with outside A/E firms will complement the ongoing CFS scope of work in the areas of

- Surface building design and layout at shaft locations
- Computer modeling of the single tunnel life safety and egress solution
- Additional Main Linac single tunnel studies as needed

Advanced Beam Monitors for ILC (WBS 1.8.2.1)

Cold cavity BPM:

All brazing steps are complete. A few remaining parts are still being manufactured. Some precision welding still has to be accomplished to allow the assembly of the UHV RF feed-throughs. The cavity BPM is expected to be ready for RF characterization this summer.

ATF Damping Ring BPM Upgrade:
All electronics hardware for the 96 BPMs plus spares are assembled, tested, and will be shipped shortly. Installation and commissioning for the complete BPM system is scheduled in May/June.

LLRF Control System Analysis (WBS 1.8.3.1)

In the first half of FY10, Fermilab's LLRF efforts have been on the 9 mA Tests at FLASH relating to S2 and S3 goals, ongoing evaluation of RF distribution system proposals such as the Klystron Cluster and Distributed RF schemes, and development and evaluation of LLRF systems at FLASH and NML. There was a workshop at DESY on high current operation which had a large focus on the 9mA test results. Analysis and publication of the data continues as well as planning for the next steps of the 9 mA Tests with international WebEx meetings.

While no fundamental show stoppers have been encountered, the test goals have yet to be reached and there is still a large enough uncertainty to justify continued study. Some of the lessons learned have already been incorporated in the LLRF systems at NML for CC2 and CM1. Specifically, the loop controller has been optimized to operate with higher proportional and integral gains to handle the larger disturbances encountered with high beam current. Final installation of cables and LLRF equipment and piezo controller for CM1 is in progress and we look forward to testing soon. Bench testing of the phase reference line is near completion with stability measured at better than 100 milli-degrees. The line will be installed in the next few months. This line will be much lower cost than the present ILC design.

Plans for the rest of FY10 include continued involvement with the 9 mA Tests, NML field and resonance control on Gun, CC2, CM1 and possibly CM2, reference line and ongoing control simulation work of RF distribution schemes.

Cryogenic System Design (WBS 1.8.4.1)

Cryogenic system work for the ILC has remained at a very low level, consisting mostly of participation in WebEx meetings and responses to questions from people re-evaluating ILC design and costs. ILC cryogenics and cryomodule tasks are the subject of a joint WebEx meeting every other week, organized by Norihito Ohuchi. Cryomodule heat load estimates, thermal modeling, and plans for heat load measurements at test facilities, such as the test of S1 Global, are joint cryomodule/cryogenics topics that have been the focus of various discussions.

HLRF System Design @ FNAL (WBS 1.9.1.3)

Fermilab collaborates with SLAC on HLRF tasks involving klystron and modulator design and development, RF distribution and power coupler procurement. This equipment will be used in the FNAL SRF facilities to test cavities and cryomodules. During the first half of FY10 there was minimal interaction in this area.

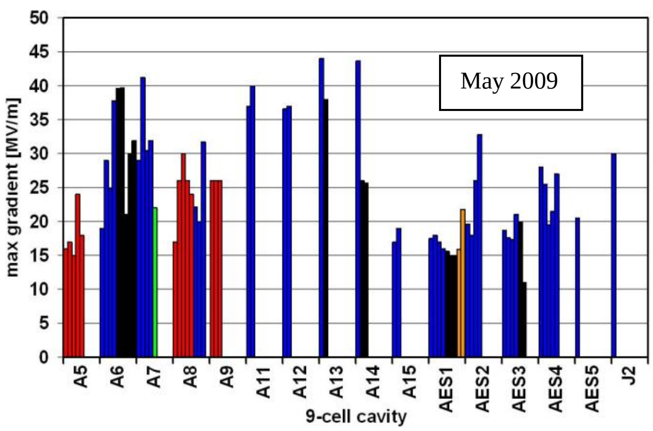
Cavity Coordination & Management @ FNAL (1.10.1.1)

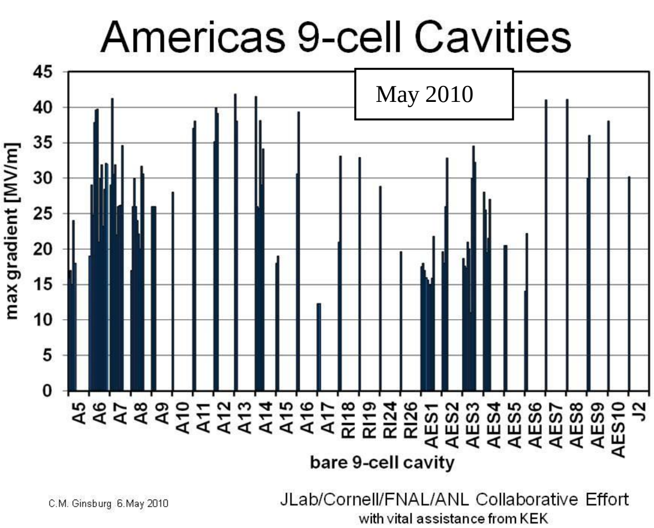
Fermilab has a major role in coordinating and executing the U.S. ILC cavity program. In the first half of FY10, Mark Champion continued as the ILC/ART Cavity Coordinator. In this role, he managed the U.S. 1.3 GHz Cavity Program, deciding on the scope and distribution of work planned for the fiscal year. He interfaces with all of the major contributors (JLab, Cornell, ANL, FNAL…) to assure that there is a cohesive cavity production and R&D program in place. Camille Ginsburg serves as the Data Coordinator and acts to maintain a stable database of cavity information. A major accomplishment was the creation of a cavity yield plot vs. gradient using cavity data from Europe and the U.S. employing consistent data selection criterion.

Cavity Database (1.10.1.4)

The plan is to have a worldwide collection of cavity data to allow for better statistics and identification of problems. There is also a need to store and manage all of the data collected during the cavity procurement and testing that is in excess of what is normally kept in the DESY database. This effort will continue in the future.

Two 9 cell cavity gradient plots are shown below, one from May 2009 and the other from May 2010. Each plot shows the final maximum gradient of a test, for all reported cavity tests on Americas 9-cell cavities. Sometimes there is no surface processing between tests. The number of tests became so large that the colors were removed because they became indiscernible.





The update in the past year is quite substantial. First pass processing and testing of the new batch of 8 ACCEL cavities (TB9ACC010-TB9ACC017), and the new batch of 6 AES cavities (TB9AES005-TB9AES010) was completed. Five of the 8 ACCEL cavities, all processed and tested at JLab, reached 35 MV/m. Four of the 6 AES cavities, all processed and tested at JLab, reached 35 MV/m. Processing and testing of the first RI cavities has started, having done a first pass on four of the 12, half at FNAL/ANL and half at JLab. Also notable is the improvement of AES003, by local grinding of defects, from about 20 MV/m to about 30 MV/m. Both TB9ACC017 and TB9RI026 were fully processed at FNAL/ANL facilities, except for hydrogen degassing at JLab.

Cavity Vertical Testing @ FNAL (WBS 1.10.4.4)

In the first half of FY10, the Vertical Cavity Test Facility (VCTF) provided 33 test cycles (15 for 9-cell cavities, 16 for 1-cell cavities, and two for a novel traveling-wave cavity). These tests were funded from a variety of programs, including ILC. The ANL/FNAL joint cavity processing facility operation has now been well established for high-quality single-cells; the operation for 9-cells is being optimized. The primary goal of the single-cell tests is now fundamental cavity R&D, such as studies of defects, defect-repair, and fundamental cavity limitations. In addition to the tests directed at 9-cell cavity processing optimization, the 9-cell cavity tests have been directed at qualifying cavities for cryomodule assembly; several of the 9-cell cavity tests were performed on dressed cavities.

Delivery of the 24 new 9-cell cavities was delayed, and tests of these cavities will start in the second half of FY10. The cavity tests for the remainder of FY10 will be used to optimize ANL/FNAL cavity processing for 9-cells, to qualify the remaining cavities needed to populate CM2, and to qualify Niowave-Roark as a 9-cell cavity vendor.

Cavity Processing @ ANL/FNAL Facility (1.10.4.5)

The Joint ANL/FNAL Processing Facility (SCSPF) ramped up processing and testing throughput during the first half of FY10. In November, the ANL SCSPF HPR processed dressed cavities that were provided to KEK to meet S1 Global obligations. These cavities were the first dressed cavities to be processed in the SCSPF. During this 6-month period, a total of 13 vertical tests and 2 horizontal tests were performed on 9-cell cavities directly processed at the SCSPF. A total of 12 vertical tests were performed on 1-cell cavities following processing directly from the SCSPF. This rate of processing and testing is continuing to slowly increase with time as facility operation and maintenance schedules become better understood. Processing highlights include: Field Emission-free vertical test on all 1-cell tests performed at VTS; gradients in 1-cell cavities well above 40 MV/m after multiple processing cycles; 9-cell cavity gradients on good cavities near 35 MV/m. The only two cavities fully processed at the SCSPF had substantial weld defects unrelated to the processing regime.

The remainder of the year, the SCSPF will be employing modified procedures to attempt to reduce field emission in 9-cell cavities and improve the surface finish quality achieved during electropolishing. Expected throughput during the rest of FY10 should remain at approximately four performance (vertical + horizontal) tests/month on cavities processed at the SCSPF.

Cavity Gradient R&D @ FNAL (WBS 1.10.5.4)

In general, cavity performance has been encouraging. As seen with the recent results from cavities reaching greater than 35 MV/m, cavities can be manufactured, processed and tested to high gradients. However, consistency in fabricating high gradient cavities is still elusive. Issues of the yield and the exact cause for underperforming cavities are still to be resolved. This work focuses on single cell tests and processing R&D for improving the steps taken to prepare a cavity and the countermeasures to repair a bad cavity. Work includes cavity tumbling, laser re-melt, optical inspection, and mechanical repair as well as investigating more basic material R&D.

Cavity Dressing @ FNAL (WBS 1.10.6.1)

The necessary infrastructure to dress 1.3 GHz cavities is in place and operational. To date, six cavities have been dressed, including two prototypes, two for S1 Global and two as possible candidates for CM2. Unfortunately due to problems unrelated to the dressing procedure itself, we have yet to complete a dressed, high gradient cavity for CM2. Obtaining sufficient dressed cavities to initiate CM2 assembly remains the critical path. The planned dressed cavity rate is one dressed cavity approximately every two weeks. Sufficient parts, such as helium vessels and bellows, are in hand and available to dress all cavities for CM2. As cavities pass vertical testing with high gradient and acceptable field emission, they are queued up for dressing. A consistent work flow through the cavity dressing stage has been established.

Cavity Horizontal Testing @ FNAL (WBS 1.10.7.1)

The Horizontal Test System (HTS) is in place and operational. In FY09, successful testing of several 3.9 GHz cavities verified the system integrity and repeatability. The horizontal test cryostat was then prepared for 1.3 GHz activity and two test cavities were cycled through. As cavity horizontal testing for CM2 began, several issues associated with the 1.3 GHz power couplers and power testing arose which have caused delays in getting to a steady state throughput. These issues are being resolved and a backlog of dressed cavities is being established. Significant 1.3GHz cavity horizontal testing is planned in the remainder of FY10.

Cavity R&D – Value Engineering (WBS 1.10.8.1)

This work package includes effort focused on improving the design, material choices and fabrication steps for the cavity and cryomodule. Work continues in collaboration with Indian Institutions (RRCAT, BARC, etc.), Michigan State University, and various industrial vendors. Indian engineers are doing value engineering on different parts of the cavity and cryomodule both in terms of specific parts as well as the assembly process. The MSU work is focused on finding ways to simplify the welding techniques and fabrication of cavities. Another aspect being investigated is the proposal to switch to a stainless steel helium vessel. Work on a stainless steel helium vessel design will continue in FY10. A prototype design (based on a modified JLab design) was completed and preparations made to create the critical niobium-to-stainless steel braze joint for evaluation and testing. Fermilab also agreed to provide testing support for a Phase II SBIR stainless steel helium vessel design being worked on by Advanced Energy Systems. R&D on explosively bonded Ti-SS tube pairs as part of an international collaboration between JINR and IEP in Russia, and INFN, Pisa, and Fermilab was carried out.

Type IV Cryomodule Design (WBS 1.10.9.1)

The Type IV cryomodule design work is essentially complete. Drawing packages (2-D) were finished and approved so that parts for future cryomodules (CM3, 4 and 5) could be ordered. The decision to revise the design of the Type IV cryomodule to include the capability for magnets located at the cavity 2-5-8 locations was approved and is fully incorporated into the current design (3D model and 2D drawings). As fabrication and testing of cryomodules continues in the future, modification requests (Engineering Change Orders) are expected.

Type IV Cryomodule Components w/o cavities (WBS 1.10.9.3)

All major cryomodule parts for CM3 (first Type IV with 2-5-8 configuration) have been ordered. Using a combination of ILC and SRF ARRA funds, parts for CM3, 4 and 5 are being procured. One of the goals is to qualify US vendors to supply these components for future cryomodules.

Cryomodule Magnet Design (WBS 1.10.9.4)

The corrector coil magnet design for CM2 was completed and the components are ready for final assembly. The magnetic coil itself has been successfully cold tested. The magnet specification for the Type IV cryomodule has been created. Magnets used in NML cryomodules will have a different specification than those eventually used for the ILC due to varying beam parameters.

Design work has begun on a split coil quad design that if successful would offer several advantages over the existing quadrupole. There was a joint ILC/ART/FNAL split coil quad review held which resulted in positive comments and a recommendation that the work continue with additional funding.

Cryomodule Instrumentation Design (WBS 1.10.9.5)

The CM2 BPM will be the standard DESY “button” BPM and one is currently being fabricated using DESY-supplied drawings. Instrumentation in CM2 will essentially be of the same type and quantity as that used in CM1. The instrumentation design for the cryomodule at NML will not be typical of the ILC due to differences in beam parameters.

Cryomodule Assembly (WBS 1.10.9.6)

Final installation and connection of CM1in NML continues. The engineering and QC documentation package and the approval for the Operational Readiness Clearance for CM1 should be completed in May 2010. Commissioning will commence immediately thereafter and CM1 will be operated in NML until the test plan is finished and CM2 is ready to be installed.

The start of string assembly for CM2 will be triggered by receiving positive feedback from the CM1 test and by having sufficient dressed and horizontally tested high gradient cavities. Currently we have one such cavity, but it is anticipated others in the pipeline will soon become available. Dressed cavities remain the critical path items for CM2 assembly. All of the other parts for CM2 are in hand. Depending upon how the CM1 tests take shape and the ability to collect dressed and tested cavities, the assembly of CM2 could continue into FY11.

Two Dressed Cavities for S1 Global (WBS 1.10.10.1)

Two dressed and tested 1.3 GHz cavities were delivered to KEK for inclusion in the S1 Global Cryomodule, consistent with the overall S1 Global Plan. Several Fermilab technical staff visited KEK to participate in the cavity string assembly and tuner checkout. Collaboration continues as the module prepares for the testing phase.

Table 1 FY10 Mid-Year Financial Report

This table displays the mid-year ILC ART financial data. Personnel costs closely matched the budget while the Materials and Services obligations reflect the current technical state of the work and the pending obligation of several large orders.

				FY 10 BUDGET (incl. Carry Over)			YTD OBLG + RIPS				
ART WBS (K$)	**FY09 Carry Over**	**FY10 Budget**	**Total FY10 Budget (incl. Carry Over)**	**Labor**	**Materials & Services**	**Overhead**	**Labor**	**Materials & Services**	**Overhead**	**Total BUDGET**	**Total YTD OBLG + RIPS**
1.1.2.1 FNAL program management	535.7	1,258.3	1,794.0	300.2	694.9	263.2	136.6	172.6	102.6	1,258.3	411.7
1.5.1.1 Accelerator physics at FNAL		1,275.3	1,275.3	640.0	50.0	585.3	271.4	8.9	257.1	1,275.3	537.3
1.7.1.1 CFS In-house		806.7	806.7	231.8	425.0	149.9	111.6	155.5	100.2	806.7	367.3
1.7.1.2 CFS Outside A&E services		629.2	629.2	0.0	550.0	79.2	0.0	129.9	72.9	629.2	202.8
1.8.2.1 Advanced beam monitors for ILC		132.2	132.2	40.1	50.0	42.1	161.0	3.8	151.3	132.2	316.0
1.8.3.1 LLRF control system analysis		348.4	348.4	149.4	75.0	124.0	66.1	0.0	48.5	348.4	114.6
1.8.4.1 Cryogenic System Design		75.8	75.8	33.0	10.0	32.8	3.0	0.0	2.9	75.8	5.9
1.9.1.3 HLRF System Design @ FNAL		65.9	65.9	19.9	25.0	21.0	0.0	0.0	0.0	65.9	0.0
1.10.1.1 Cavity Coordination & Mgmt @ FNAL		217.8	217.8	96.5	26.0	95.3	96.2	63.9	107.6	217.8	267.7
1.10.1.4 Cavity Database		159.7	159.7	65.5	28.0	66.2	0.0	0.0	0.0	159.7	0.0
1.10.4.4 Cavity Vertical Testing @ FNAL	91.5	452.1	543.6	167.4	110.0	174.7	45.8	93.5	56.0	452.1	195.2
1.10.4.5 Cavity Processing @ ANL/FNAL Facility	85.8	581.3	667.1	131.0	285.0	165.3	144.4	71.8	163.1	581.3	379.3
1.10.5.4 Cavity Gradient R&D @ FNAL		289.3	289.3	117.7	55.0	116.7	194.7	27.6	189.3	289.3	411.6
1.10.6.1 Cavity Dressing @ FNAL	262.6	1,899.1	2,161.7	387.8	999.5	511.8	328.2	313.2	456.6	1,899.1	1,098.0
1.10.7.1 Cavity Horizontal Testing @ FNAL		825.9	825.9	290.0	235.0	300.8	54.2	37.4	59.1	825.9	150.7
1.10.8.1 Cavity R&D - Value Engineering		408.8	408.8	131.0	140.0	137.8	79.2	144.3	135.9	408.8	359.4
1.10.9.1 Type IV Cryomodule design		312.5	312.5	131.0	50.0	131.5	38.1	0.0	46.1	312.5	84.2
1.10.9.2 Cavity & Cryomodule Safety Analysis		184.9	184.9	65.5	50.0	69.4	22.4	4.5	22.4	184.9	49.2
1.10.9.3 Type IV Cryomodule Components (except cavities)	140.5	332.5	473.0	10.5	272.8	49.2	6.5	147.8	63.9	332.5	218.2
1.10.9.4 Cryomodule Magnet Design		470.8	470.8	116.0	214.0	140.9	83.3	122.2	105.0	470.8	310.5
1.10.9.5 Cryomodule Instrumentation Design		117.6	117.6	20.0	70.0	27.6	43.2	40.9	51.9	117.6	136.0
1.10.9.6 Cryomodule Assembly		1,455.2	1,455.2	429.0	530.0	496.2	177.9	187.2	204.2	1,455.2	569.3
1.10.10.1 Two Dressed Cavities for S1 Global		138.0	138.0	45.0	44.0	49.0	75.0	16.1	79.9	138.0	170.9
Grand Total	**1,116.1**	**12,437.1**	**13,553.2**	**3,618.3**	**4,989.2**	**3,829.7**	**2,138.5**	**1,741.0**	**2,476.5**	**12,437.1**	**6,356.0**