This is a summary of all the major problems (that I can remember) since setting up the TCS experiment.

- Original ADC/DAC Box did not function
  - Description: ADC did not register voltages below 5V at all. Later, I broke the ADC completely.
  - Caused by: Original cause unknown. ADC was completely broken after I applied > 10V to it. I believe it did not have input protection.
  - Solutions:
    1. Wait for new ADC/DAC Box - Never arrived
    2. Built custom ADC/DAC Box - Fortunately I decided to do this instead of waiting. I tested the ADC channels and DAC output, and all behaved linearly as expected.
- Original data acquistion computer was unreliable
  - Description: When rebooted, it crashed 5 out of 6 times. It crashed twice for no apparent reason during the week I used it.
  - Caused by: The computer is probably older than I am.
  - Solutions:
    * I am now using my own laptop for data acquisition. I have found it much more convenient for the software developement, since I can use a linux environment.
- Many of the connectors on coaxial cables were unreliable (shorting to ground).
- Death of the first filament
  - Description: First filament showed a very slow decay in emission current. Current eventually became too low to measure reliably.
  - Caused by: Possibly changed filament current too rapidly. Turned the filament on and off many times.
  - Solutions:
    * Increase heating current - this worked in the short term, but lead to the filament blowing once $I_F > 1.3$A
    * Replace filament
    * Avoid changing the new filament's heating current. It has been stable for > 1 month now (apart from periodic variation).
- Exponential decays on DAC steps
  - Description: A very slow exponential decay occured
  - Caused by: Probably an insulator charging. The angle at which I had the sample holder allowed reflected electrons to strike the ceramic insulators. It took a long time for me to realise this.
  - Solutions:
    1. Cover all insultators - this did not seem to have much effect
    2. Change angle of sample holder - the decays almost disappeared completely after doing this
    3. Make smaller DAC steps - decays were less noticable if the step size was reduced
- Changing shape of curves
  - Description: Two curves taken sequentially can have slightly different shapes. This makes it difficult to rely on averaging of sequential curves.

- Caused by: Suspect a combination of the exponential decays, and the changing emission current. When the decays were reduced, the changes in curve shape became less noticable, but were still present.
    - Solutions: See below

- Changing Emission Current
    - Description: The emission current should be constant; it wasn't. This could effect the shape of curves over long time periods.
    - Caused by: ??? ??? ??? - Three different effects noticed
        1. Small linear dependence of emission current on initial energy. Noted current flowing into heating power supply with gun disconnected at the plug and initial energy varied. Current depended on which power supply was used. Dependence is small; 10 ADC counts over 4000 DAC counts.
        2. When varying DAC in steps of 25, note a square wave in emission current; every 2nd step of the DAC caused a about 20 count change in emission current. Possible software error? Cannot find anything wrong with the code.
        3. Noticed emission current varies in direct proportion to chamber pressure and room temperature. about 24 hour cycle. Tests with sputtering filaments, and turning off air conditioning confirmed link between emission current and pressure/temperature. $PV = NRT$ - Not sure whether Pressure or Temperature is the direct cause, since P should be (and is) proportional to T.
    - Solutions:
        * Recorded emission current with 602 until the 610B broke. Hoped to be able to normalise sample to emission current. However the amount of noise in the data made this unpracticle.
        * Make sure sweep times are short compared to the period of variation. Not much else I can do.
        * Use step sizes other than 25, and the square wave disappears (????)
        * After the 610B broke, I am using the 602 for sample current, and not recording emission current. But I am putting the 602 into ADC5 instead of ADC4. ADC5 has buffered inputs, which means (ideally) no current can flow into the ADC from the measurement circuit. ADC4 has large (150K) input impedence, but the op amp buffers on ADC5 are at least $1G$. Maybe ADC4 was affecting the measurement circuit, causing the strange dependence of emission current on initial energy.

- Measuring emission current
    - Description: The electrometers output voltages referenced to their negative terminal. The ADC measures ground referenced voltages. Connecting electrometer to emission current measurement point, and then output to the ADC directly would create a short circuit.
    - Caused by: The electrometers do not behave as stated in the manual. Supposed to output relative to ground. They do not.
    - Solutions:
        * Added differential amplifier onto ADC5. This works as long as the initial energy is below about 10-11V. If the initial energy is above about 10-11V, the op-amps saturate, and the output is unreliable. Could measure emission current for about 60% of each sweep.

- 50Hz AC Noise on outputs of electrometers
    - Description: Looking with an oscilloscope, pick up 50Hz noise. Level was +/- 200mv on 610B, +/- 1V on 602 (and more triangular). When sampled, the noise was about 1Hz due to Shannon-Nyquist sampling theorem. Noise from 602 in particular was larger than the signal (0-1V DC). The ADC reads negative voltages as "0", which affects averages.

- Caused by: Ground loops. There are numerous paths to mains ground. Input cables pick up 50Hz noise by inductance.
- Solutions:
  1. Software averaging - moved from the laptop to the AVR Butterfly to increase sampling rate. Acts as low pass filter. The standard deviation for many values can be several times larger than the value.
  2. Hardware filtering - Noise on the 602 was too large to average in software. Added low pass filters ($f_c \approx 5$Hz) to ADC5. Thus have hardware *and* software filtering on ADC5.
  3. Repositioned inputs of electrometers to reduce noise
  4. Connected all instruments to same power board (at risk of overloading!)

- Breaking of the 610B electrometer (sample current measurement)
  - Description: At about 1:03pm on 31st September, the 610B electrometer malfunctioned. It outputs a constant voltage regardless of input or zero lock. The dial cannot be adjusted to read zero using the zero adjusts. For most scale settings, the dial is maxed out.
  - Caused by: I have no idea. ADC4 seems to function correctly. The voltages never exceeded the ADC input. Perhaps the ammeter just wore out after weeks of continuous operation.
  - Solutions:
    1. No longer measure emission current with the 602; use it to measure sample current.
    2. Use ADC5 instead of ADC4, in case something is wrong with ADC4.

- Results recorded with the 602 electrometer disagree with earlier results taken using the 610B
  - Description:
    - There is less noise. This is probably due to the combination of hardware and software averaging, and the different output characteristics of the 602.
    - There are 2 peaks observable in the TCS. However, with the 602, the second peak is almost equal in height to the first. With the 610B, the second peak is roughly half the height of the first.
    - No variables have been altered. Measurement of the electrode values shows differences $< 1\%$
    - I have processed the data taken with the 610B. In particular, it shows a lot of noise when small DAC steps are made. However, the 602 shows much less noise when small DAC steps are made. I have not seen whether I get the ”square wave” using step sizes of 25.
    - In general, the shape of the curves taken using the 602 do not vary.
  - Caused by:
    - Maybe the 610B electrometer never functioned entirely reliably?
    - Use of different ADC? Unlikely. ADCs all behaved linearly in initial testing.
    - The 602 electrometer has not drifted after 24 hours. The 610B electrometer drifted by about 2 - 5% of its scale over 24 hours.
  - Solutions:
    1. Consider all data taken with the 610B to be unreliable. Repeat experiments using the 602 instead. Since I have only created one sample anyway, this doesn't put me much further behind than I am already.
    2. Do not attempt to measure emission current. Leave measurement point shorted. Perhaps the presence of the ammeter's impedance at this measurement point was affecting the experiment.
    3. Use ADC5 instead of ADC4 for sample current measurement.