First round reply to the reviewer comments on GPS Timing and Control System of the HAWC Detector.

September 22, 2015

We greatly appreciate the reviewers' thoughtful responses. The revised paper has adopted most of the suggested corrections. We respond to all points of the review below. In this response, referee comments are written in red italic type and our replies are written in standard type. In order to be consistent with the review report, we used the line numbers from the original manuscript on which the reviewer commented.

1 Reviewer 1:

The manuscript entitled "The GPS Timing and Control System of the HAWC Detector" provides a very detailed discussion on the design of the GPS system and the Control system for the HAWC detector. The documentation is very important for subsequent analysis and publication. However, my concern with the paper is there is not enough detail in the performance section especially when "performance" is the fourth word of the abstract. The paper reads more like a manual rather than a scientific paper. I recommend that the paper be resubmitted with an expansion of section "7". In this paper, it is very important to demonstrate that the design goals are implemented. Section 7 should be expanded. For instance there was a mention (line 397) that over a period of 24 hours there was no "event with unequal timestamps". The paper should include the number of timestamps so one can evaluate the upper limit of the error rate.

Reply:
Section 7 is expanded in the new version, and we expanded the discussion of performances.

There are no plots in this section showing the accuracy. This section is important so that the reader can evaluate the performance.

Reply:
We have several monitoring plots that we monitor everyday. All of our plots have boolean values (good and bad) except Time Dilution of Precision (TDOP) plot. All of our boolean value plots give good status all the time, we have included screen shots of those plots. However, TDOP is varying with time, we included a TDOP vs time plot in the discussion.

There is a mention that the jitter is 25 ns, which is 40 times better than the required accuracy of 1 μs. Is the system over designed or is it just easy to achieve 25 ns.

Reply:
The 25 ns jitter is between two signal outputs (1 PPS signal and 10 MHz output) that are coming from the commercial GPS receiver (Navsynch CW46s). Our custom designed system uses these two signals to derive the time stamps. Therefore, no matter how well we design our system the best precision we could guarantee is 25 ns. However, this precision is 40 times better than the required accuracy for HAWC. The message we wanted to deliver is. "We noticed a jitter that sets the limit of our precision. However, the limit is much lower that what HAWC wants. Future, experiments that might refer our design should keep this limit in mind." In the new version, we explained our text in section 7, to make sure that we delivered our message.

Furthermore, it would be interesting know what determines the goal of 1 μs.

Reply:
We added an explanation about the physics phenomenon we are interested in measuring with HAWC, and the required precision.

Similarly, there is a mention that the error rate is 11/hour (line 405). What is magnitude of the error rate? What error rate can be tolerated? This section is where the performance of the system should be expanded.

Reply:
We agree that our explanation was not extensive enough, in the new version we expanded the explanation. These error flags are produced by the jitter between 10 MHz and 1PPS outputs of the commercial GPS receiver. Error rate of 11/hour means these two signals go out of phase by more than ±25 ns for 11 time per hour. One of the fact that we didn't mention here is, in a lab experiment (24 hour long) we found that the mean jitter is 0. Therefor this jitter is not adding a permanent shift between these two signals. In the firmware we have a counter, with 25 ns granularity, that measure the average jitter. If the average jitter goes above 200 ns we sets a new error flag. We monitored this error flag for nearly 4 year, but this error flag was never appeared. Therefore, we could conclude that even in longer term this jitter is not adding a permanent shift between these two signals. There this jitter does not affect the accuracy of our time stamp.

The performance section is where performance plots should be included.

Reply:
We included a plot.

There is a statement (line 409) saying that the "module is sufficient for the HAWC's requirements". Maybe, I missed it but I did see a detailed requirement list that needed to be satisfied. Section 7 should prove that the design require-

ments of the Timing and Control system are met.

Reply:
We added an explanation about the physics phenomenon that we intend to measure using HAWC.

Several of the figures had type that was very small, which made get the information difficult. I recommend that the font size of the smallest text in Figures 1, 2, 4 and 7 be increased.

Reply:

Done:

I am very surprised that the authors did not remove the background of the photo in Figures 3 and 6. With a program such as Photoshop, that is easy to do.

Reply:
Done

In addition, I suggest that a photograph of the front panel be added to the figures.

Reply:
Done

Understanding all of the input and outputs is an excellent way to understand how a module works. While reviewing the paper I found a number of typos that could be easily fixed. These are lines
2. Remove period from the title
15. Space between 1 and μs
16. I do not understand the meaning of the word "slack" in this context. Please use a more definitive term.
50. "Low dead time" should be made quantitative
149. Remove space before footnote "4".
221. There needs to be a space before μs in figure caption "5".
397. Expand contraction

Reply:
Done.

2 Reviewer 2:

This paper reports some details of the GPS and DAQ system of the HAWC detector, and is of sufficient interest for NIMA. There are some issues which should be addressed by the authors however.
1) Figure 1:
The text in the figure is too small. There are some labels not explained in the

text or misleading: What means GTC CH2? What means PMT X in channel 33/?

Reply:
In the new text, we added text to explain these labels in Figure 1. CH2 is a short-form for Channel 2. PMT X is a short-form for the signal coming from the X^{th} PMT.

2) The table 1 with the error codes implemented does not add any useful information at the paper. I suggest to remove the table and the reference to it. If no, more details about the error codes has to be given and has to be given the proof that the error codes defined are sufficient to fully debug the system.

Reply:
Done.

3) section 4.4.3 Trigger Derived Timestamp.
It is not evident if this correction is necessary. The main source of uncertainty is the TDC timestamp (1 micro sec). The order of magnitude of the trigger derived correction is not evident from the text. If it is significantly smaller that 1 microsecond then is useless.

Reply:
The GTC issued time stamp has a granularity of 10 microseconds, therefore the trigger derived timestamp is needed for calculating the microseconds digit. We agree that, the trigger derived timestamp calculates the time to a finer granularity than HAWC required. We designed the system to use the full capability of the TDC, and to be used with any future upgrades of HAWC. In the new text we mentioned that this extra high resolution values are not necessary for current requirements of HAWC.

4) References:
The style of the references is not uniform. The WEB references: the date when the reference was last accessed should be given.

Reply:
Done