The support of analysis tools to flight inspection activities

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ABSTRACT

The increasing use of RNAV routes and approaches/departures increase the challenges of flight inspection teams.

The terrestrial based navigation aids use requires the contemporary checks of signal-in-space features and also geometrical parameters like the DME/DME subtended angle. This has to be done for has many equipment as possible.

In many airspaces the selection of the navaids to flight check during each mission can be critical, due to redundancy of ground equipments, due to the vintage siting criteria for these facilities.

In these cases the selection of the equipment to flight check is left (in many cases) to the responsibility of the flight checking teams, which shall take decisions taking into account for well known parameter such as radio coverage, and for brand new parameters such as the subtended angle form a DME couple.

For GNSS case the flight inspection activity should also take into account for the satellite geometry and availability at the time of the mission: almanacs and NANU messages are a major concern for this activity.

What IDS proposes is a suite of tools integrated with an ATS reference DB which support design and flight checking teams to accomplish these tasks in an efficient and integrity respectful manner.

INTRODUCTION

Until today instrument flight navigation procedures rely upon to fixed ground Navaids, but this cannot be assumed any more. Recent RNAV safety cases highlighted risks and hazards associated with poor data quality Today's data integrity performance is far from that specified by ICAO. Area Navigation and the potential to apply GNSS together depend ENTIRELY upon data quality.

Interoperability and collaboration is a key to the future AIS , Flight inspection and MIL ORG all this is reliant on data of the required content, quality & timeliness to reach "The right digital info, right place, right time"

The Electromagnetic modeling and simulation environment for radio navigation aids performances computation and EMC/EMI assessment using EMACS can help: Periodic flight calibrations and checks Feasibility analysis of new or upgraded airports/equipments, CAA planning permissions , ATC with radars and navaids systems siting, Interference, PSR/SSR coverage and radar maps.

IDS is continuously improving the system by adding all the latest requirement in the simulation environment to cover also the future GNSS navigation

NEW DESIGN CHALLENGES FROM RNAV NAVIGATION

PANS-OPS ([1]) states that during an instrument flight procedure (IFP) design, the designer shall take into account for the worst case.

As long as the IFP was based on a classical use of the ground based radio-navigation aids, the identification of a worst case condition was a task which could be accomplished by an experienced designer by using "basic tools" (i.e. a pencil, some paper charts and a ruler) .

The advent of area navigation gave a wider degree of freedom to the designers, but introduced new challenges related to:

- the possible use by the aircraft Flight Management Systems (FMS) of different sets of ground based radio-navigation aids with respect to the ones identified by the designer
- the use of sources of navigation signal not spatially fixed (i.e. GPS satellites).

These new features have dramatically increased the complexity of the IFP design work.

Additional requirements are coming from the new integrity requirements form the AIS/AIM community: ICAO Annex 15 ([2]) requires that AIS data shall demonstrate an high degree of integrity along their life cycle (from their origination up their use by the end user).

This latest requirement has as consequence the practical impossibility to proceed with a hand manipulation of sensitive ATS data.

The route to an all SW tool based data manipulation has been opened.

GNSS related topics

When dealing with GNSS navigation the IFP designer and the flight checking teams shall be aware that their attention shall be focused on identification of possible sources of degradation of the quality of the GNSS signal. This goal shall be achieved by means of ([4], chapter 1):

1. GNSS analysis
2. geodetic survey
3. GNSS monitoring
4. Record keeping
5. availability of prediction SW
6. GPS selective availability

These means that the availability of computer aided tools connected to a reference ATS database where all the stored data has been collected by means of a professional site survey will enable the designers to achieve their tasks in a safe, robust and traceable manner.

In these latest years a lot of work has been executed on the field of site surveys and the way in which the terrain and the obstacles information shall be collected, processed and stored (see [8]). The work related to this item is focused on the identification of a conceptual model to the representation of the information related to the aerodrome and to the surrounding environment.

Another very important task is related to the prediction of possible failures of the GNSS signals due to bad satellite geometries, terrain masking, multipath and or interferences.

As stated in [5], the availability of a prediction tools which make use of GPS almanacs is very important both in the pre-flight phase and in the design phase of and IFP.

During the design of an instrument flight procedure it'd very interesting to have tools which enable the analysis of the satellite performance to failures due both to satellite expected or unexpected failures, and to the effect of ground based sources of radio interference.

If an IFP designer were able to assess constraints related to the intrinsic GNSS geometries limitations (i.e. few satellites in view) and to the additional constraints coming from the operational environment (i.e. terrain masking and sources of interference), the following work phases bring to the IFP publication (ie. design quality check, IFP fight checking) will have many benefits in terms of:

1. reduced time to publication
2. optimization of man power
3. increased work quality.

DME/DME related topics

ICAO in [1] volume 2, part III, section I, chapter 3 says that when a DME/DME IFP is designed, it's "*not possible to know which DME facilities the airborne system will use for a position update, a check should be made to ensure the appropriate DME coverage is available throughout the proposed route* …". In practical terms this means that the designer should look for the worst geometry of the DME couples and check the obstacles clearances against that case. But how many cases shall be investigated in order to look for the worst case ([7]) ?

Let's assume that N DMEs with the required coverage and geometry are available, then the number of possible DME couples to be used for DME/DME navigation can be computed as:

$$N_{DMEcouples} = \sum_{i=1}^{N-1} i$$

In practical terms when 5 DMEs (N in the above formula) are in radio coverage and are compliant to the 30°/150° angle criterion the designer shall inspect up to 10 couples in order to look for the worst case. A very time consuming task !

When the aircraft is flying at low altitudes the terrain masking is becoming an important factor, and the complexity of this problem is increased due to a not straightforward way to account for terrain masking.

In complex environments where the DME density is high like in the core Europe, the need to use SW tools has been recognized by some years by Eurocontrol ([7]).

ICAO in its document on the navigation infrastructure assessment in support of PBN ([9]) says that "*Appropriate tools should be used to assess navigation infrastructure. While the assessment could be conducted using manual analysis and flight inspection, the use of a software tool is recommended in order to make the assessment more efficient. The software tool should be tailored to allow evaluating the infrastructure in light of the requirements imposed by a specific navigation specification, such as RNAV-1. Such a tool could, but does not have to be integrated with procedure design tools. In general, RNAV assessment tools should include a 3D terrain model with sufficient resolution and accuracy to allow predicting the line of sight visibility of navaids along a procedure service volume, including an analysis of their respective subtended angles and a variety of other geometric constraints.*"

<u>Procedure validation related topics</u>

ICAO ([1][4]) JAA ([5][6]), and Eurocontrol ([7]) recognize that the flyability check is part of the quality process related to an IFP design and publication.

Between the goals related to the flyability checks are (from [7]):

- Aircraft maneuvering in context of safe operating practices for the category of aircraft
- Cockpit workload
- Charting aspects
- Navigation database aspects

The complete workflow described by Eurocontrol ([7]) is shown in Figure 1

<u>Data Integrity</u>

ICAO in its Annex 15 ([2]) requires the "*Contracting States shall ensure that integrity of aeronautical data is maintained throughout the data process from survey/origin to the distribution to the next intended user. Aeronautical data integrity requirements shall be based upon the potential risk resulting from the corruption of data and upon the use to which the data item is put*"

The following classification and data integrity levels apply:

- routine: $1x10^{-3}$
- essential: $1x10^{-5}$
- critical: $1x10^{-8}$

In order to demonstrate that the above stated level of data integrity has been achieved and maintained throughout the complete data process, the old style hands and paper dissemination of the AIS data has reached its end.

What the future is preparing for us is a set of tools which enable to store, import and export data in electronic format, whit most of the data protected by cyclic redundancy checks (CRC) and other means in order to guarantee the data integrity.

A relevant work is executed by the international community on the field of data acquisition and to its dissemination. The following items are of main concerns:

- Survey of airport terminal areas (terrain and obstacles);
- Development of a systems (named eTOD) able to manage terrain and obstacles according to ICAO ANNEX 15 and EUROCAE requirements;
- Capability of interfacing with the flight procedures and airspace management system;
- ICAO A & B Obstacle Charts Production;
- Full adoption of ICAO data Quality standards;
- Use of high technology sensors and processes.

The cutting edge of the activities in this field is related to the development (see [8]) *for guidance material, which should assist States, inter-alia, in the definition of:*

- *the responsibilities and roles of the different bodies involved in the implementation process;*
- *the quality of data collection techniques;*
- *the Methods for the validation and verification of eTOD;*
- *the data model(s) to be used;*
- *the Mechanisms for the storage and exchange of eTOD; and*
- *the cost recovery mechanism to be used*.

Instrument Flight Inspection data management related topics

The use of standardized data products and procedures is an effective mean to improve the quality of flight inspecting air navigation services.

As stated in [11] *the data must accurately reflect the references to be used in the performance of inspecting the systems supporting the National Airspace System (NAS). These data will be the references for certifying the quality of signal-in-space, and the instrument flight procedures.*

The availability of

- data used by the Automated Flight Inspection Systems (AFIS) which has been validated by AIS teams
- tools for the Flight Inspection Report Processing (see [10])
- tools the distribution of data collected during the flight inspection mission

are recognized as tools which are improving the proficiency of the flight inspection teams.

THE IDS APPROACH TO THE PROBLEM

IDS has been involved by many years in the provision of tools and qualified personnel (engineers and expert services), to, improve and optimize the safety and quality of data managed through the information technology, key factors for matching requirements of Airport Infrastructure, the Physical Airport and Air Traffic Management.

IDS relies on advanced graphics and databases, integrating multiple data sources such as maps, photos, property records, survey and engineering data, inspections reports, traffic safety prescriptions, congestion statistics, documents, aeronautical charts. IDS solutions help the air transport industry to manage strategically and efficiently their information.

IDS applications in the Aeronavigation field span from the design to the exploitation of aeronautical data.

More specifically the Airspace and Flight Procedures design are addressed by some of the most stable and worldwide diffused software tools, designed and developed by IDS according to the international regulations.

To be effective in today's fast-pace world, AIS agencies must be able to manage changes in a very efficient way. IDS Aeronautical Systems provide an interactive environment that automatically propagates to output products the changes applied to aeronautical information. The aeronautical database, AeroDB is the heart of IDS Aeronautical Solutions to change management (see Figure 2 and Figure 3). By their very nature, changes to aeronautical information are time critical. The IDS AeroDB Suite is unique to the industry, in that it provides for the efficient management and monitoring of time related information. This is accomplished by allowing the user to enter changes to the database that will not become effective until some future date. These changes remain frozen until the Future Update date occurs or until a request is made to view the aeronautical data or generate an aeronautical product as it would look at some time in the future. This is a very powerful tool for AIS personnel, allowing for the preparation of large aeronautical products well in advance of their (re)issue dates. This "Temporal" functionality is an integral part of the Aeronautical Solutions database and software products.

The aeronautical database is the central repository for all aeronautical information. Data is analyzed, validated and entered into the database only once; then it becomes available to all aeronautical database users. This avoids duplication of effort and ensures quick access to the most up-to-date information by all personnel. Temporality maintains the integrity and security of the aeronautical information by keeping track of the date and source of all changes applied to the database. The Aeronautical Systems database management creates a truly integrated environment for data maintenance that enhances the efficiency and effectiveness of any AIS organization.

The IDS Aeronautical Solution to the automation of aeronautical information management, is uniquely designed to simplify the everyday activities of the AIS organization, while also providing for the following (see also Figure 2 and Figure 3):

- Maintain and improve quality levels of the products produced.
- Provide the flexibility to produce new and improved products.
- Increase efficiency by realizing shorter turnaround times for production, printing and distribution of aeronautical information products.
- Provide management with a tool for tracking the status of the many phases involved in aeronautical information publication and maintenance.
- Provide access to new and/or changed information early in the cycle of chart and document production and maintenance.
- Decrease chance of errors in transmission or exchange of aeronautical data.
- The capability to exchange aeronautical data in many standard aeronautical formats (ARINC, DAFIF, DTED, AICM).
- The capability to interactively design flight procedures (Standard, RNAV, etc.)
- The capability to simulate performance of radio navigation aids (bearing error, coverage, etc.)

As support tool for the prediction and analysis of the signal in space is available the EMACS tool (Electromagnetic Airport Control and Survey). This is a modular analysis tool devoted to inspect and modeling radio electrical feature and the installed and proposed Navaids, and is based on a set of numerical codes totally developed in IDS's laboratories in order to solve the Maxwell equations in complex environments such as the airport scenarios. The numerical tools of EMACS cover the whole aeronautical frequency band, and are based on the most sophisticated and widely known computational electromagnetic techniques.

Recently has been developed a new add-on module to EMACS able to analyze the expected performances of DME/ DME and GNSS systems. (see Figure 4) This module is called ASUV/DME. Being an add-on module of EMACS it shares the basic GIS/CAD utilities and, of course, the database connection of EMACS. ASUV/DME (Airborne Signal Usability Verification) is an analysis tool to inspect if the GNSS and the ground DME infrastructure is sufficient to support the RNAV operations. The ASUV module is able to compute the following set of parameters:

- Total number of DME in coverage
- Number of couples of DME which are in coverage and usable according to the 30°-150° angle requirement (refer to Figure 5)
- An estimate of the Position Estimation Error (i.e. PEE) maximum and minimum value (see Figure 6)
- An estimate of the Multi DME continuity of service (refer to Figure 7)
- Number of critical DME

Within the frame of ASUV/DME is available a feature that enable the programming of AFIS equipment in order to flight check the DMEs which are of interest for DME/DME navigation (see Figure 8).

Within the frame of the ASUV/GNSS is possible to assess:

- the number of satellites in view and the quality of their geometry;
- the radiated interference risk for GNSS receivers for potential threats coming from ground based transmitters (see Figure 9);
- the effect of multipath from man made obstacles and terrain on GNSS receivers (see Figure 10).

Recently IDS has developed (under ENAV contract [12]) the Flight Inspection Planning & Post-processing (FLIPP) tool, whose main goals are the following:

- being a tool for the mission planning support. This task is accomplished through the selection of the aircraft, the crew and the radionavigation aids to be flight checked during a flight checking mission (these latter are selected form the central AIS/Design database),
- being a repository for the data collected during the flight check. At the return form the flight checking mission is possible to store in the FLIPP database the data collected from the ground based equipment and from the GNSS satellites
- being a post-processing tool. FLIPP is able to show the variation of the performance parameter collected during the flight checking mission of ground based equipments. The post-processing of the GNSS data is executed by means of the PEGASUS tool from Eurocontrol ([13])

CONCLUSIONS AND RECCOMENDATIONS

The increasing use of RNAV routes and approaches/departures increase the challenges of flight inspection teams.

The international rules from ICAO, Eurocontrol, JAA and FAA are asking for increased level of integrity in aeronautical data due to the fact that aircraft flying strongly rely in the data loaded in the navigation DataBase.

This paper has given a short overview of those requirements and has given some snapshots of the solution developed by IDS to meet the though requirements which are asked from the regulators to the air navigation service providers.

ACKNOWLEDGMENTS

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[6] JAA Administrative & Guidance Material, Section One: General Part 3: Temporary Guidance Leaflets, LEAFLET NO 10: Airworthiness and operational approval for precision RNAV operations in designated European airspace

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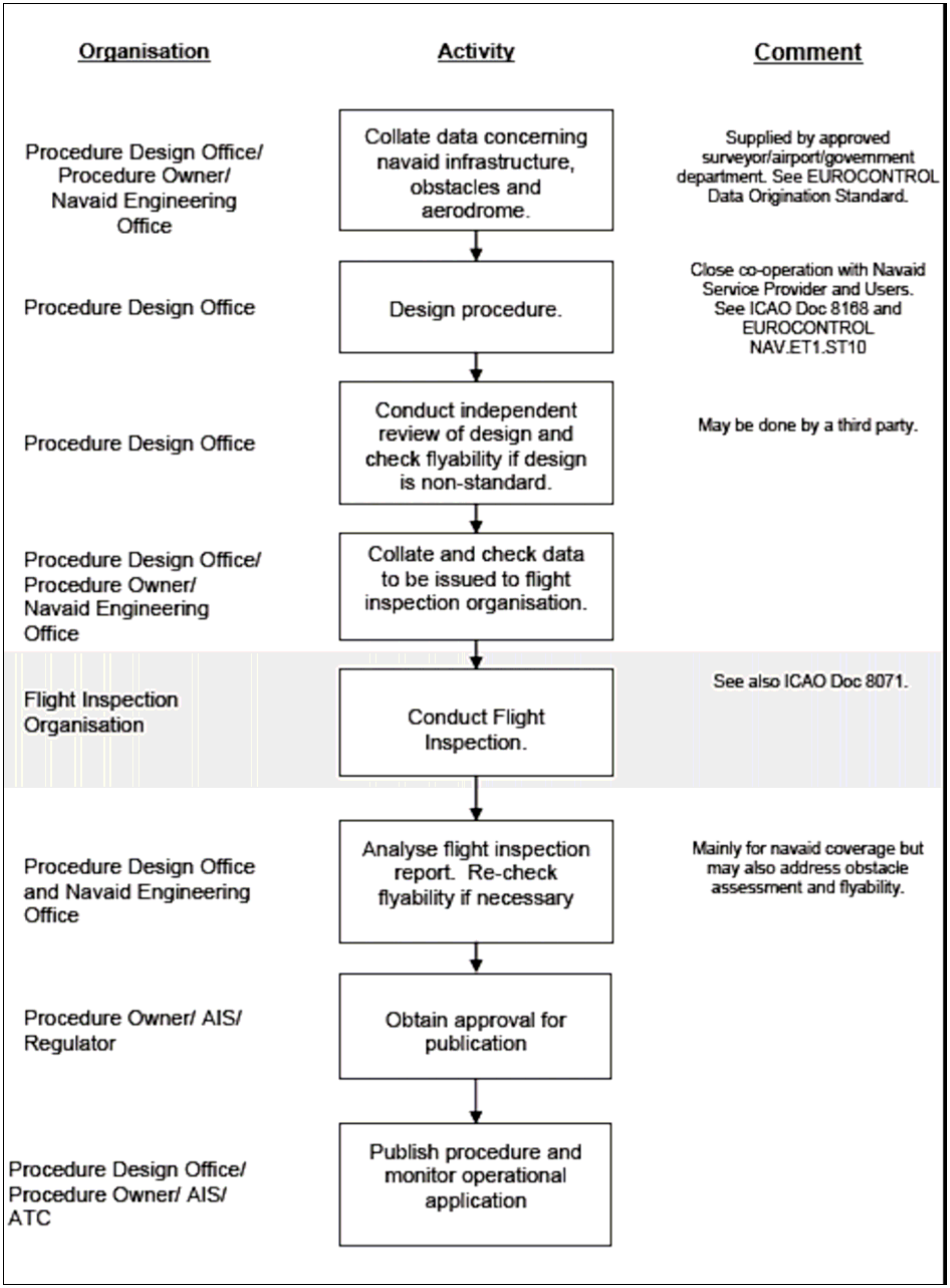

Figure 1 - Workflow described by Eurocontrol in [7]

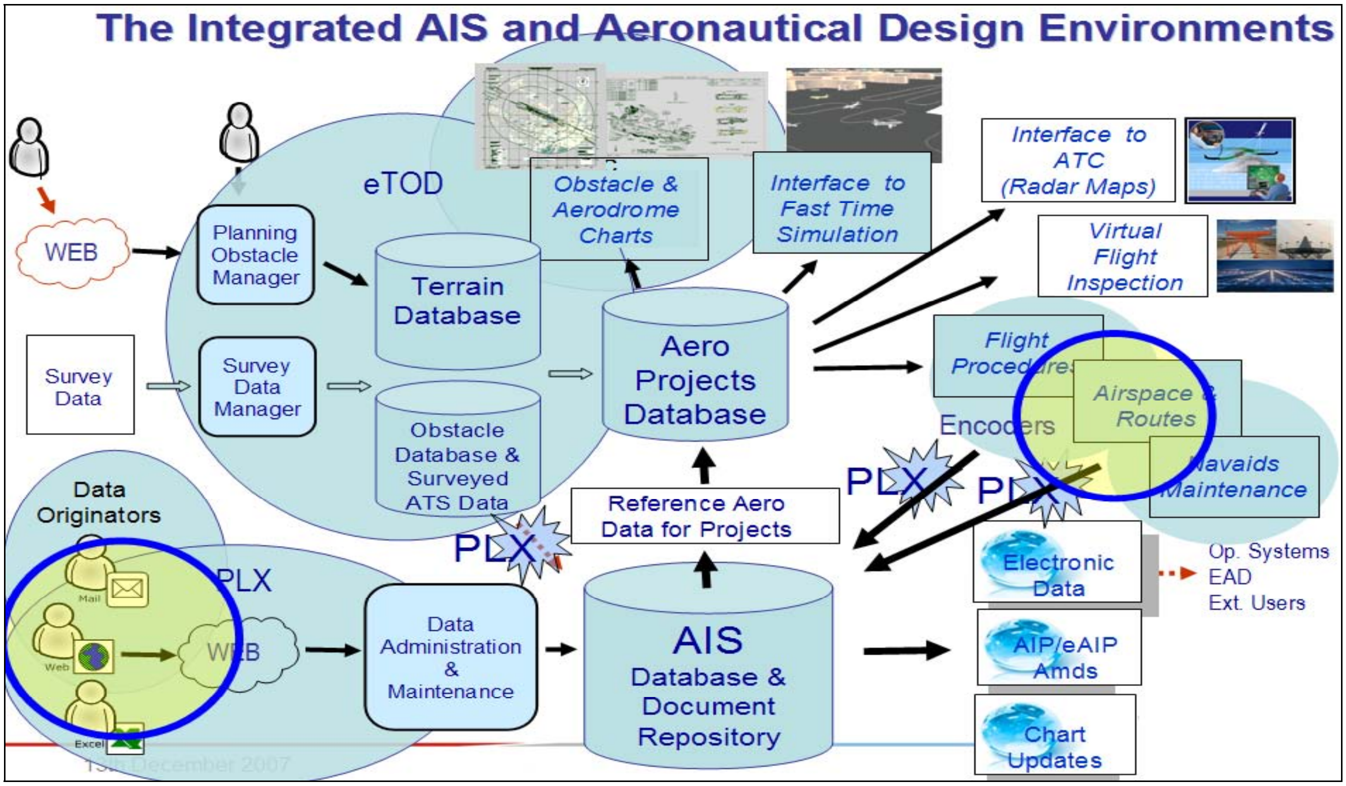

Figure 2 - Integrated AIS and Aeronautical Design Environments

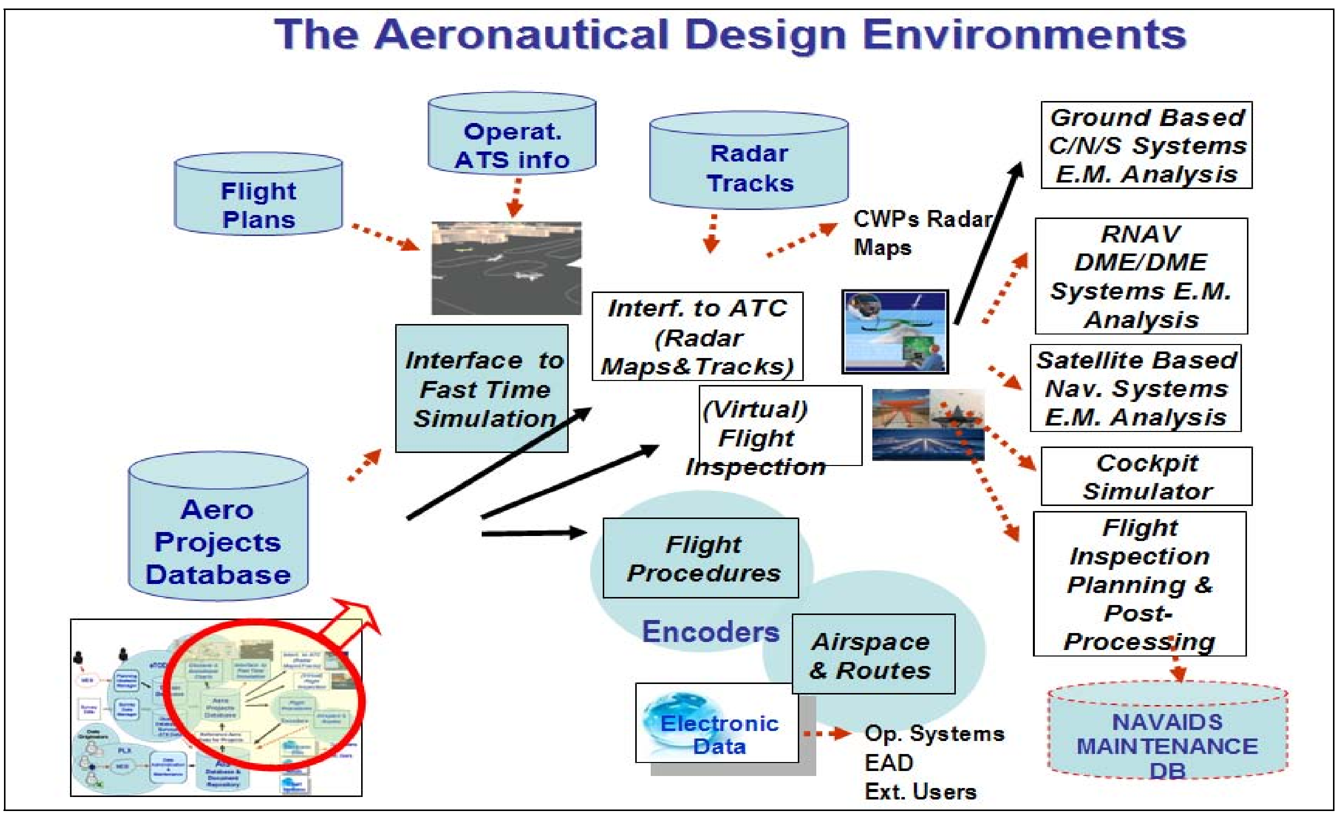

Figure 3 - Aeronautical Design Environments

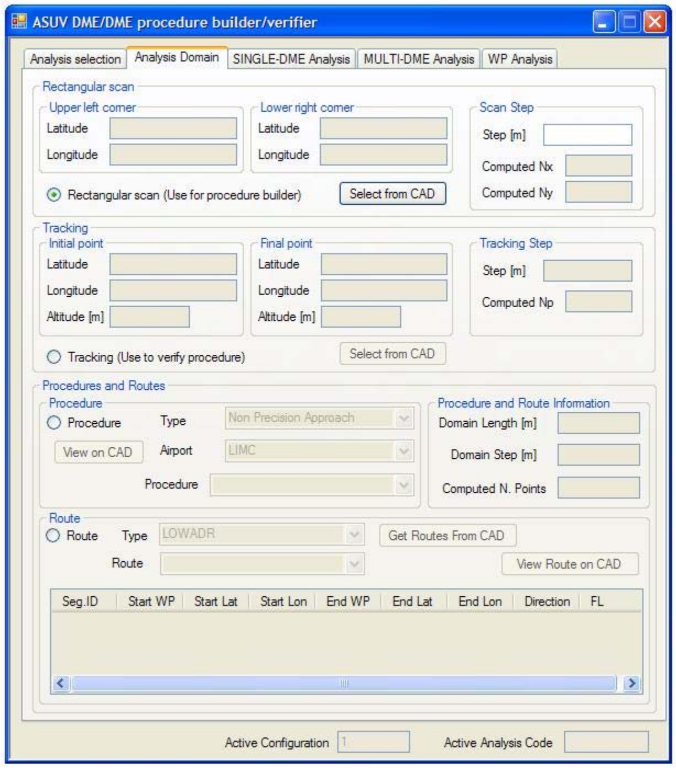

Figure 4 - ASUV DME analysis domain section

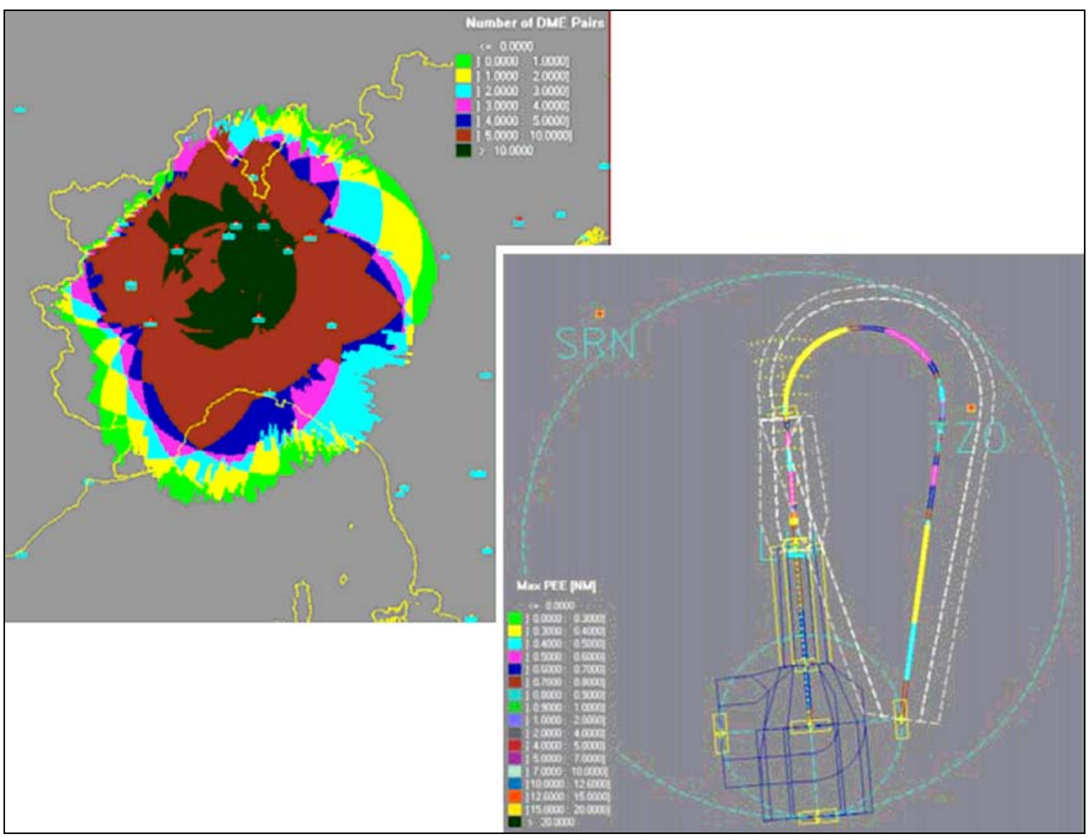

Figure 5 - Samples of DME pairs computation along procedures and areas

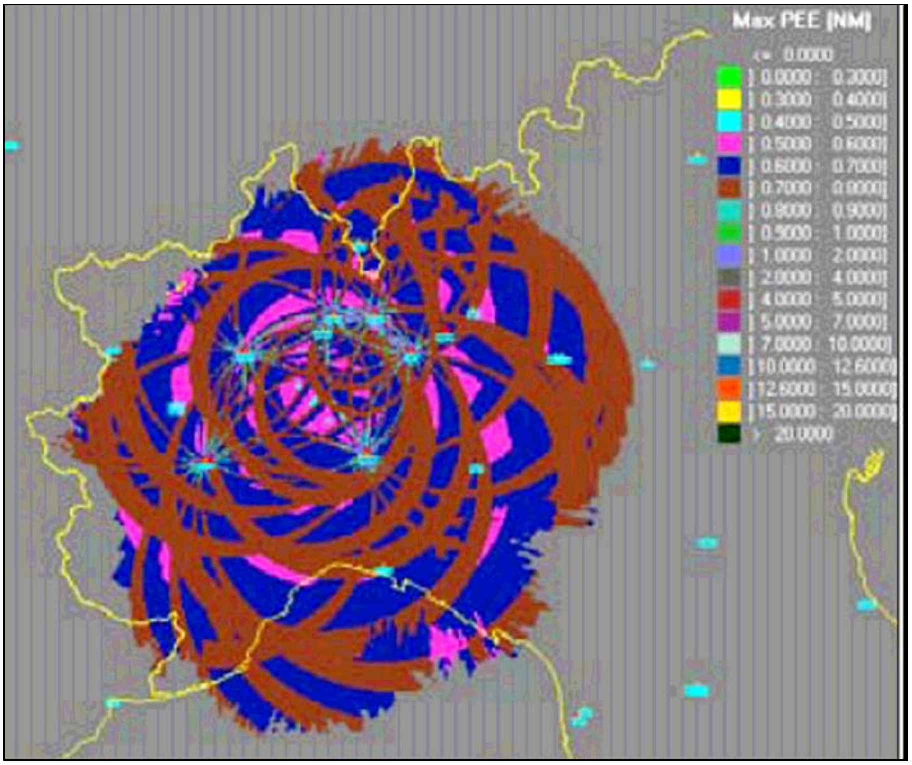

Figure 6 - Sample of DME positioning error estimate on an area

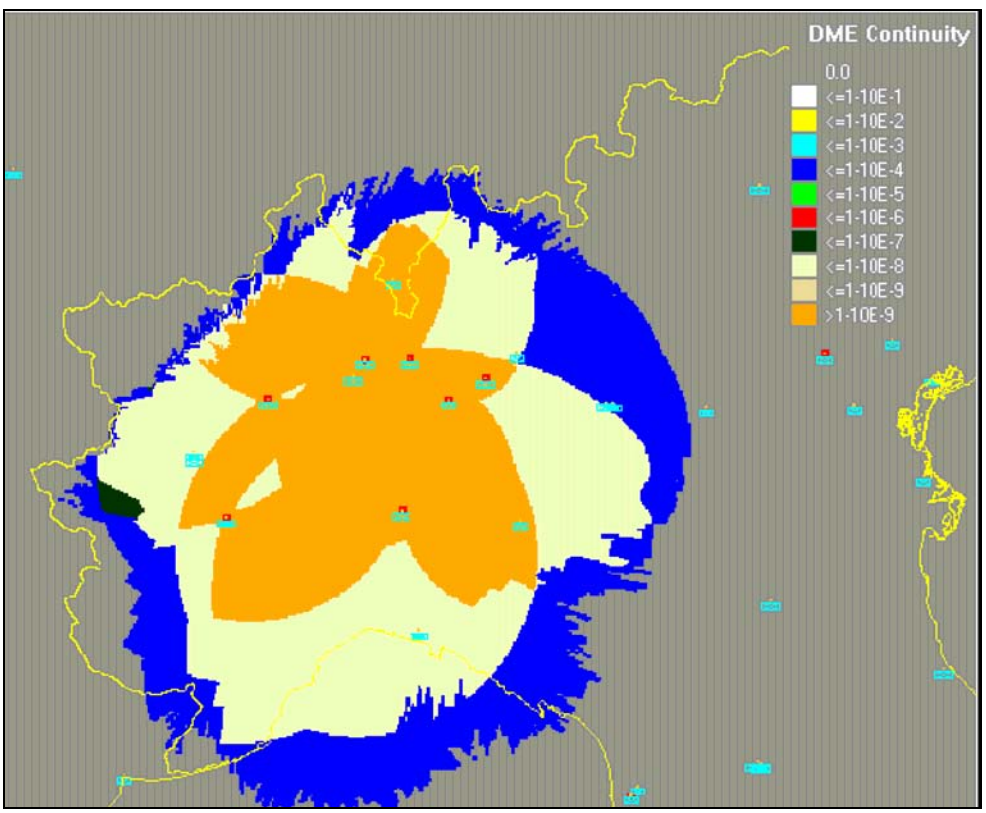

Figure 7 - Sample of DME continuity of service estimate on an area

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1,fukuoka rwy16 star east,STAR,NA
2,*,NA,NA
3,Kirin,0340717.93,1304919.31,HOPPS,0340229.08,1304102.41
4,1,8.4,0340717.93,1304919.31,0.0,0340229.08,1304102.41
5,SWE,0,0
5,DGC,0,0
5,MIT,0,0
5,FMT,0,0
5,OCT,0,0
3,HOPPS,0340229.08,1304102.41,TANRE,0335446.35,1302747.15
4,1,13.4,0340229.08,1304102.41,0.0,0335446.35,1302747.15
5,SWE,0,0
5,DGC,0,0
5,MIT,0,0
5,FMT,0,0
5,OCT,0,0
3,TANRE,0335446.35,1302747.15,MALTS,0334520.80,1302005.94
4,1,11.4,0335446.35,1302747.15,0.0,0334520.80,1302005.94
5,FUE,0,0
5,SWE,0,0
5,DGC,0,0
5,FMT,0,0
5,MPE,0,0
3,MALTS,0334520.80,1302005.94,SANDY,0334309.95,1302133.89
4,1,2.5,0334520.80,1302005.94,2.0,0334452.50,1302024.97
5,FUE,0,0
5,SWE,0,0
5,DGC,0,0
5,MPE,0,0
5,TQT,0,0
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5,FUE,0,0
5,DGC,0,0
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Figure 8 – Sample of ASCII file for flight inspection of DME along an RNAV-DME/DME instrument procedure

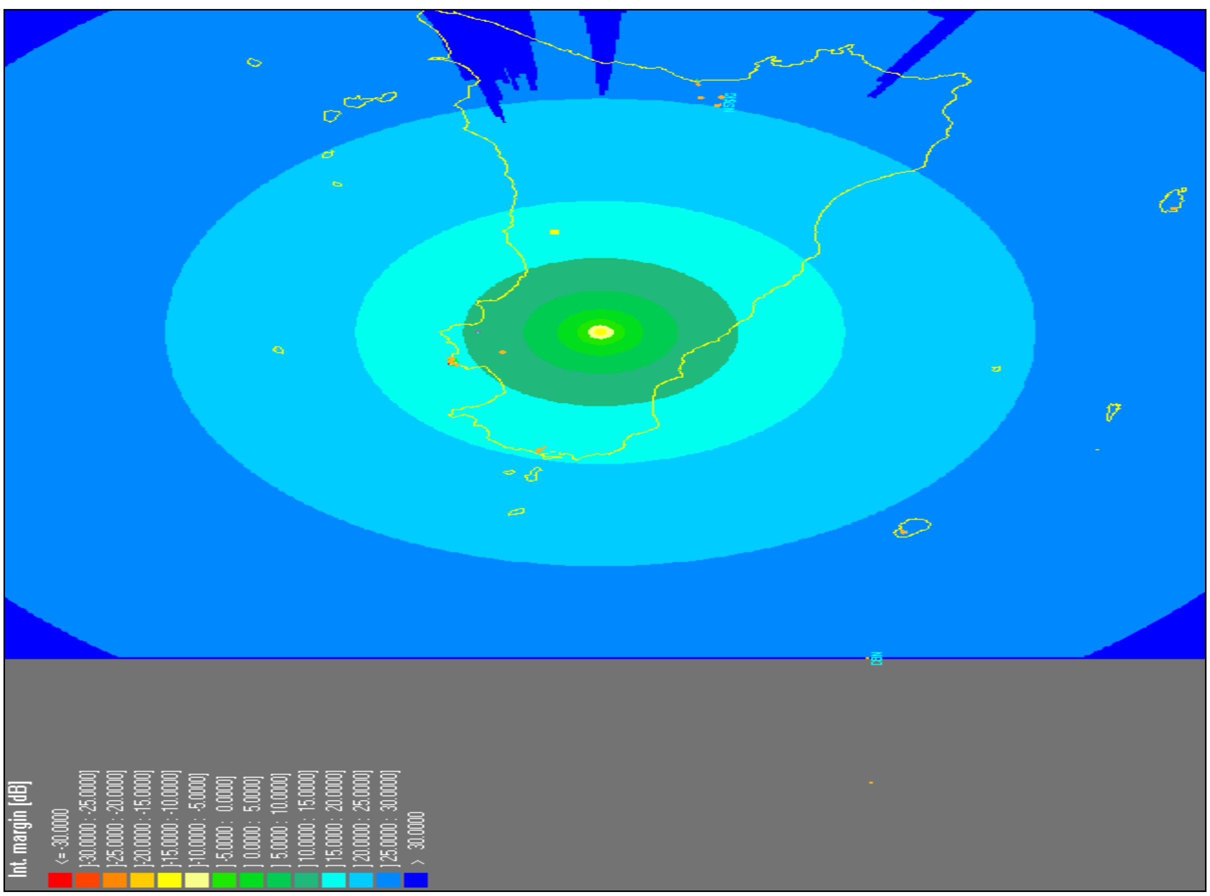

Figure 9 – Sample of interference margin calculation

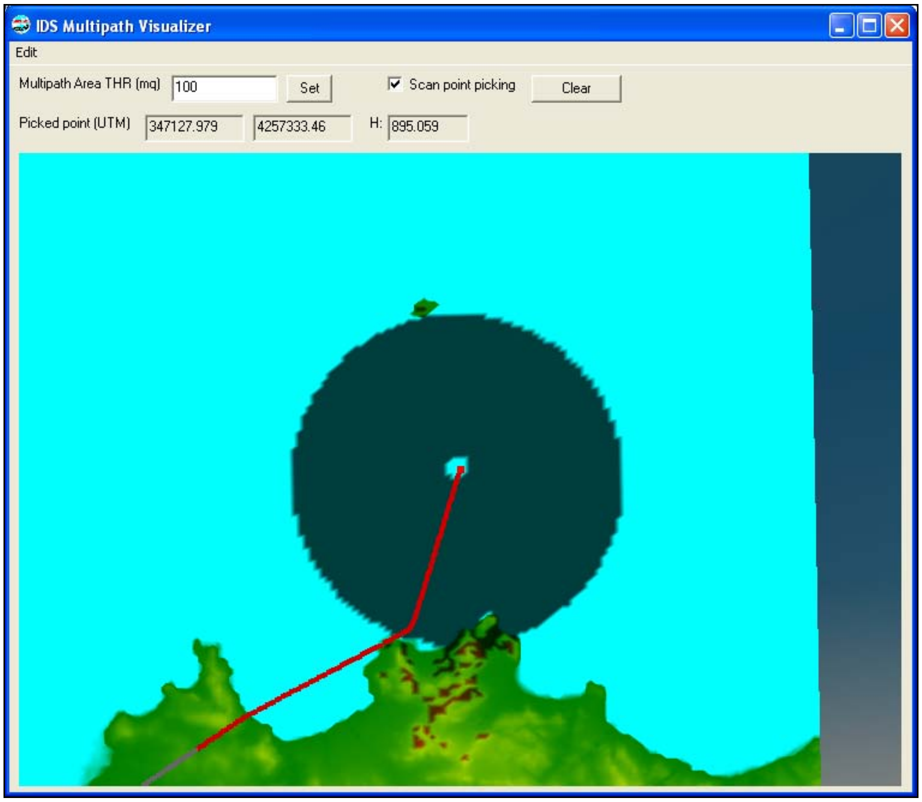

Figure 10 – Sample of multipath area computation

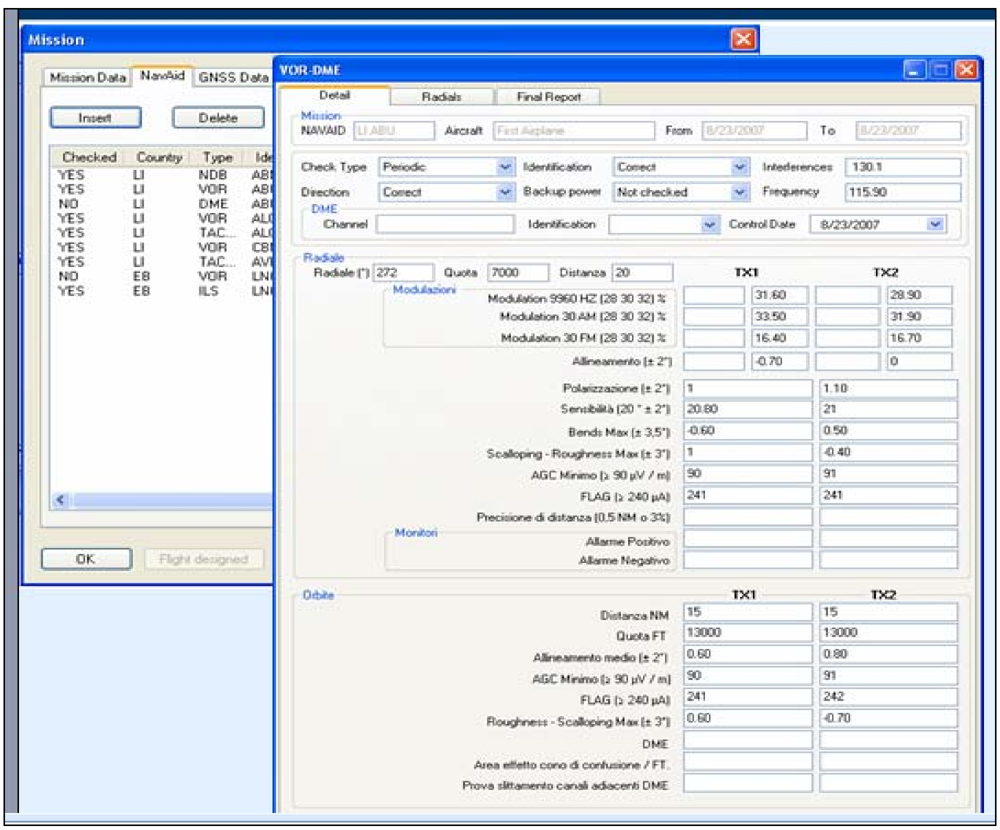

Figure 11 - FLIPP user interface snapshots

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Alessandro Nobiletti was graduated in electronic engineering (telecommunications) from the Pisa University, and joined IDS in 1992. Since that period he worked as system analyst and EMC specialist in the field of antenna siting on board of naval ships.
Since its establishment, Alessandro joined the IDS Aeronavigation Division acting as project leader in the field of C/N/S systems siting analysis using numerical analysis techniques.
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