Revision History:

Revision	Date Released	Description of Change
R0	August 2nd, 2018	Original release.

Table of Contents

1 Purpose and Scope

This document enumerates past and present HGVPU control issues up until the time of writing. Issues prior to the controls FDR in February 2017 are not included.

2 Hardware Issues

2.1 Lack of undulator availability to controls team

Occurrence: Ongoing

Current Status

Dedicated access to a fully working HGVPU in the SLAC long-term test (LTT) area was to be provided to the controls team in May 2017. As of August 2018, the LTT HGVPU remains incomplete.

This is an ongoing issue that has led to many delays and issues for the controls team to provide fully-vetted solutions to all vendors and LBNL, leaving additional features and debugging of software to be done using production undulators on an as-needed or as-discovered basis.

Major issues with the LTT configuration are as follows:

- Full-gap encoders are not installed
- Cam gearbox is missing
- Some motion-inhibit and E-STOP switches are unavailable and been bypassed
- The undulator itself is only a prototype

2.2 D-Sub 7W2 connector mating on UCMI-2
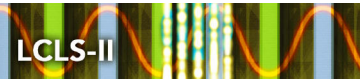
Occurrence: frequent (> 5 incidents; SLAC, Motion Solutions, LBNL)

Symptoms

- Gap control fails despite all limits and interlocks being in working order
- SmartMotor LEDs remain yellow
- SmartMotor communication failure in IOC console
- Intermittent motion failure

Diagnosis

An initial set of SLAC-built UCMI-2 chassis were made for the planned 7 test stands for SLAC and the vendors. These initial chassis had D-Sub 7W2 connectors with recessed 1mm diameter pin receptacles. Combined with the large mating connector back shell and recessed receptacle mounting on the UCMI-2, this caused intermittent connectivity of the essential motor controller RS-232 serial signal.

Figure 1. Left to right: Rear panel motor PCB assembly diagram portion, problematic UCMI-2 translation motor section, and fixed section of the production UCMI-2 chassis.

Resolution and Current Status

The source of the problem has been determined and a fix is underway. A plan has been made to replace the affected PCBs in the original 7 test-stand UCMI-2 chassis. Cable connector backshells have been replaced. The production UCMI-2 chassis are unaffected as a different and better connector was sourced for the production run. These production chassis have been used as temporary replacements for the test stands:

- Replacement production UCMI-2 was shipped to Keller in July
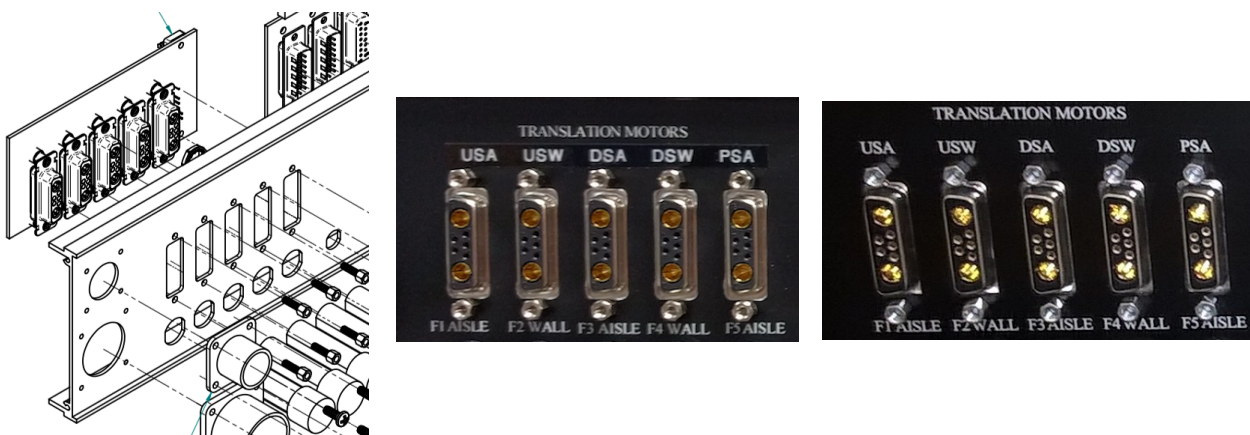
- Replacement production UCMI-2 was shipped to Motion Solutions in July by LBNL, SLAC to replace in August

- SLAC long-term test stand, floating test stand, and MMF test stand have had UCMI-2 replaced

- Replacement PCBs with the production connectors were ordered in May.

2.3 Lack of hardware-level gap-encoder closed-loop control

Occurrence: frequent
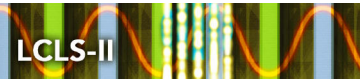
Symptoms

- Maximum asymmetry is exceeded during motion

- Control system is unable to account for imperfections in drive system

- Control system is unable to account for spring cage imbalance

- Speed of gap opening/closure is unacceptable due to 90% motion

Diagnosis

The control system that was allowed to be built had this critical flaw from the outset, despite the motion control team's objections and concerns.

Resolution and Current Status

- Ideally, the entire LCLS-I control system would have been sent to storage and an Aerotech controller would have been used to unify the SXR and HXR line motion control. However, as this was deemed both too late and not cost-effective, an alternative solution had to be found.

- Renishaw interpolators were first attempted to convert the SSI signal into a quadrature signal that the SmartMotors could directly interpret, but noise-related issues in the prototype first lead to concerns over the viability of the solution and later the disqualification of the solution.

- Lastly, preliminary approval has been given to add a Power PMAC motion controller to handle synchronized gap motion closing each loop on the respective half-gap encoders. This would include support for the full-gap encoders and phase shifter as well.

2.4 HPDB50 SCSI-2 male plug pin fragility

Occurrence: frequent (> 5 incidents)

Symptoms

- Limit switches fail to read appropriately, disallowing motion

- Motor communication does not work

- System is in an unrecoverable state

Diagnosis

The high-density SCSI-2 connector has 50- 0.8mm pins which are very fragile and prone to bending if even slightly misaligned when inserted in the UCMI-1 or UCMI-2. Compounding the issue, the chassis back panels are recessed in the rack, are surrounded by many other sturdy cables, and are rather difficult to access.

Figure 2. Male SCSI-2 50-pin connector.

Resolution and Current Status

- Vendors have been apprised to carefully connect these cables, and inspect when initial setup issues occur

- Multiple spares have been purchased of the current cable

- Preliminary work has been done to investigate a sturdier replacement. Stand-offs and new cables will have to be purchased to mitigate the issue altogether.

2.5 VME crate failure

Occurrence: once

Symptoms

- *Limit switches not reading back correctly*

- *"Raw bug" monitor shown in MVME3100 console*

Diagnosis

Seemingly random errors occurred during the first checkout of HXU001 in the B081 high bay, leading to days of checking cables and hardware swapping attempting to determine the cause of the issue. Local VME/RTEMS experts were contacted regarding the "raw bug" that was displayed, but it was a new issue to them.

Resolution and Current Status

Eventually, swapping the VME crate (keeping the original VME modules, CPU, and IP cards and carriers) brought the system back online, allowing it to be checked out and readied for the CMM. The failed crate was brought to local hardware experts for analysis.

Aging VME hardware remains a concern for the project and recent requests for hardware spares recently have been somewhat successful.

2.6 Blown fuses after UMPI bypass pushbutton pressed

Occurrence: several times

Symptoms

- No power coming from UMPI chassis

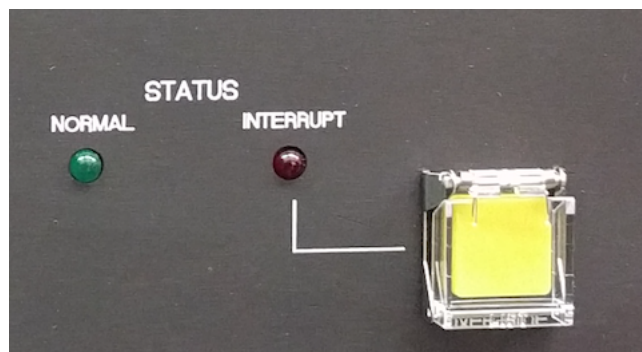- Supply LEDs are off; motors do not move

Figure 3. UMPI bypass push-button.

Diagnosis

Rapidly pressing the UMPI bypass pushbutton (located under a plastic flip-cover) causes one of the fuses in the UMPI chassis to blow.

Resolution and Current Status

This has been deemed something that should be taught to users of the system. This will not be fixed with a modification to the UMPI chassis.

2.7   UCMI-2 DC voltage threshold

Occurrence: at each vendor

Symptoms

- 42 VDC supply appears functional, but drops out during gap motion
- Gap motion is extremely slow, with motors moving in increments of 1-5mm despite a large motion request
- "MOTOR POWER OFF" message flashes in the user interface while moving.

Diagnosis

The UCMI-2 was designed with circuitry to detect the DC supply voltages dropping below safe values. Specific thresholds for the minimum DC voltages are set through potentiometers on the UCMI400 board inside the UCMI-2 chassis.

Resolution and Current Status

The potentiometers are set at each facility upon configuration of the control system. If a UCMI-2 chassis is moved from one facility to another, it should be verified due to differing AC line voltages and variations in the internal DC supplies.

When this issue was encountered at Motion Solutions in July 2018, a UMPI debugging checklist and a simplified potentiometer calibration procedure were generated for non-expert usage, resolving the issue.

2.8   Improperly assembled LEMO connectors

Occurrence: several times

Symptoms

- FPGA denies requests to close the gap, though no physical limit is actuated
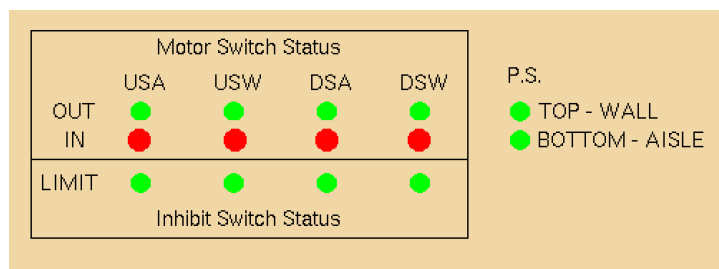
Figure 4. The result in the user interface when a UCMI-2 status cable is made incorrectly. Note that all gap closing motion is inhibited, though no limit switches are reportedly actuated.

Diagnosis

After lengthy debugging procedures and cable verification, the cause was determined to be improperly assembled 4-pin LEMO cables. The design of these connectors is such that the alignment red dot on top should be in the same location as the alignment key inside the connector. However, there is a failure mode

in which it is possible for the inner key to be moved 180 degrees outside of the correct position (see figures below).

(a)   *(b)*   *(c)*   *(d)*

Figure 5. 4-pin male LEMO connector FGG.0B used for interlock status signals to the UMPI. (a) Cable and pins (b) the problematic connector (c) a correctly keyed connector (d) an incorrectly keyed connector.

Resolution and Current Status

Knowing the symptoms, this issue is now signifcantly easier to debug for the test stands. For installation, the cables will be verified prior to the 1-year shutdown.

2.9   System complexity leads to debugging nightmares

Occurrence: almost weekly

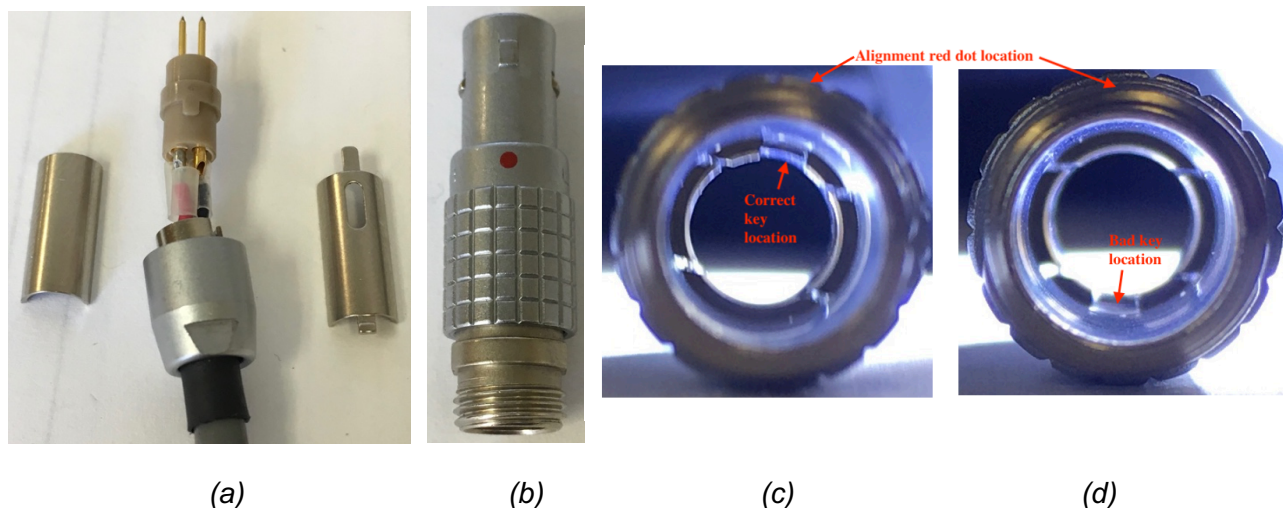*Symptoms*

- Every new issue requires hours of debugging, cable/hardware swapping

- Issues that were seemingly the same as in the past often do not have the same solution

- Massive cable set and connectivity thereof take significant time and effort to ensure correctness

- The FPGA is a black box, often leading to confusion as to its inner workings and the role it plays in issues

- SLAC controls team currently has 4 facilities to support, with no controls engineers at LBNL, Motion Solutions, or Keller available for the project

Diagnosis

N/A

Resolution and Current Status

Suggestions have been made as to the replacement of the system. A final solution may require AIP (Accelerator Improvement Project) funding and many months of development effort.

2.10   SmartMotor gap motor failed

Occurrence: once

Symptoms

- Gap SmartMotor makes odd noises when in motion

- SmartMotor, when removed from the undulator, has shaft that does not turn

- Brake does not fully disengage from motor

Diagnosis

SLAC sent the failed motor for a root-cause analysis and replaced the motor with a spare.

Resolution and Current Status

The root-cause analysis indicated that the set screws on the brake hub were loose, indicating that it either was a manufacturing defect or accidentally caused by someone loosening the wrong screw when removing the motor from the undulator.

2.11   Cable set identification

Occurrence: several separate instances

Issue: HGVPU cables that belong in a complete set were not shipped to SLAC. This caused delays and additional effort on SLAC's part to come up with alternatives.

Resolution: Those responsible for shipping the cables have been contacted and reminded of the full set of cables.

2.12   Industrial PC failed to boot

Occurrence: once

Symptoms

- PC did not boot; power supply lights were on but pressing power button was ineffective

Diagnosis

Debugging attempts were unsuccessful, so we reached out to the server vendor Advantech.
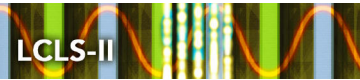
Resolution and Current Status

Advantech responded promptly with a proposed solution to re-seat a PCI riser card inside the computer, which fixed the issue. This new failure mode was communicated back to experts in SLAC/EED who had not previously seen the issue.

2.13   All hardware needs may not have been considered

Addition of the following to the baseline requirements of the control system has been suggested:

- Interferometer system (for undulator gap setting)

- Load-cell readout (as an additional debugging tool)

- Hardware closed-loop control using SSI encoders (gap and phase shifter)

2.14   Controls checkout procedure duration is excessive

Controls checkout procedures for the HGVPU have been found to take too much time and effort. There are several reasons for this:

- The standalone nature of controls racks (compared to the controller pairing that takes place upon receipt of an SXU) means that racks are disconnected/reconnected at each station in B81

- The overall complexity of the system

- The consequences of any one section of the fragile system not being thoroughly checked out could damage the undulator

- Cabling and cable management

- The significant expense of test stands (including labor involved in sourcing parts and assembly)

Recent changes to plans of the path that a single HGVPU takes in B81 during its course of validation, tuning, calibration, and vacuum chamber installation, have created the need for additional checkouts beyond the original scope of the approved controls final design and schedule.

Mitigations have been suggested, including developing a method to keep the control system firmly attached to the undulator support frame thereby obviating the need for disconnection/reconnection of most cables. The controls team is looking to see what can be done in this regard, but further development and hardware procurement may be necessary to make this happen.

3   Software Issues

3.1   Coordinated motion never completes

Occurrence: very frequently

Symptoms

- Requested gap motion gets within a few µm of the setpoint, but does not settle

- Gap motion remains with the message "Device Busy" without further attempts at correction

Diagnosis

This failure is buried deep within the twisted logic of the HGVPU IOC. Attempts thus far have not proved successful in fixing the issue.

Resolution and Current Status

Resolution of this issue is pending. This issue is a primary target of the source code refactor currently underway.

3.2   Full-gap encoder readout was not functional

Occurrence: once; no longer an issue

Symptoms

- *Full-gap encoder readout on user interface is not updating*

- *Full-gap encoder on user interface is not scaled correctly*

Diagnosis

Remote support of LBNL's full-gap encoder usage drove debugging the functionality as their usage became a requirement. Miscommunication regarding model numbers (the manufacturer AMO had recently been acquired by Heidenhain and changed all model numbers at this time) caused several issues with scaling.

Resolution and Current Status

With the correct model number, the correct scaling factor is now in use (28 data bits, 1 warning, 1 error, 1 even parity bit; 250nm resolution). This functionality can be utilized at any facility requiring it after the IOC changes are migrated.

Figure 6. The correct full-gap encoder readhead model (LMKA-2010S.1512FA01-20- 3,00-16S15-IU).

3.3 FPGA SSI encoder read-out implementation faulty

Occurrence: was very frequent; now no longer an issue

Symptoms

- FPGA read-out of encoder did not match up with that of the commercial SSI encoder reader

- FPGA skew and asymmetry trips unexpectedly reported

Diagnosis

Comparing the read-out of both encoder read-out electronics led us to doubt the FPGA implementation, originally done by hand in a block-schematic style. Monitoring the position at a fast rate with EPICS confirmed that the implementation was indeed faulty.
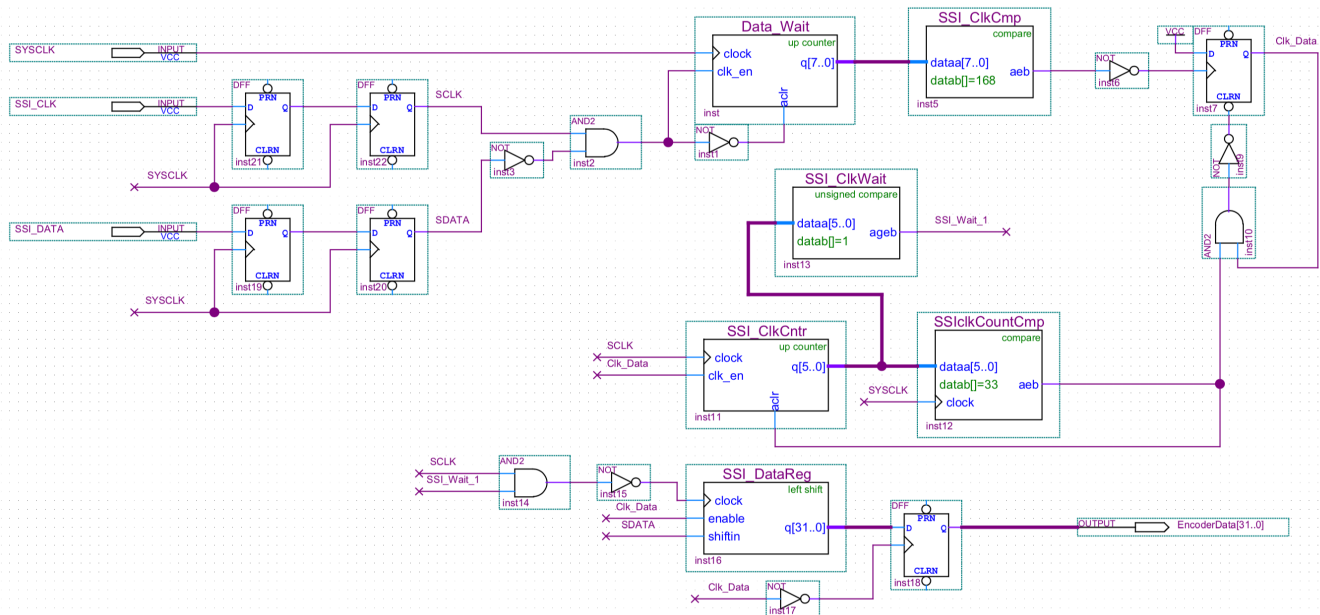
Figure 7. The faulty SSI encoder readout FPGA implementation.

Resolution and Current Status
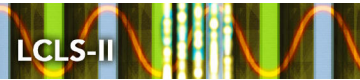
The functionality was re-implemented in VHDL, included in the current FPGA firmware. It has been working flawlessly since.

3.4 Brakes do not always release in synchronized motion mode

Occurrence: infrequent

Symptoms

- Brakes engage before synchronized motion occurs, causing a squealing sound as the motor attempts motion with the brake engaged

- Skew error occurs due to a single motor brake not disengaging at the right time

- Motor exhibits overcurrent error

Diagnosis

This failure is buried deep within the twisted logic of the HGVPU IOC. Attempts thus far have not proved successful in fixing the issue.

Resolution and Current Status

Resolution of this issue is pending. This issue is another target of the source code refactor currently underway.

3.5   User interface is unintuitive and confusing

Occurrence: N/A

Symptoms

- Setpoint and readback values are unclear as to their source or meaning
- Useful screens are buried in several layers of "Other Controls" buttons
- Warning messages for bad setpoints are inconsistently displayed
- Aging EDM user interface does not follow modern user interface patterns
- (Expert) When switching to single motor mode, the operator first must manually synchronize the motor position with that of the encoders, or a fault may occur
- (Expert) When switching between synchronous/single motor mode, motion can occur unexpectedly

Diagnosis

A large source of confusion here is not just at the user interface level but buried within the IOC database configuration.

Resolution and Current Status

The intention is to unify the user interface screens from the soft x-ray line and reduce the importance of the FPGA status screens after the refactor has been completed.

3.6   Cam calibration software is not fully integrated into the control system
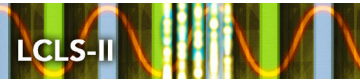
Response: A single, simple cam calibration software for both SXR interspaces and HXR girder motion has been developed and tested. It will be made available to LBNL and Argonne soon.

3.7   Cam motion is not well-integrated into the control system

Related Issues:

- Cam motion requests fail to respond
- Cam motion script requires a restart from SLAC controls engineers

Response: Currently, a Python-based IOC (utilizing the libraries pyepics and pcaspy) is in use for forward and inverse calculations of girder position/cam rotary position. This script occasionally fails and requires user intervention to restart. Eventually, this will be better integrated into the control system. After the refactor, the same forward and inverse kinematics software available for the soft x-ray line will be ported to the hard x-ray line, obviating the need for this software altogether.

3.8   SmartMotor CAN bus addresses were not configured correctly

Occurrence: once

Symptoms

- Motion does not work as expected, and the system quickly gets into a taper condition

- Releasing of upstream wall motor brake appears to instead release that of the downstream motor

Diagnosis

A CAN bus address identifies each SmartMotor in its own daisy-chained network of motors. This identifier is essential to know which motor is the motor nearest the upstream-wall or downstream-aisle, for example, and also identifies the master motor. Verifying connectivity by manually enabling/disabling the brakes of the motors and audibly identifying which motor responded can be a quick method of solving this.
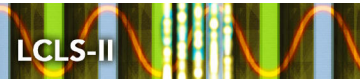
Resolution and Current Status

The improperly-configured SmartMotor motors were correctly reconfigured, and the responsible team was advised on following the procedure.

3.9   Full-gap encoders not used for software-level loop-closing

Currently, the half-gap encoders are used for software-level position-loop closing of all gap motors. Full-gap encoders are only for verification and display. The half-gap encoders are sensitive to angle errors due to the position in which they are mounted and possible girder deformations.

Plans to implement loop-closing with the full-gap encoders are underway.

4   Issues as described by users of the HGVPU
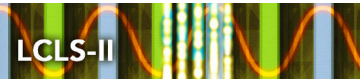
Cory Andrews

- The FPGA is something of a black box when trying to get a new system running. It is very difficult to determine if an issue is physical (cables, PCBs, fuses, etc) or if the FPGA is not happy for some reason. See next issue.

- The building voltage must be sufficient for the comparator in the UCMI2 to supply TTL signal to FPGA.

- HGVPU user interface hangs up occasionally and will not allow switching between single motion and synchronized motion.

- HGVPU User interface seems to "buffer" inputs with the net effect of having things happen unexpectedly (This may be related to delay in switching modes mentioned above.)

- Warning messages for requested taper or gap are not consistently displayed.

- After gap move, the system will sometimes not reach desired gap and will require user to hit stop button before issuing new command. This may also contribute to "buffered" commands or inputs mentioned above.

- System requires that operator manually "synchronize motors" before every single motion move. If this is missed, the motors may move in opposite direction than expected.

- System requires toggling of state button prior to enabling 42V PS. This should happen automatically when attempting enable.

- Naming of user interface buttons and readback value fields is not intuitive or consistent with checkout procedure wording.

- Pressing "Bypass" button on front of UMPI twice in quick succession will blow internal PS fuse, requiring removal from rack for replacement.

- SCSI connections from VME crate to UCMI and UCMI2 are very fragile, and susceptible to becoming loose or damaged.

Daniel Sadlier

- RS-232 connection on the UCMI-2 boxes and motors was bad in the vendor boxes. Was corrected but would have been nice to know there was a potential issue beforehand.

- UMPI at MOSO quit unexpectedly. Not sure what the resolution was on it, but did continuity check on the fuses and then went into the box with a voltmeter.

- Control program has gotten better. Keller for sure will need the latest version updated to their computer. Not sure about MOSO, but it is either the latest or close to it.

- The FPGA tends to be a point of confusion with the vendors and system altogether.
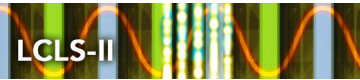
- Motor brake engaging/disengaging issue is not frequent but common. Motor brake is on when device tries moving in synchronous mode. Makes awful squealing and puts the undulator alignment out. Potential point of motor failure down the road.

- LBNL needs CAM alignment calibration capability. Not sure where this stands [regarding current status], but LBNL and potentially Argonne need a way to independently calibrate the CAM motors to expedite the tuning process.

Diego Arbelaez, Kyle Mccombs, and Erik Wallen

- Software Issues

    o Occasionally it seems like one motor break does not disengage and it will cause an immediate taper

    o The values on the gap encoders seem to drift after you reach the destination, but there is no further correction

    o Often the desired destination is not reached and we do not hear the motors try to further correct, the program just hangs and the front panel says "busy"

    o Feedback is not based on full gap encoders

    o Need feature to permanently save encoder offsets for all devices

    o CAM mover script often stops working requiring a restart from SLAC controls

    o Have to hard reset UCMI-2 at SLAC before system is operational

- Hardware Issues

    o UCMI-2 has needed to be replaced a few times on multiple racks

    o Motor Power Supply 1 amp fuse can cause challenges

    o High density cables for UCMI are known to be a culprit

    o Both racks at LBNL have "limit-in" errors and had to be bypassed

Zack Wolf

- After the temperature test at Berkeley, the gap did not go back to the correct value. My understanding is that this was because of the mounting of the half-gap encoders. But we will need to use the actual gap encoder to set the gap. The half-gap encoders do not have the accuracy to set the gap because of the positions where they are mounted (sensitive to angle errors) and because of possible deformations of the girder.

- I think the load cell readouts should be in the control system. The HXU seems to be fairly delicate, so the load cell values might give valuable feedback during use of the undulator.

- The HXU has many wires hanging off it with delicate connectors. We have already been asked to make compromises in our testing because of the time it takes to connect all the wires. This is very uncomfortable. We should look for ways to mount equipment to the HXU, like you did for the SXU, and/or we should have robust reliable connectors.

- Related to the previous item, the controls checkout in the MMF seemed to be time consuming and it will have to be repeated a number of times at different stations during production. I think it should be possible to automate this. A program can ask an operator to actuate a switch, for instance, instead of having someone read a procedure and have to figure things out as he goes.
- We would like to do radiation damage measurements in the tunnel. For this, we need fast and smooth settling of the gap. Perhaps we can work together on a mode of operation for these measurements.
- My opinion so far is that we will need an interferometer system to set the gap of the undulators. It would be good for now to start imagining how that might affect the controls.