Predicting EGI Failures

Abstract. The Embedded GPS/INS standard navigator (EGI), a critical component in military aircraft, provides precise platform position information which is critical for navigation, targeting, and attitude reference. These functions are required for military operations thus an EGI failure cripples the platform. As such, predicting EGI failures is highly desired. In order to determine if EGI failures could be predicted using data already being collected, maintenance data recorder (MDR) data was acquired and analyzed. The data consisted of built in test (BIT) messages and error measurements. Preliminary results indicate that some EGI failures can be predicted and that additional data, not currently being recorded by the MDR, may allow for improved EGI failure prognostics.

Introduction. Starting in September 2012, the AMRDEC Diagnostic/Prognostic Laboratory (DPL) began working with the CECOM Condition Based Maintenance (CBM+) Director on an assessment of common Avionics for inclusion in the CECOM CBM+ program. The goal is to create and validate a repeatable process for implementing CBM+ on electronic systems. To date, the AMRDEC team has had access to and processed failure data. Analysis of this data confirms that the Embedded GPS Inertial Navigation system (EGI) is one of the top “bad actors” of the CECOM managed systems. Further analysis of the data showed the frequency at which the failure modes occur. This analysis was used to develop a framework for calculating return on investment (ROI). In the framework, we selected failure modes that readily present themselves for CBM+ and performed a cost/benefit analysis (CBA). Since the EGI provided the largest potential for ROI, it was selected for initial analysis.

Method. The typical maintenance process for an EGI unit usually starts with the pilot reporting that the system has a problem. Detailed maintenance procedures are then followed to rule out numerous causes. Maintenance procedures are recorded on the 13-1, 2410 and other forms. These ultimately feed into the Aviation System Assessment Program (ASAP) and the Maintenance Consolidated Database System (MCDS). In addition to the data available from these two databases, MDR records, which contain sensor data, can be analyzed.

Analysis of the MDR and ASAP records revealed 7 confirmed EGI failures. Utilizing the MDR Analysis Support Tool (MAST) we identified several parameters in the MDR data that may be of use in predicting impending EGI failure. The results that follow are from the first EGI for which we were provided data. The data consists of 6 months of MDR data leading up to the confirmed EGI GEMS failure.

Analysis. Two of the identified parameters are heading error and inertial error. Figure 1a shows the normal start up progression for these two parameters. Of particular note, the heading error has a median convergence time of 66 seconds. Figure 1b shows the failure mode where the heading error fails to converge with times in excess of 400 seconds.

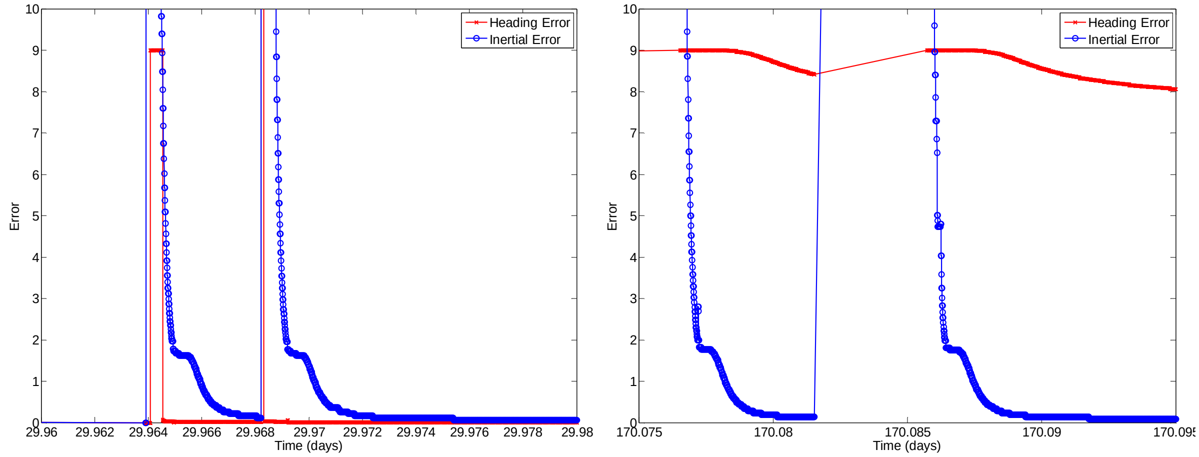

Figure 1: a) Heading error and inertial error in a working EGI. b) Heading error and inertial error in a failing EGI.

Analysis of the inertial error indicates that it may be useful in the prognostics of the heading error failure. Figure 2 shows every start of the EGI over a 6 month period. The duration of each start will be referred to as a run. Blue indicates where the EGI was switched off. Inspection of Figure 2 shows that the inertial error consistently converged to 0.2 degrees in the early stages but continued to degrade until EGI failure occurred on start #117.

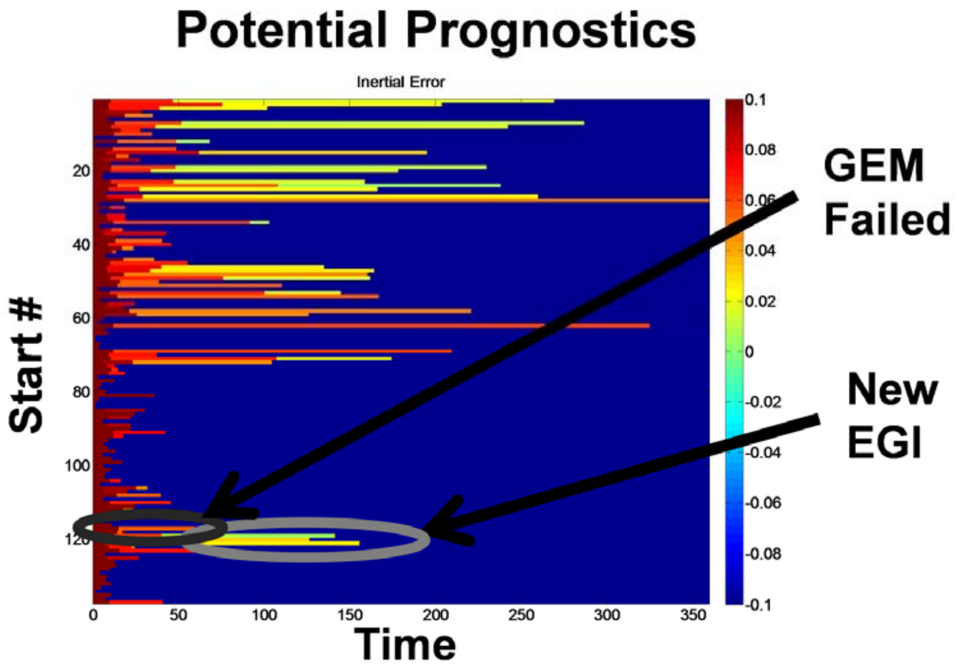

Figure 2: Potential Prognostics - inertial error increases until EGI failure.

In order convert this data into a metric, an exponential model as given by Eq. (1) was fit to each run having at least 36 minutes of duration. This duration of time was chosen to attempt to eliminate runs not associated with flights. Future data will use altitude change for run selection, but altitude was not available for this data set. Figure 3 shows the estimated parameters obtained for each run using Eq. (1). All three parameters display an increasing trend, as shown by the linear fit, especially parameter “c”, which is the steady state error estimate.

$$ae^{-bx^{\wedge}0.1} + c \tag{1}$$

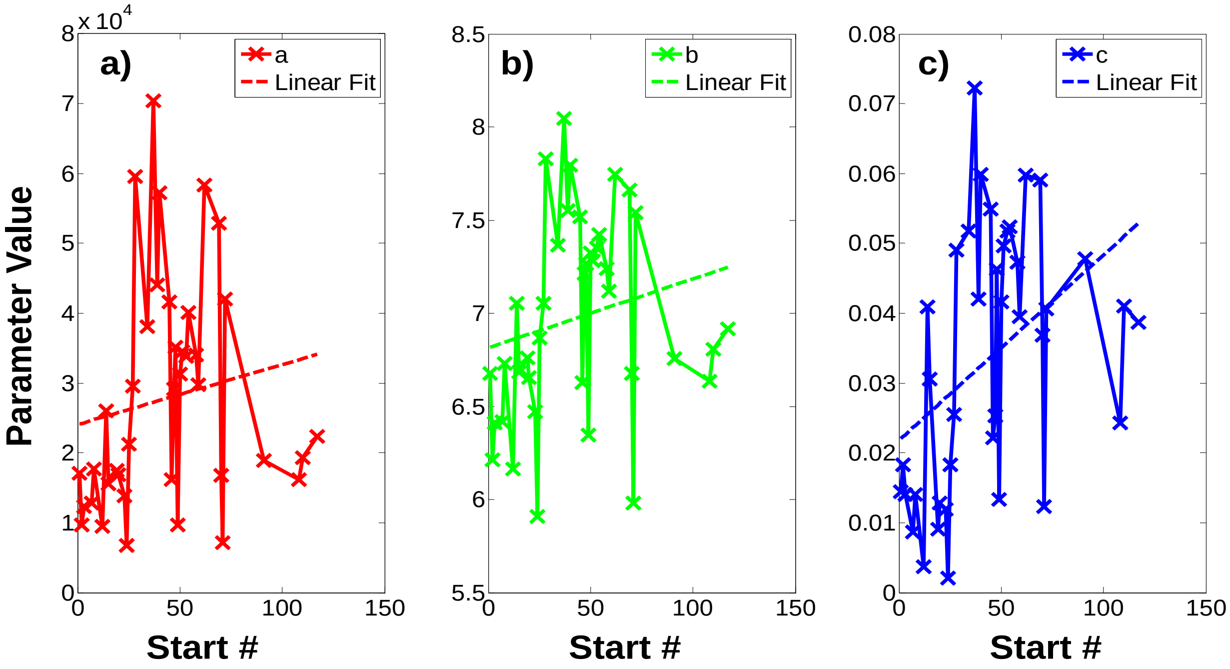

Figure 3: Estimated parameters of exponential “a” “b” and “c” and the linear fit to each. a) parameter “a”, b) parameter “b”, and c) parameter “c”.

A factor analysis was performed on these parameters vs. the remaining life and since the steady state estimate appeared to be promising, the final inertial error “iErr” of each run was also included. The two component factor analysis, shown in Figure (4) confirms an inverse relationship between the remaining life and estimated parameters and an almost perfectly inverse relationship between final inertial error and remaining life “Life”. Parameters “a” and “b” seem to provide some information with regards to remaining life; however they are much closer to being orthogonal to remaining life than “c” and “iErr”.

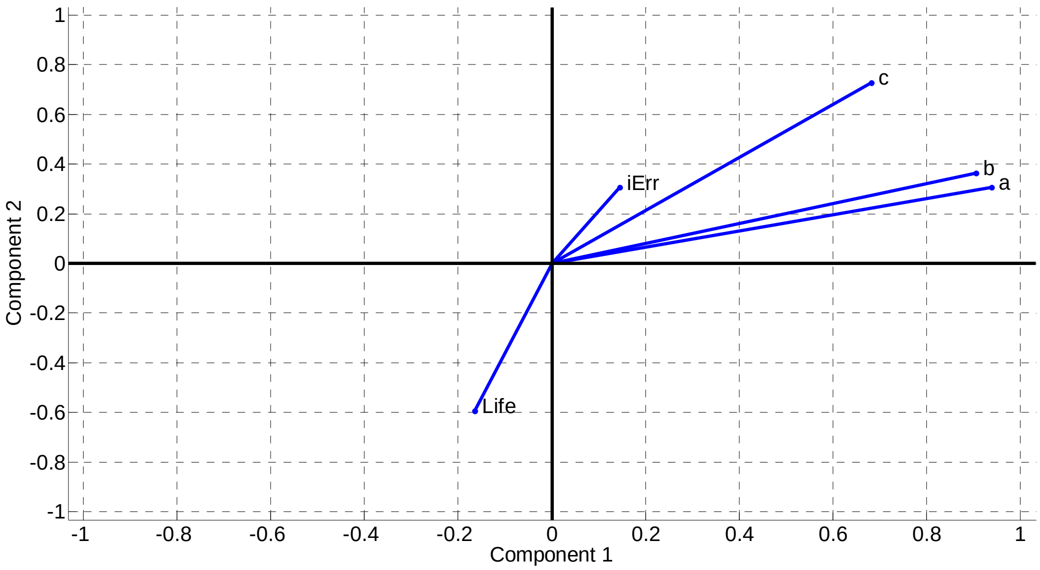

Figure 4: Factor analysis of exponential estimated parameters (a, b, and c), final inertial error (iErr), and remaining life (Life).

Conclusion. These data are from only one EGI that exhibits a GEMS fault so it is hard to draw broad conclusions without more data but it is felt that this is a promising avenue for monitoring this failure mode using data that is currently captured. More data is to being collected to confirm this analysis, but if confirmed, predicting this failure is a critical step to increase reliability.