THE TESTING AND EVALUATION OF THE EH101 MERLIN NAVIGATION SYSTEM

M A Grenfell Avionic Systems Engineer and S M Biss Avionic Systems Engineer, GKN Westland Helicopters, Yeovil, UK.

Abstract

This paper details the test and evaluation philosophy employed by GKN Westland Helicopters, in the development of the EH101 Merlin helicopter, which is in production by Lockheed Martin ASIC for the UK Royal Navy. The aircraft is fitted with a highly sophisticated integrated navigation system utilizing GPS, INS and DVS data. Particular attention is paid in the paper to the risk reduction activities conducted early in the development of the system.

Introduction

The trend in the western military towards "superiority through technology" has led towards the requirement for more mobile and efficient forces and equipments to address defence needs in a post- "cold war" world. A world where ever more systems and equipments are being proliferated and finding their way in to the hands of unstable and unpredictable regimes.

This trend towards more sophisticated technology is evident in the naval aviation field where the threat of the submarine is still taken seriously , and where the "kill" probability of an anti-submarine warfare (ASW) helicopter, is directly linked to the accuracy, availability and integrity of its navigation system. There is therefore increasing pressure to improve navigation system accuracy, which in turn leads to an attendant pressure to improve the accuracy of datum equipments and test techniques during development.

This paper briefly illustrates the system architecture devised by GKN Westland Helicopters for the Merlin ASW helicopter, and then goes on to describe the equipments and techniques employed in the testing of this system, together with a description of the early risk reduction trials conducted by the GKN Westland Helicopters Navigation Systems Department.

The EH101 Merlin Navigation System

The EH101 Merlin navigation system is configured as shown in Figure 1.

The prime navigation sensor is the Inertial Reference Unit (IRU), which can be aligned in the air utilizing the Doppler Velocity Sensor (DVS), or in the air/on the deck of a ship utilizing the Global Positioning System (GPS). The IRU uses two discrete Kalman Filter's (KF) in this process which is termed Aided Align (AA).

AA mode has three sub-modes; AA Filter Mode 1 (AAFM1) which uses DVS aiding, AAFM2 which uses GPS aiding, and AAFM3 which calculates both DVS and GPS corrections and then arbitrates between the two every 16 seconds to decide upon the source of the measurement update. Any difference between the aiding information (velocity or position and velocity) and the IRU's own inertial sensed values, are attributed to platform mis-alignment, and a convergent feedback process progressively reduces the platform mis-alignment errors (heading and attitude).

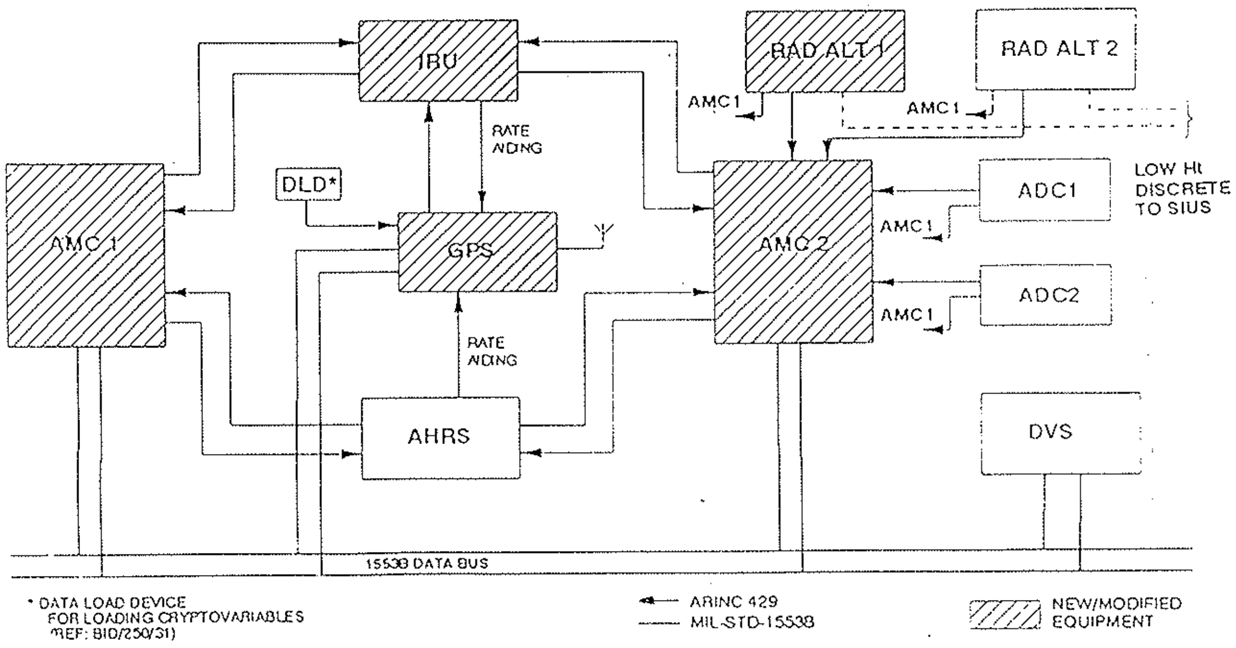

Figure 1: Merlin Navigation System

The IRU requires coarse heading and attitude initialization before this process can commence. IRU attitude levelling can be conducted on the deck of the ship or in the air using optimized acceleration averaging loops. Heading initialization can be either be provided manually, automatically from the aircraft's Attitude and Heading Reference System (AHRS), or using a GPS based Coarse Azimuth (C/Az) function, which is resident in filter modes 1 and 3.

The C/Az function can operate from position only GPS data, or position and velocity GPS data, as can the fine alignment filter which takes over the alignment once C/Az has completed. When utilizing GPS data, the filter can align using a transfer alignment function provided the platform is accelerating in a geographic frame. If no acceleration is present, or if the platform is stationary, the IRU will align using the velocity referenced Gyro-Compassing (GC) mechanism. Transfer between the two mechanisms is transparent to the user.

The GPS and IRU are directly linked using a low latency, two way ARINC 429 data bus. With the GPS sending position and velocity data, plus status and quality indicators to the IRU. And the IRU sending heading, pitch and roll data (for lever arm corrections) plus rate and acceleration data (for tracking loop aiding) to the GPS.

Mode control for the navigation sensors, and management of navigation data for other aircraft systems, is carried out by the dual redundant Aircraft Management System (AMS). The AMS also relays the DVS velocity data to the IRU after first carrying out corrections for scale factor errors and back-scatter, and additionally when operating over-water, surface motion (due to wind) and Bulk Water Motion (BWM) due to tide and current. Wind and BWM can either be manually entered into the AMS by the operator using one of the Common Control Unit's (CCU), or the data can be automatically calculated in the AMS.

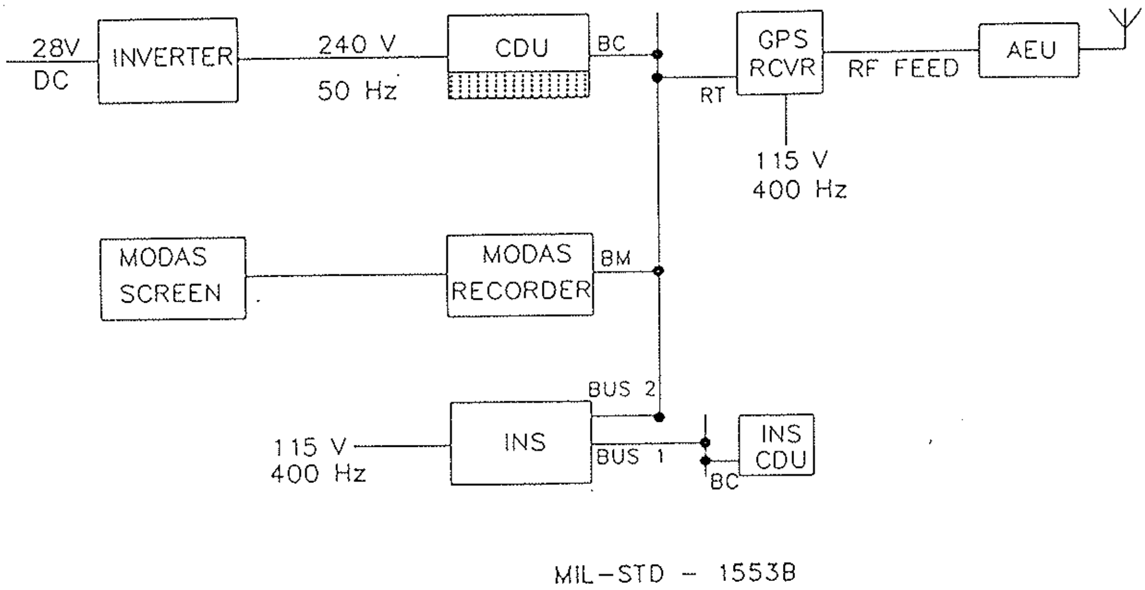

Figure 2: Merlin Navigation Instrumentation

EH 101 Merlin Navigation Instrumentation

Currently, the EH101 navigation trials aircraft has navigation datum instrumentation consisting of a Honeywell H423 Inertial Navigation System (INS) as a heading and attitude reference, and a Cossor Precise Positioning Service (PPS) GPS as a position and velocity reference. The data from this instrumentation and the equipment under test is logged on a Modular Data Acquisition System (MODAS). This is shown in Figure 2 above.

The performance of the aircraft datum GPS can be further enhanced by the deployment of the GKN Westland Helicopters differential GPS (DGPS) ground station. The data from the ground station is post-processed with the aircraft GPS data improving accuracy from 21 metres (95% confidence interval)[1], to around 3.5 metres (measured statically).

In previous trials GKN Westland Helicopters have also made use of a transportable Ocean Surface Current Radar (OSCR)[2] to measure BWM when aligning the IRU with DVS data over water. This system is not being used during the Merlin trials.

For Merlin, specialist analysis programs have been written both to automate performance assessment, and to enhance the capabilities of the aircraft instrumentation by post-processing.

One of the programs updates the datum INS with datum DGPS position and velocity data when certain DGPS quality criteria are met. This process should allow the high instantaneous accuracy of the DGPS to be combined with the smooth, high frequency output of the INS in a complementary manner.

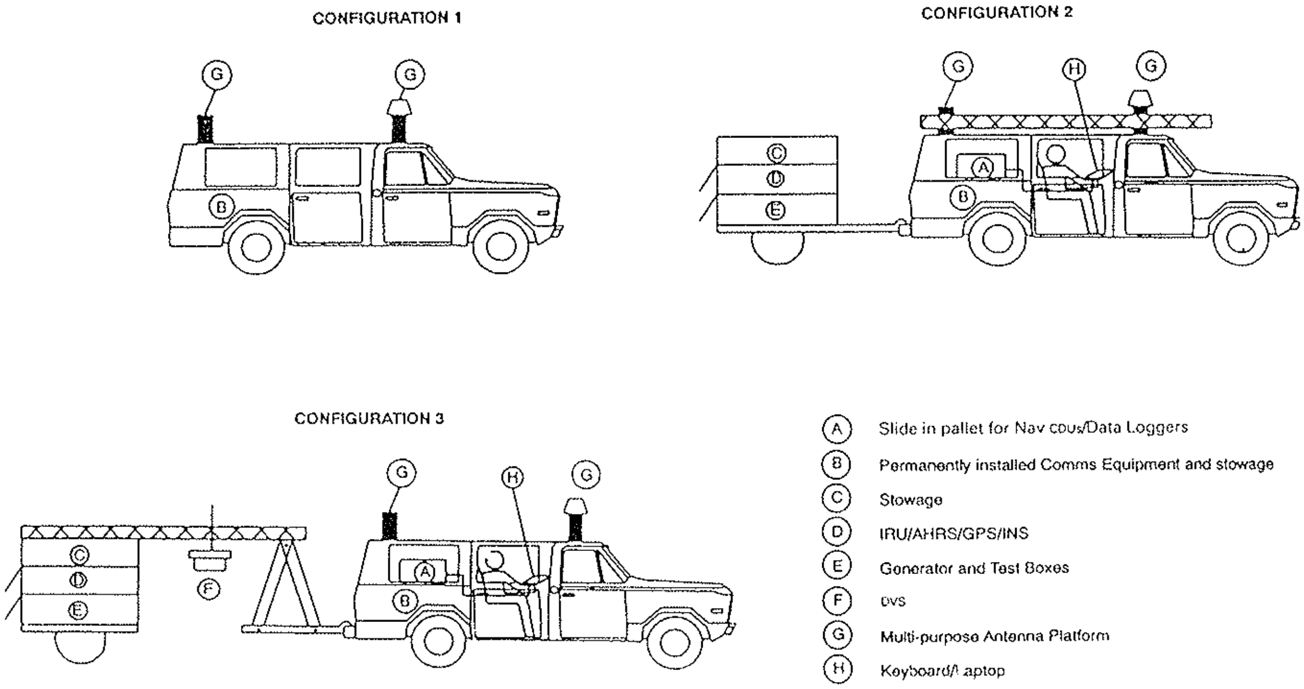

Figure 3: Mobile Trials Facility

Lever arm corrections are implemented by the datum (D)GPS receiver utilizing datum INS heading, pitch and roll data. The datum (D)GPS Control and Display Unit (CDU) act's as the bus controller on the MIL-STD-1553B bus and issues the necessary commands to the (D)GPS and INS, these commands include issue of a Synchronise Mode Code (SMC) command to instruct the INS and (D)GPS to issue Time of Validity (TOV) information. This provides a precise time mark for the datum measurements.

Mobile Trials Facility

GKN Westland Helicopters have for some time made use of a mobile trials facility to provide a stepping stone between bench/rig testing, and aircraft testing of navigation systems. Use of this facility provides a dynamic environment for the equipment under test, which is obviously important when testing a navigation system, at a fraction of the cost of conducting aircraft trials.

The mobile trials facility is configured as shown in Figure 3.

This system was used extensively to test an initial MIL-STD-1553B based version of the EH101 Merlin Navigation System, ahead of the flight trials with the formal A429 release. Two phases of local area trials were conducted during February/March and August of 1995, the later trail being conducted with an updated software standard following the identification of a number of issues with the first release. This updated standard was then taken to Norway in September 1995 to conduct a high latitude trial, the details of which are given in the next section.

The main difference between the vehicle installation and the aircraft installation is the replacement of the AMS with a custom-built MIL-STD-1553B/A429 data analyser to carry out mode control of the equipments. This system also takes the place of MODAS in the data logging role.

Use of the mobile trials facility helped to ensure that the first delivery of the A429 Merlin standard IRU, which was fitted to the trials aircraft at the beginning of 1996, was as fault free as any first delivery can be. The results of the preliminary flying have been better than expected thanks to the contribution from the vehicle trials, and bench/rig evaluation.

Test and Evaluation Philosophy

The test and evaluation philosophy employed by GKN Westland Helicopters involves 5 key stages:

* Bench and vehicle development of early/interim releases of key equipments

* Bench and integration development of equipments that conform fully to requirement specifications.

* Vehicle development of above equipments

* Aircraft development of above equipments

* Qualification of the system using rig, vehicle and aircraft facilities.

GKN Westland Helicopters are currently part way through development of specification representative equipments using the aircraft, and using the vehicle in a supporting role. Evaluation issues of software for the IRU are being assessed during this process.

The evaluation programme is structured such that a period of 2-3 weeks navigation flying takes place, comprising of approximately 7 hours flying, followed by a period of 2 months during which data can be analysed, and modifications to the equipments designed and incorporated if required.

The programme allows for 3 such iterations, before formalization of standards and the commencement of the qualification activity.

Norway High Latitude Trial

GKN Westland Helicopters Navigation Systems Department conducted a trial using the vehicle based test facilities described above in Norway during September of 1995.

The aim of the trial was threefold:

* To assess system performance at high latitudes to reduce risk in the programme

* To provide a source of reference data against which to compare simulation results

* To provide a potential source of qualification data for certain Merlin requirements

The trial was conducted at the locations annotated on the map at Figure 4. The aim being to conduct a sample of different alignment types at three latitudes in Norway (nominally at 60° N, 65° N and 70° N), and one latitude in the UK at 55° N. The trial took almost 1 month to conduct, and during that period the vehicle covered 7000 miles.

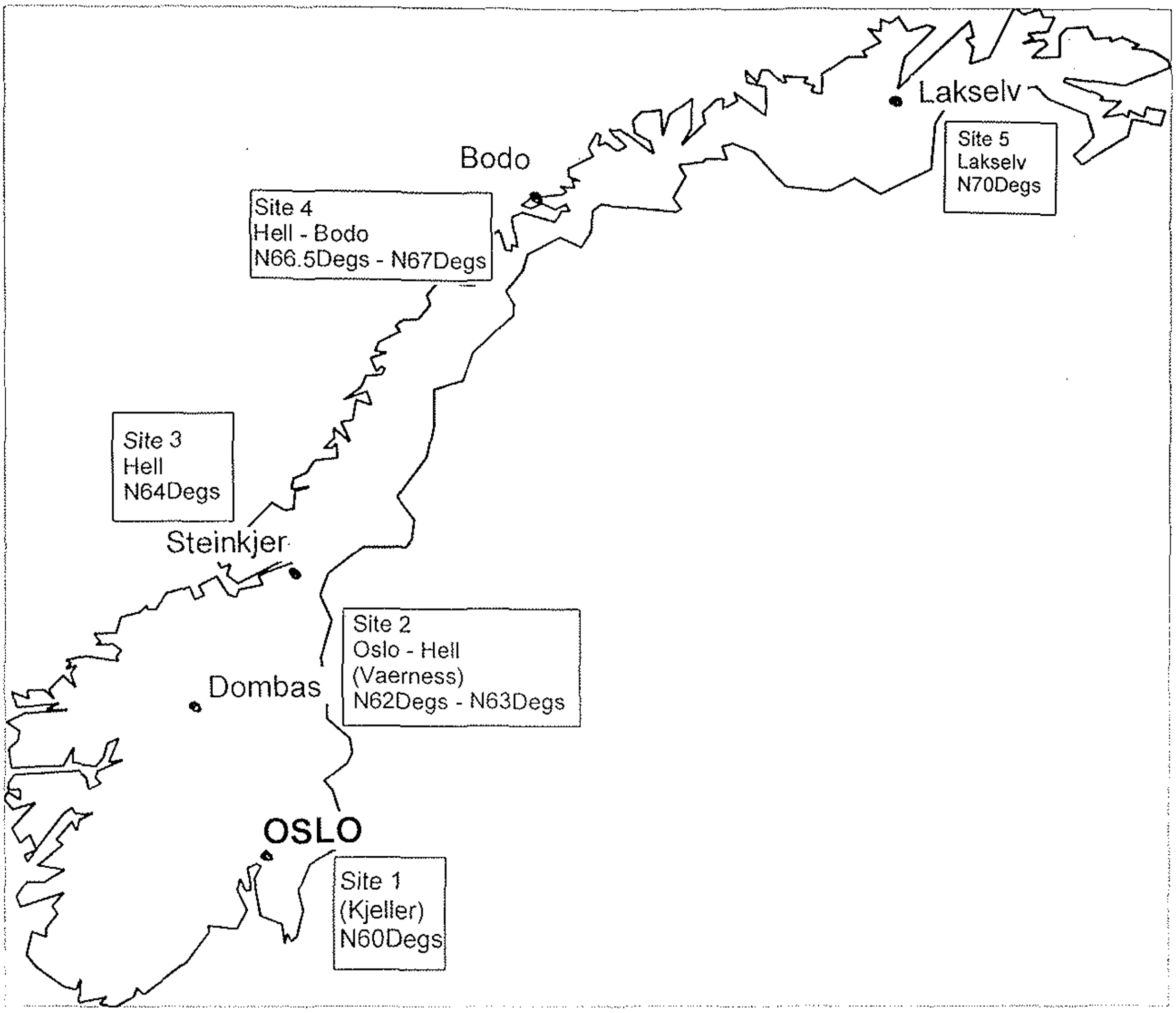

Figure 4: Norwegian Test Locations

The trial was conducted by two GKN Westland Helicopters personnel, supported at the half-way stage by two additional personnel to carry out an intermediate analysis of the data. Following this analysis the schedule for the return journey was revised to gather more data in areas that had proved significant during the analysis.

The additional staff also proved helpful when overcoming the only equipment fault of the whole journey, a leaking water pump on the Range Rover.

The trials proved highly successful, both in terms of execution and the results obtained. Over 100 separate alignments of the integrated system were conducted, with the results for heading alignment time/accuracy and positional error being within or close to the Merlin specifications.

It is hoped that the results obtained can contribute towards the qualification of the Merlin Navigation System.

The Norwegian military kindly provided GKN Westland Helicopters with permission to use certain bases to store the vehicle, and with other assistance during the course of the trial.

GKN Westland Helicopters also recently took part in the Aries '96 polar flight using the same system employed on the Norway trial. This activity consists of two round trips to the North Pole from RAF Brize Norton via Keflavik in Iceland, and Thule in Greenland on-board the DTEO Boscombe Down Comet Laboratory aircraft "Canopus".

The polar region provides a tough test for Inertial Systems as the reduced earth rate makes alignment more difficult when Gyro-Compassing. It is also a good test for GPS receivers as the constellation visible in polar regions leads to decreased vertical accuracy, due to all of the satellites being close to the horizon.

The testing therefore took the high latitude trials conducted in Norway a stage further both in terms of the closeness of the dynamic environment to that found on a helicopter, and the latitude at which the trial was conducted.

The data is still under analysis, but the initial indications are that the system aligned successfully at latitudes well above 80° N.

Concluding Remarks

It is reasonable to assume that for EH101 derivatives and future helicopter projects, the performance levels specified by the customer will become even more exacting. Therefore it is important that GKN Westland Helicopters spend time developing instrumentation and testing/analysis techniques that are suitable for future programmes.

Also the value of conducting risk reduction activities for certain equipments/ specification points has been recognised by GKN Westland Helicopters as an important element of complex integrated development programmes.

In particular the use of a road vehicle and involvement in other non-core testing opportunities early in the development programme, has yielded substantial benefits later in the test and evaluation process.

Acknowledgements

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References

1) Navstar GPS System Characteristics, STANAG 4294 Issue 1.

2) A Blended Solution: Integrated Navigation System Design and Development. M A Grenfell and J A Read, Proceedings of the American Helicopter Society Forum 50, May 1994.