Realization of a High Performance Modular Flight Inspection System

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ABSTRACT

User requirements for a Flight Inspection System cover a wide area of interest. Flight inspection receiver handling capabilities also cover a wide range from controlling one or two NAV-Receivers to full parallel control and monitoring of multiple receivers for various purposes.

A wide gap from a position reference by a simple DGPS receiver to a fully integrated INS/ GPS/ Scan-DME/ Camera/ Laser Tracker system with built-in integrity monitoring has to be covered.

Data result presentation may be preferred as x/t diagram, color graphics, alphanumerical tables or export to a central result database.

To fulfill this wide span of software requirements a thorough system design is necessary. On the one hand, it has to ensure usability of the same modules for a lightweight, simple system and, on the other hand, it has to provide massive user support for sophisticated tasks. This modular approach ensures an easy upgrade path by integrating already delivered software parts, without losing a familiar look-and-feel.

This paper describes such an approach for the software realization of a high performance system. After a short glance at the system architecture, it shows some of the modules in detail, concentrating on the user interface. Finally, it gives an overview of the realization in two aircraft, which are successfully being used for almost two years.

INTRODUCTION

From a system manufacturer's view, handling diverging customers requirements is a challenge, especially within software. It is desirable to fulfill the requirements of several customer systems with a common software. This gives benefits in design, coding, testing and documentation. Of course, this shall not compromise the flexibility for individual solutions.

Regulations differ between the different organizations. Additionally to the recommendations of ICAO and FAA, each system may have to handle country-specific preferences concerning algorithms and tolerances which have to be applied additionally.

The software has to handle different types and brands of receivers, e.g. Bendix RNA 34AF or multimode receivers, like AD-RNZ850, a Honeywell Nav receiver upgraded for flight inspection measurement purposes. Position reference requirements may be fulfilled by application of a GPS-carrier phase capable receiver or a fully sophisticated system including a lot of sensors including GPS, INS, Multi-DME and so on. While it is comparably straightforward to connect a few more wires in hardware, keeping things together in software may become a bigger task. Some possible solutions are shown.

Economically, it is required to reuse Flight Inspection software modules for new systems. Adding new requirements, this can increase complexity to a level which is difficult and therefore costly to maintain. Basic information about the software can be found in [1], [2].

So, there is a basic contradiction in

- Having the same software for all systems
- Handle individual, different requirements

It would be an idea to have all possible options in one, overall software and use switches to activate what is currently needed. This makes it complex and increases the "footprint" of memory and CPU resource needs. The footprint can be reduced by using compiler switches, leaving complexity and testing effort.

Thinking of the European Space Project Ariane 5, where an error in a superfluous piece of software caused a shutdown of all INUs with catastrophic outcome of the first launch, software shall contain no unused code. The following sections show a small selection of options which typically vary between systems:

Receiver

Using different receiver types show some subtle, non-obvious differences in

- Warm-up behavior
- Filtering of output data
- Dynamic behavior
- Timing of output data
- Timing of tuning commands
- Precision and error effects on output data
- Applicable calibration curves

Not to forget, the amount of receiver equipment may always change individually, e.g. usage of primary or FI dedicated receivers, tuning by pilot, manually or fully automatic etc.

Position Reference

Typical position reference systems are

- GPS/DGPS/P-DGPS
- Laser Tracker
- Camera System

Additionally, each GPS and Laser Tracker may be combined with INS data, while the camera system does require it. It has to be selectable to use either one single of these options or a combination.

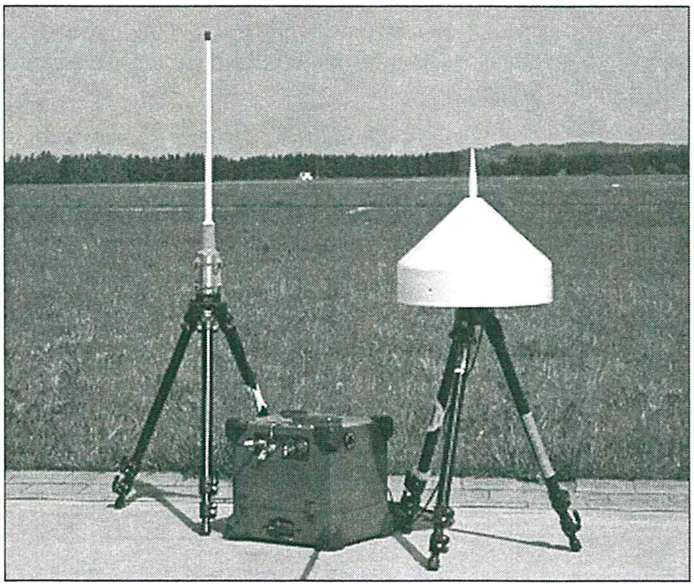

Figure 1: DGPS Reference Station

The DGPS Reference Station provides GPS reference data from the ground. It contains a GPS receiver, power supply and telemetry. It comes with antennas for GPS and telemetry uplink.

The Laser Tracker option includes the Laser Tracker itself with hand terminal, the ground station containing telemetry, radio and power supply and antennas for up- and downlink.

The camera head contains a line scan camera for low runway overflights, a laser altimeter for precise altitude information and an area scan camera for higher altitude landmark updates. Details can be found in [3].

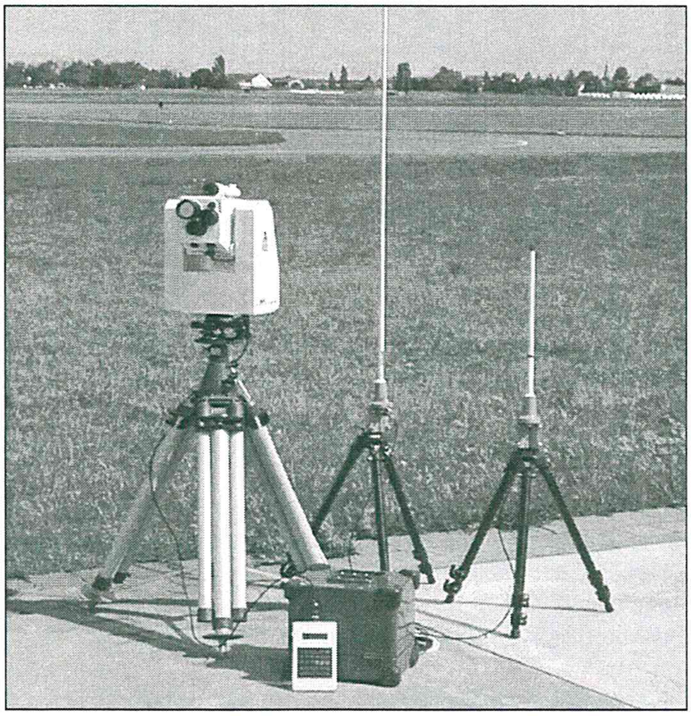

Figure 2: Laser Tracker and Ground Equipment

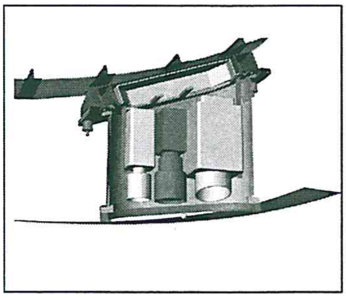

Figure 3: Sketch of Camera Head

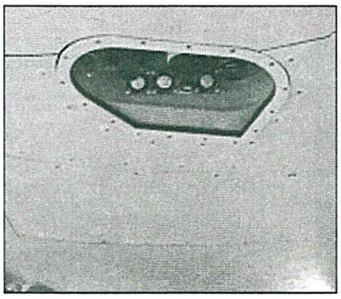

Figure 4: Camera Head mounted on Bombardier Global Express

Data Result Presentation

For the presentation of the Flight Inspection results, it is desirable to be flexible in the

- Selection of parameters to be shown
- Units of these parameters, e.g. field strength to be presented in [µV] or [dB]
- Layout and perhaps customer logo to be included
- Easy data exchange with a database or office software

Regulations

Different regulations like ICAO, FAA or country specific tolerance requirements have to be handled by the software.

HARDWARE BASIS

Basis for a modular system is also a modular hardware approach, using standardized computer hardware with standard interfaces.

Compact System

The equipment rack contains all computers, receivers and antenna switching units. It also contains the power distribution.

These racks are typically mounted on the seat rails. On top of the rack, the system printer can be mounted. The standard rack shown in Figure 5 contains

- Power Distribution
- Antenna Distribution
- Dual GPS Receiver
- Audio Recorder
- Dual Multimode Receiver (LLZ, GP, VOR, MKR, DME)
- Dual Mode-S Transponder
- Dual ADF
- Telemetry Unit
- Realtime and Display Computers
- Extension Slot

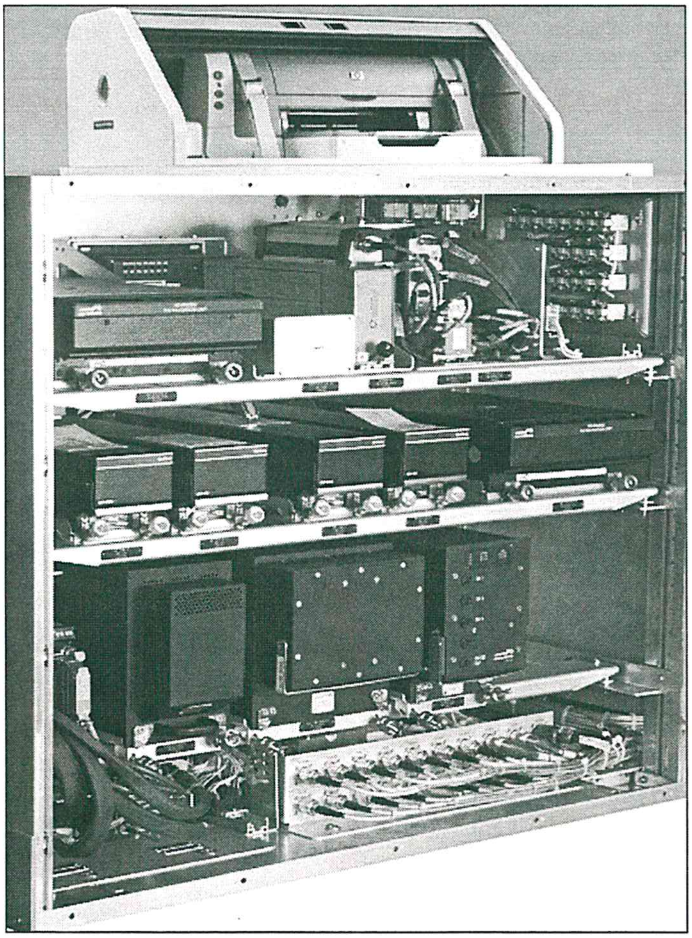

Figure 5: Equipment Rack of compact AD-AFIS

The Operator Workstation shown in Figure 6 has been optimized for weight and extremely compact size. It contains

- two 18" Flat Panel Displays
- Keyboard and Trackball
- Intercom
- Control Heads for VHF, Transponder, FI FMS

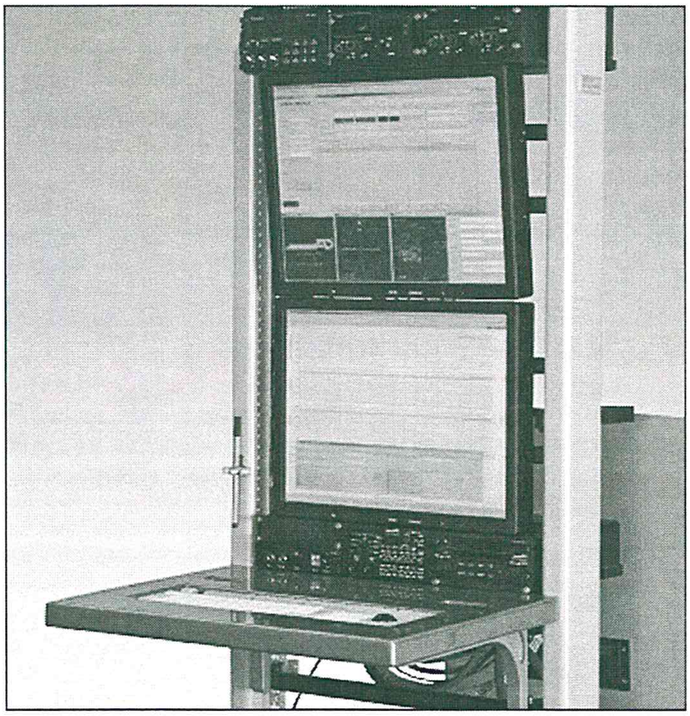

Figure 6: Operator Workstation for AD-FIS-100 and AD-AFIS-200

A possible cabin layout for a combination of equipment rack and operator workstation is illustrated in the next figure.

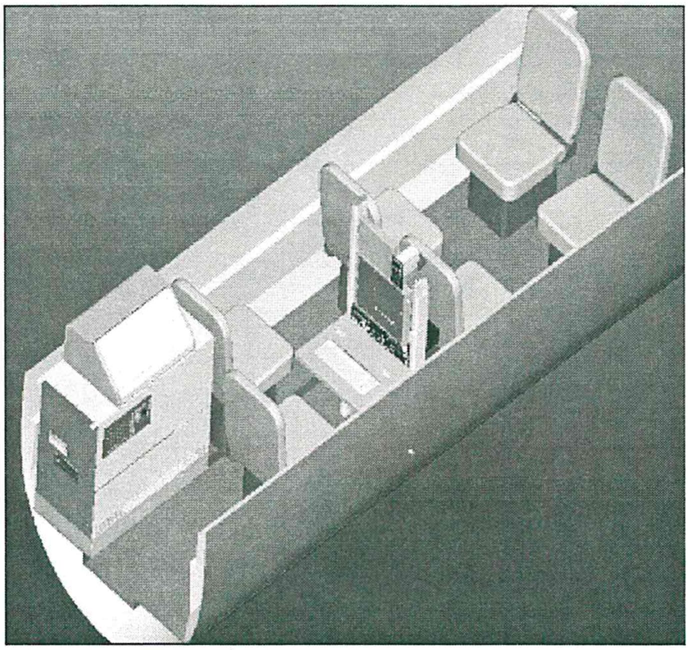

Figure 7: Sample Cabin Layout for compact AD-AFIS

High-End System

In a Flight Inspection Aircraft like the Bombardier Global Express, the importance of size and weight stays back behind operators comfort.

Figure 8: Bombardier Global Express

It allows to integrate more options into the system, including an observer workstation, an additional rack containing signal generator, oscilloscope and spectrum analyzer and two additional printer-plotter devices.

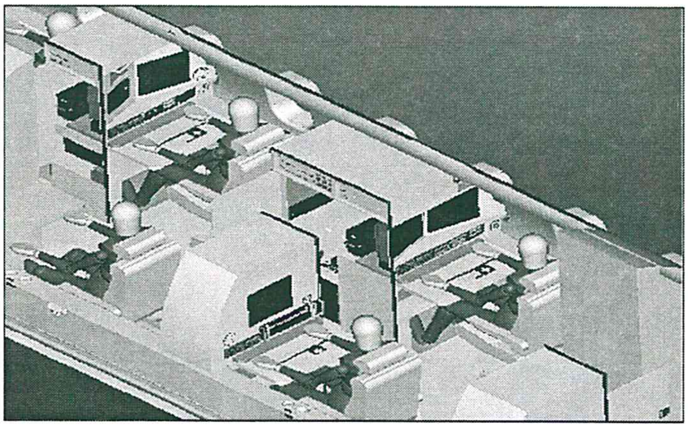

Figure 9: Cabin Layout for AD-AFIS-400 and AD-ACMS

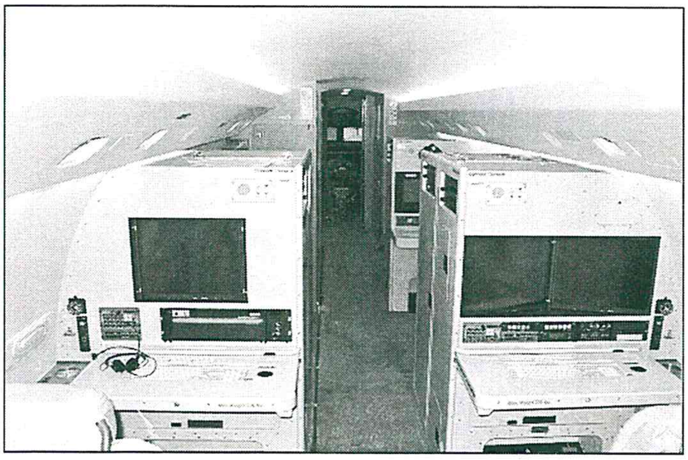

Figure 10: Cabin View showing AD-AFIS-400 and AD-ACMS

Additionally to this AD-AFIS-400, a complete second system is integrated into the Flight Inspection aircraft to monitor the aircraft data itself- the AD-ACMS (Aircraft Condition Monitoring System). It is the system on the left of Figure 9.

For integration of this system, the non-FI specific parts of the software were reused, e.g. for recording and data visualization.

On the right side, the operator and observer working positions can be seen. The 4th seat is intended for a crew member.

SOFTWARE SYSTEM DESIGN

The preceding descriptions lead to some requirements for the software system design:

- Use configurable elements wherever possible
- Limit individual implementations to a minimum
- Don't refer to unused functionality to avoid complexity and side effects
- Use an environment that allows dynamic loading of software elements

The following levels of configuration are available. Each has its advantages and drawback. The decision is based on the individual needs, therefore each of these techniques are used.

Hard coded Behaviour

Functionality is fully defined in the source code.

+ Small complexity, easy source code
+ No restrictions in functionality
+ Customer specific options are quickly and easily implemented
+ Customer specific changes do not affect other systems
- Code duplication for "almost" the same functionality for different systems
- Maintenance and Test effort multiplies with number of duplicates

Switchable Behaviour

The source code contains the superset of all possible options. A "License file" defines, which of those are active.

- Increased complexity
- New functionality may require new switching options. These do affect also other systems
+ No code duplication
- High test effort

Dynamically loadable Elements

The software is capable of dynamically loading the required functionality, e.g. a driver for a receiver type A or type B. The driver knows the details of the units behavior and provides this information to the other sections of the software, e.g. filter algorithms and GUI.

O Medium complexity
+ Driver modules can be developed and changed independently of each other
+ Optimal test effort
+ Drivers contain a generic description of their behavior, thus allowing other parts of the software to automatically reflect this without the need of implementation of variants

Factory Configuration

The Factory Configuration defines, which elements are to be loaded, e.g. type and number of receivers, available positioning options.

Additionally, the software reads configuration data, e.g. antenna patterns, cable losses, antenna locations. These are stored in a database which is loaded on delivery. These data can be changed without affecting a software release version.

User Configuration

Similar to the factory configuration, the user can also configure parts of the system. The limits are set by factory configuration.

Certain users can perform receivers calibration. The calibration data is then also stored in a database.

SOLUTIONS AND EXAMPLES

This chapter illustrates some examples, taken from the software of a high end system (AD-AFIS-400) and a medium-sized system (AD-AFIS-200).

Status Display

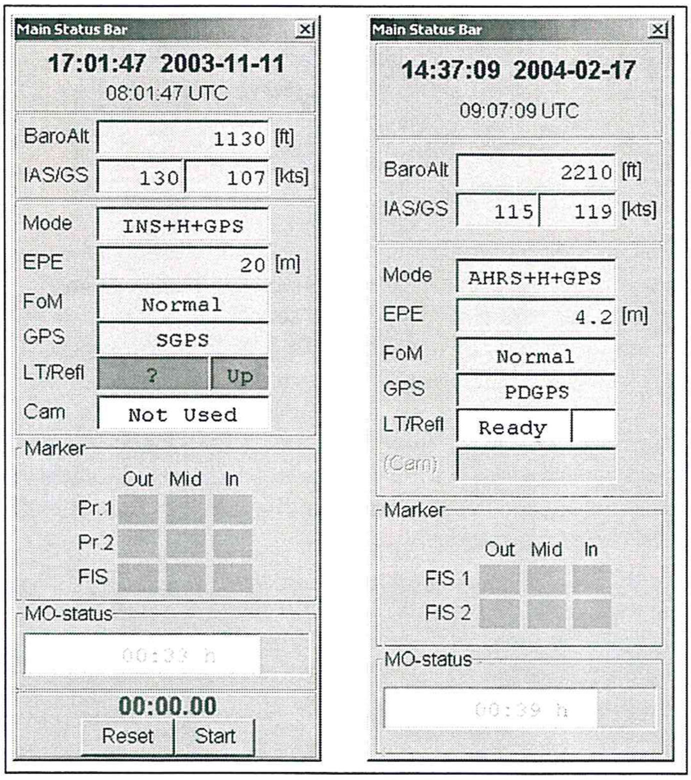

Figure 11: Main Status Bars

The main status bar is always visible to the operator, showing vital basic information. Although the information in both products is similar, there are some differences. The display contains

- Local time and UTC
- Barometric Altitude and Speed
- Reference Position Status
- Marker
- Recording Status
- Optional Stopwatch

The local time is configured to individual time zones. The reference position area reflects different sensor equipment: AD-AFIS-400 has camera and INS equipment, while AD-AFIS-200 has an AHRS and doesn't have a camera.

The marker configuration is also different: Dual primary marker and one FI marker vs. dual FI marker.

Additionally the AD-AFIS-400 has a stopwatch.

The differences are implemented using a library of standard elements and configuring them according to the systems description. Marker display is implemented two times. The unused "camera" field is shown disabled to indicate a possible upgrade option.

Offline Calibration

The offline calibration software has to handle various different receiver combinations. It does not require adaptations to various receiver equipment. It is implemented fully generic and just uses factory configuration. Figure 12 and Figure 13 show different settings for AD-AFIS-400 and –200, respectively.

The calibration window consists of two levels of "tabbed panes". The outer level allows to select the hardware line replaceable unit (LRU), while the second level allows to select the function within the LRU. A NAV-receiver has GP, LLZ and VOR functionality built-in. Using the multimode receiver AD-RNZ850 (see [5]) combines even marker and DME function in the same LRU. The software handles all settings and serial numbers. It controls a signal generator and is also capable of manual handling, export, import and report generation.

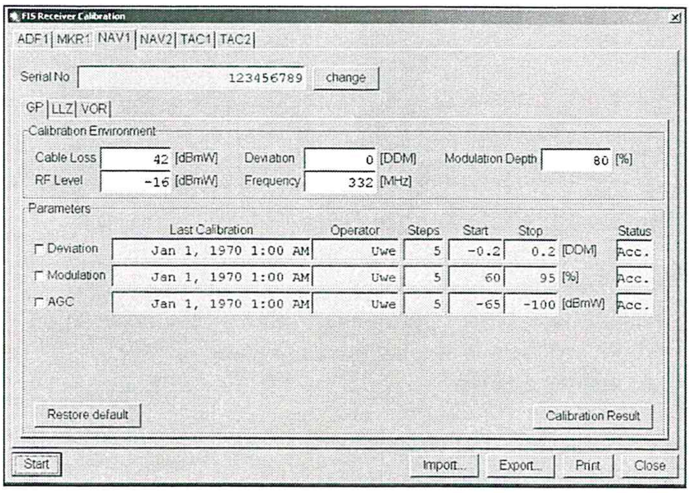

Figure 12: Calibration Window AD-AFIS-400

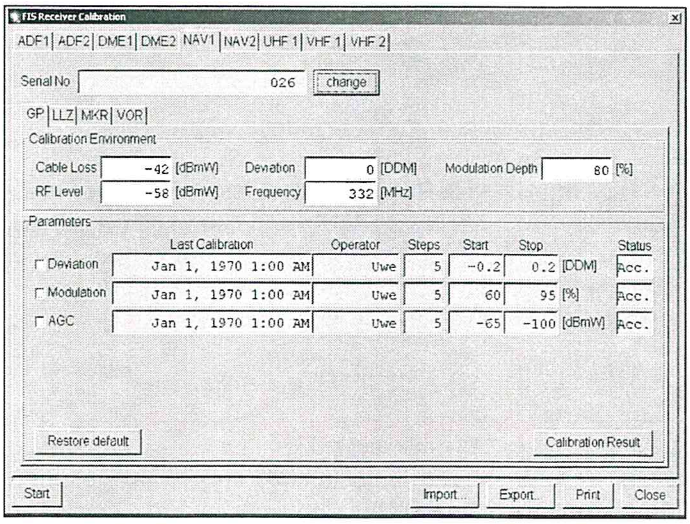

Figure 13: Calibration Window AD-AFIS-200

Receiver Control

Receiver Control provides an overview over the FI receivers, allowing manual tuning, status display, enabling/disabling and antenna switching. The AD-AFIS-400 has

- Dual Bendix RNA34 NAV receivers
- Dual Collins TCN500FI TACAN receivers
- One MKR51Z4 MARKER
- Two ADF-462 ADF (One FI)

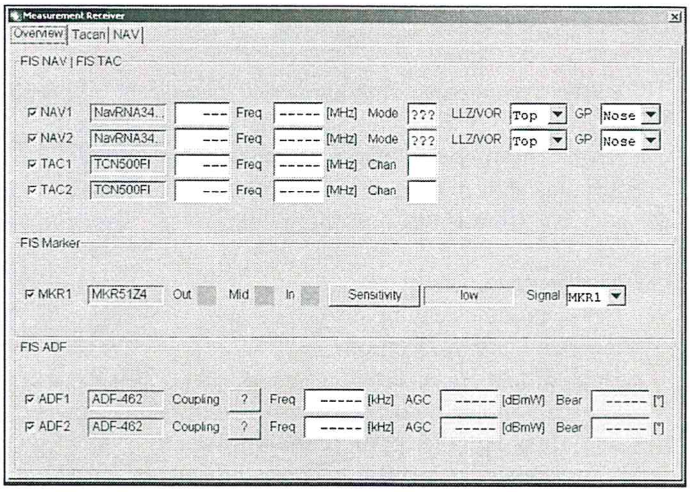

Figure 14: Receiver Window AD-AFIS-400

Contrary to this, the same software in a different factory configuration, handles the receiver set for the AD-AFIS-200:

- Dual AD-RNZ850 NAV, DME, MKR
- Dual ADF-462 (Two FI)
- Dual Mode-S Transponder TDR 94D

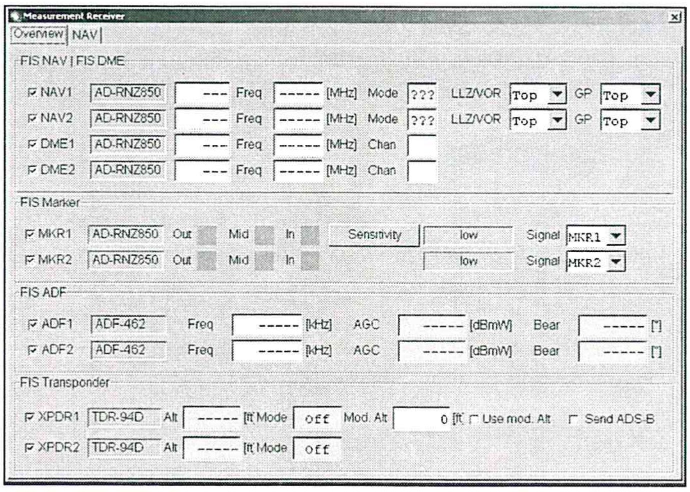

Figure 15: Receiver Window AD-AFIS-200

Flight List

The Flight List window is the central planning tool for the Flight Inspector. It provides means to set up all profiles in advance, reorder them and finish them one by one. It gives an overview about the FI receivers, the settings of the switchable antenna connections and the currently calibrated transmitter. The receiver overview is factory configured to the receiver equipment in the system.

In case of the AD-AFIS-400, it shows:

- Dual LLZ/GP
- Dual TAC
- ADF
- Marker
- PAR

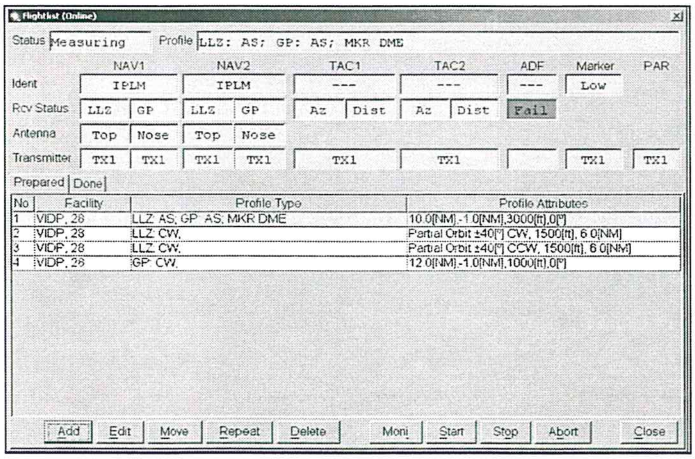

Figure 16: Flightlist Window AD-AFIS-400

In case of the AD-AFIS-200, it shows:

- Dual LLZ/GP
- Dual DME
- Dual ADF
- Dual MKR
- PAR
- GBAS

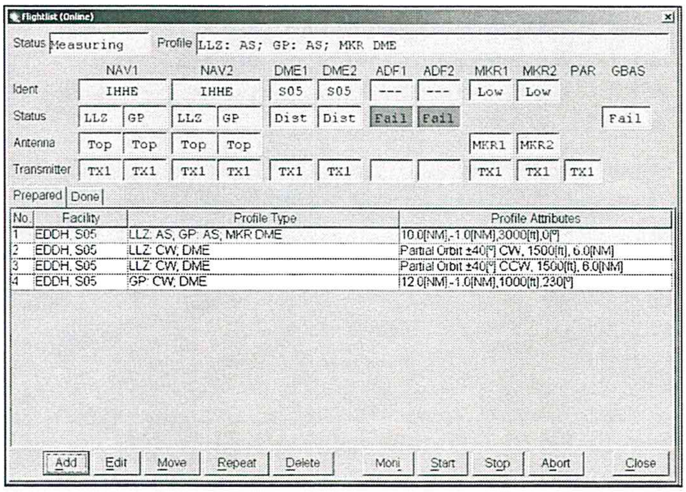

Figure 17: Flightlist Window AD-AFIS-200

The software is just the same in both cases.

Alphanumerics

Alphanumerical display of realtime data is a standard function. However, the units that have to be indicated may be different:

For instance, look at the first entry on the left. Signal Strength can be indicated as "Signal In Space AGC" in [µV] following FAA, as in the AD-AFIS-400. Alternatively, the software can provide it as "Signal In Space Power", indicated in [dBmW]. Internally, the software provides several different representations, allowing this to be fully configured without a software change.

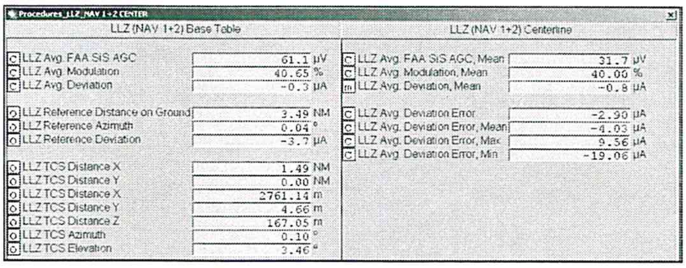

Figure 18: LLZ Data Display AD-AFIS-400

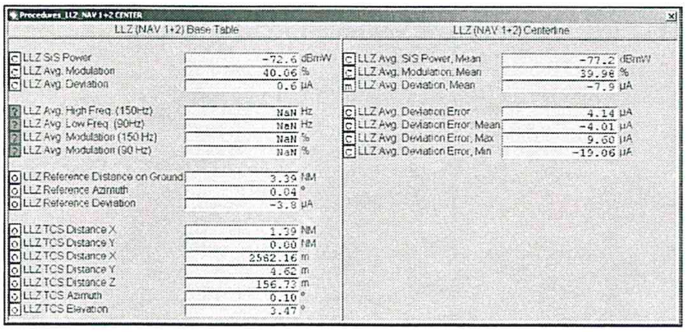

Figure 19: LLZ Data Display AD-AFIS-200

Graphics

Similar to the alphanumerics, also the graphics displays reflect different needs and can be configured to various representations. Figure 20 shows the AGC in [µV] while Figure 21 shows the Power in [dBmW].

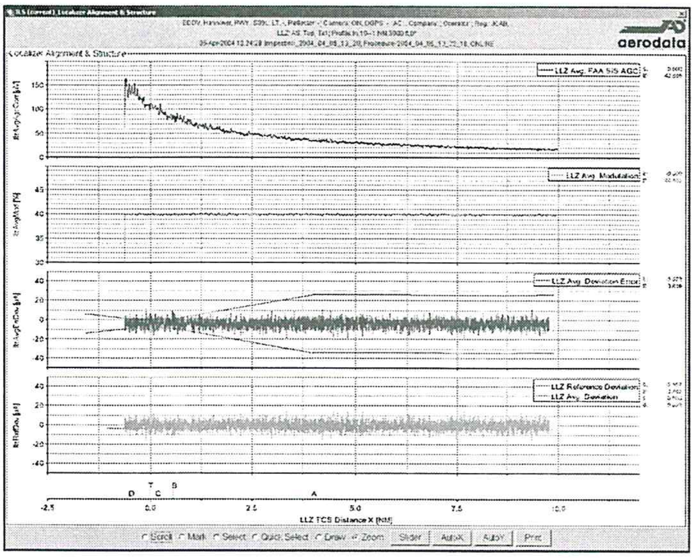

Figure 20: LLZ Graphic AD-AFIS-400

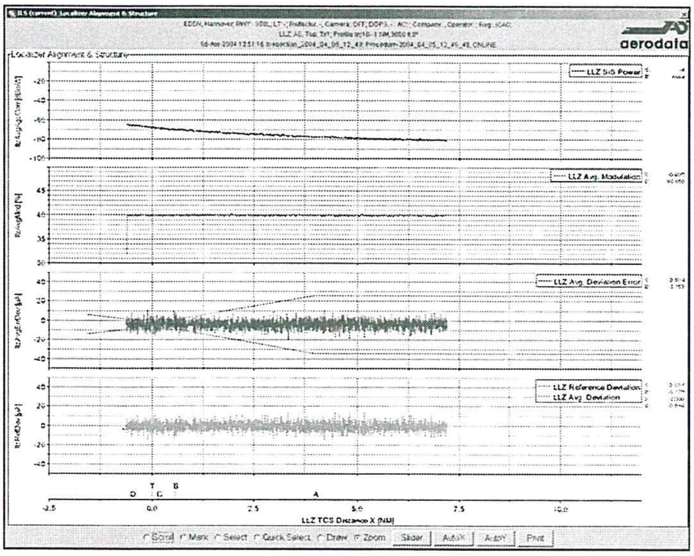

Figure 21: LLZ Graphic AD-AFIS-200

SUMMARY

A software solution that handles various aspects of a product family has been developed. On a case-to-case basis, it provides an outstanding flexibility to handle individual and common requirements with a reasonable effort. It avoids duplication of similar functionality and therefore improves testing needs and reliability.

It powers the Aerodata Flight Inspection Product family from AD-FIS-100 over AD-AFIS-200 to AD-AFIS-400.

It is not restricted to Flight Inspection. Several other systems, like Ground Support Equipment (AD-GSE) for receiver and sensor calibration and test, or Radar Inspection Application (AD-RIA) have been successfully delivered.

Up to now, five Flight Inspection Aircrafts are on duty using this new system. Figure 22 shows the first of these on its way to the customer in 2002.

REFERENCES

[1] Office in the Sky – the next Generation Flight Inspection System, Jagieniak, Schramm, IFIS 2000, Santiago de Chile, Chile

[2] Ergonomic Aspects of Flight Inspection Software Development 2002, Jagieniak, IFIS 2002, Rome, Italy

[3] Position Reference by automatic Threshold Detection with a Camera System, Dybek, Hähndel, Jagieniak, IFIS 2004, Montreal, Canada

[4] Efficient Calibration of Instrument Flight Procedures, Logemann, IFIS 2004, Montreal, Canada

[5] High End Flight Inspection Receiver, Hähndel, Heinke, IFIS 2004, Montreal, Canada

Figure 22: Bombardier Global Express, equipped with AD-AFIS-400