Thank you for the suggested corrections, those will be implemented on the next upload.

I will attempt to answer all the questions to the best of my ability. Some of these will be vague as they involve work going on behind the scenes that I am not directly involved in (yet), and will provide more information on them when it becomes available. I will preserve the original number of the question for easier reference.

2. What is the length of the boom and the distance to the two magnetometers?

Boom length is 0.9 m. There is ~40-45 cm of separation between the two magnetometers. I am not sure of the exact number and will get back to you once it can be found.

3. Part 1: what is the orbital altitude of e-POP compared to the other SWARM spacecraft?
The main Swarm spacecraft have roughly circular orbits at ~450 km for A and C and >500 km for B. e-POP was considered to be a desirable addition to the Swarm constellation because the orbit is highly elliptical with perigee at ~330 km and apogee at ~1400 km. As such, it gets an expanded look at the magnetic field as it completes a full orbit cycle.

3. Part 2: Are there any “conjunctions” that can be used to calibrate magnitude (and with field-line tracing) the direction of the field between the SWARM spacecraft?

Quite a few conjunctions do exist, and there are files that detail each one. It will be interesting to find one of these conjunctions and see what we can learn from it.

6. What is SQUAD/slerp?

The line in the paper can be edited to provide clarity. Essentially, they are methods of quaternion interpolation. The SQUAD/slerp refers to one or the other depending on what is needed.

More specifically: slerp stands for spherical linear interpolation and refers to interpolating between two orientations by moving at constant speed along a circular arc (as opposed to linear interpolation or lerp which idealizes the change in orientation by using linear polynomials and tends to result in very large angles of arc between each interpolation point). This is sufficient if there is a small enough change between orientations and can
treat each interpolation between two points as isolated, or either you don’t know or don’t really care if other changes in orientation exist before or after.

SQUAD or Spherical QUADrangle interpolation is a series of slerp interpolations that assumes that other orientations exist before, during, and after the current interpolation between the two points. It smooths the connections between the interpolations as it does not treat each interpolation as an isolated event. This has roots in computer animation and is useful for smoothing movement between multiple animation frames. This of course translates well to spacecraft attitude as the craft is constantly changing orientation while moving along the orbital path.

9. Part 1: A lot of the work is attempting to get a good handle on the attitude of the spacecraft despite the loss of sensitivity of the star trackers and other ADS efforts. Is there housekeeping information that tells you when different subsystems are on or off to attempt to assess the magnitude of the spacecraft noise?

Yes there now is a publicly available housekeeping plot that shows what instruments were active and at what particular times. There is also a public BUS telemetry file that contains flags for when other various spacecraft subsystems turn on or off. Both of these are aiding us in our current quest to assess the impact of potential noise sources. Though first we need to remove the noise from the reaction wheels before we can get a good handle on other noise sources since they tend to dominate.

9. Part 2: What is the relative magnitude of the residual pointing accuracy error on the final data product compared to your estimate of the spacecraft noise?

-I will need to get back to you on this one.

11. What is the effect of saturation of the sensor heads in terms of calibration? Was this a big effect initially (compared to the ground-calibration values), but once sensors were repeatedly permed up on orbit, minimal effect? (From Table 1 there seems to be essentially no impact on Gain.).

The saturation occurs in the forward analog loop of the electronics and not in the sensor head itself. As such, it should not have an impact on calibration.

12. Table 1: Though having a large stray field from the boom makes sense since the large X offset is seen in the outboard sensor and not the inboard, what is the boom made from that could give such a large field? It would be of interest to see the pre-flight off-set values to get a sense of the combination of the spacecraft fields and off-set drift combined.

This one is a bit of a sore spot. Compared to the preflight zeros, the offsets found in-situ are comically large and cannot be explained by the stray fields from expected noise sources, nor can it be a product of the instrument aging as those numbers have shown up from the beginning. It is also not the boom as it is made from carbon fiber. Rather, it is likely from something not magnetically clean that was used to either secure the magnetometer or something near it on the boom and was not part of the initial design. This is especially unfortunate because it appears to magnify the effects from drift (and periodic effects). It also results in a larger RMS error post-2016 in the calibration compared to the Inboard sensor which is closer to all of the spacecraft noise.

14. Figure 5. Is this “all” the data or only Kp<3 and small change in Dst “quiet” data?

This is “all” of the data (provided it was generated when one or both star trackers were providing primary attitude and the spacecraft was not undergoing a change in angular rate > 0.03 deg/sec). The Kp and Dst flags are only applied during calibration and kept
separate from the final data product.

16. Was the inboard and outboard sensor used in a “Ness”-type gradiometer way to remove any spacecraft noise? If not, why not?

As far as I know for the current processing chain, it has not. From the Wallis et. al 2015 paper, it appears that it was used early in the mission however it was abandoned when we began the in-situ calibration. The largest source of spacecraft noise by a considerable margin comes from the reaction wheels. This is especially prevalent prior to the first wheel failure in August 2016, but still is a considerable source after. Based on a limited understanding of Ness, I don’t know if it would be sufficient for removing the reaction wheel tone from before or after August 2016 as both contain large non-dipole terms.

We have tested different algorithms, two of which (simple differencing and a notch filter) were not magnitude persevering or had difficulty adapting to changing wheel rates. There will, however, be a paper being submitted soon by a post-doctoral researcher in the lab regarding a method that has shown success, especially in the early mission.

17. Figure 6. What are the red and blue traces in panel b?

The red and blue traces represent the cross-track measurements from Swarm-A and Swarm-C which passed through the same region of interest at a different time, which is useful from a scientific perspective. Those were not included in the recreation as the main goal was to show the change in the e-POP measurements. As a follow-up, it will be interesting to revisit the analysis done in the original paper and see what if anything has changed with the recent calibration and attitude updates.