NAVAID FLIGHT INSPECTION OPTIMIZATION WITH UAS TECHNOLOGY

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Abstract

Current society requires to the aerial transport system (since decades ago) the capability to fly, in a safe manner, with unfavorable visibility conditions (night flies, with fog, among the clouds). This requirement makes the use of Radio Navigation Aids critical for the Aerial Transport System.

Those NavAids could be seen as radio-frequency emitters which emission structure and geographic location allows the users (the flying aircrafts) to compute its position and course in an homogeneous way.

Since the functional objective of a NavAid is to provide a radio-frequency emission with a known structure (spectrum, timing, power...) in order to identify this emission with the known site position, it shall be demonstrated that this emission corresponds with the standard. For this demonstration, a set of parameters shall be measured from the point of view of the final user. I.e: they shall be measured from the air, which is the place where they are used.

The current use of general purpose aircrafts for flight inspection of NavAids provides the authorities with the magnitudes to be inspected measured in the same place that they are used but it has a big inconvenience: its price.

This proposal has as its masterpiece the study of the technological and regulatory constraints of NavAids flight inspection using the UAS technology. This use allows the separation of the flight inspection in two segments:

I. Air Segment. Essential elements in the air, antennas, sensors, data storage...

II. Ground Segment. All those elements not strictly necessary for the ongoing inspection, spare parts, capability to carry personnel and ground equipment...

Thanks to this, several benefits are obtained:

With the proper use of telecommunications the inspection, platform could be seen (from a mission viewpoint) as a network of computers interacting in a common mission.

The Air Segment could be resized, replacing the existing aircrafts (large, expensive of acquire and to maintain) by UAS adjusted to the needs in Flight Inspection: to carry sensors in the area to observe. This would bring flights the inherent characteristics of these devices: lower cost of the platform, lower operating costs, increased availability...

Several aerial vehicles could be used simultaneously, reporting to a single Ground Segment station. By this provision, different areas could be simultaneously inspected reducing the number of coordinated actions with air navigation and decreasing the time of the inspection Flight.

Summarizing: lower costs per flight test.

State of the Art

The report of the Volpe National Transportation Systems Center [Volpe01] shows up the vulnerability of the GPS, and proposes some risk mitigation strategies for the different GPS Users. Due to the Safety of Life use of GPS in Civil Aviation the main recommendation is clear: to keep current infrastructure (particularly VOR/DME and ILS) for its use as secondary means in case of GPS signal degradation.

As presented in [EURO08], the inherent vulnerability of GPS/GLONASS/GALILEO is translated into maintaining some ground based navigation infrastructure for being use for backup navigation in case of GNSS signal degradation. This premise projects the need for flight inspection from the present to the future with the addition of being keeping as secondary means, justifying the search for efficient flight inspection systems

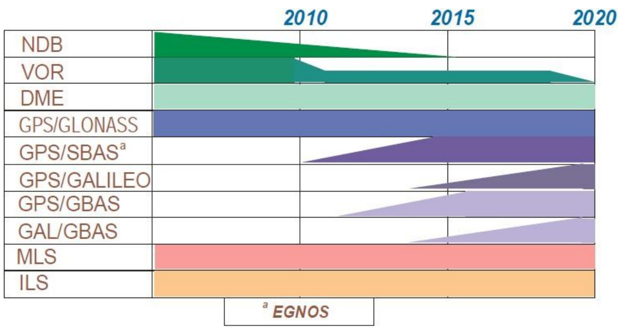

Figure 1: Navigation Infrastructure Roadmap

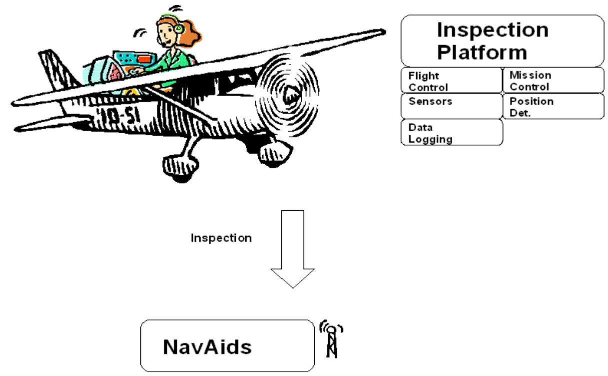

Figure 2: Current FI architecture

Figure 1 shows how VOR decommissioning is not envisaged as least until 2020. MLS and ILS decommissioning is not envisaged and for DME is even envisaged the deployment of more stations to ensure availability abroad European territory.

This remaining ground based infrastructure is, basically, a set of emitters whose standard emission and known position allows users to calculate their positions. To demonstrate that these NavAids are compliant with their standard behavior, some monitoring procedures have been developed.

ICAO reflects some actual practices of its member states in its "Manual on testing of Radio Navigation Aids" [ICAO00]. These recommendations includes periodicity, operations, parameters, aircrafts and systems.

Among the aircraft recommendations, it is specially constraining the suggestion of selecting aircrafts big enough to transport equipments and personnel. This recommendation (which is clearly different than a requirement) leads us to the current contradiction of using large-capacity aircrafts, when a flight inspection consist in carrying a few sensors to a spatial location in order to measure some electromagnetic magnitudes e.g: Beechcraft Super King Air.

Figure 2 shows the distribution of components in the current architecture, basically all the equipment (sensors, data processing, visualization...) is shipped onboard and the works for flight inspection are conducted onboard (flight inspection)

The high cost of Flight Inspection activities and the future consideration of ground based navaids as secondary means, motivates a trend to reduce cost in the flight inspection community:

In [Seide04], Seide proposes a system for flight Inspection remotely controlled from ground in order to optimise the calibration of already working NavAids.

In [Qvist06], Qvist proposes the remote calibration (or Flight Inspection) of South African NavAids as an operational procedure for 2007.

In [Wede06], Wede makes a prospective exercise identifying different trends in Flight Inspection, particularly the location of flight inspectors outside of the Calibration aircraft, thanks to Datalink technology.

In its prospective exercise [Wede06], Wede makes reference to the use of UAVs for Flight Inspection rejecting its commercial use because of the lack of certification standards and the high cost of existing military UAVs.

For the lack of certification basis, there is an ongoing activity worldwide to identify conflictive aspects of UAVs in order to regulate them. Eurocontrol shows in [EURO08] its planning for UAS ATM integration study. EASA published its ANP [EASA05] in 2005 based on the JAA/Eurocontrol initative on UAVs [JJE04].

According to the proposals of the UAVNET in its road map "European Civil Unmanned Air Vehicle Road map" [UAVNET05], Europe must establish strategic lines for the long-term and constitute a center of excellence that includes the coordination of actors devoted to research on civilians UAVs. The strategy has been named STAR21 and contemplates the deployment of UAVs during the period from 2010 to 2015.

The high cost of UAV explained in [Wede06] taking as a reference the Northrop Grumman Global Hawk which costs 75 million $ per copy is clearly controversial as it has been taken as example a high tech Research & Development program developed under military requirements.

ICARUS group previous works intends to provide a UAV technology that allows a dynamic and flexible management of the payload shipped. This flexibility and dynamism are obtained thanks to protocols of platform abstraction [ICARUS1] and mission definition [ICARUS2].

The mission definition protocol defined by ICARUS [ICARUS2] intends to improve the navigation capabilities of the UAV platform based on leading it beyond the current point to point and segments navigation that allows the aRea NAVigation (RNAV) standard [RNAV].

The UAV Abstraction Layer proposed by ICARUS [ICARUS1] intends to provide better communication management allowing management of communications at high level with an abstraction of the hardware. This UAL allows also gradual improvements on the communication capabilities (increasing bandwidth, implementing encryption, modifying physical means...) independently of the management of the payload.

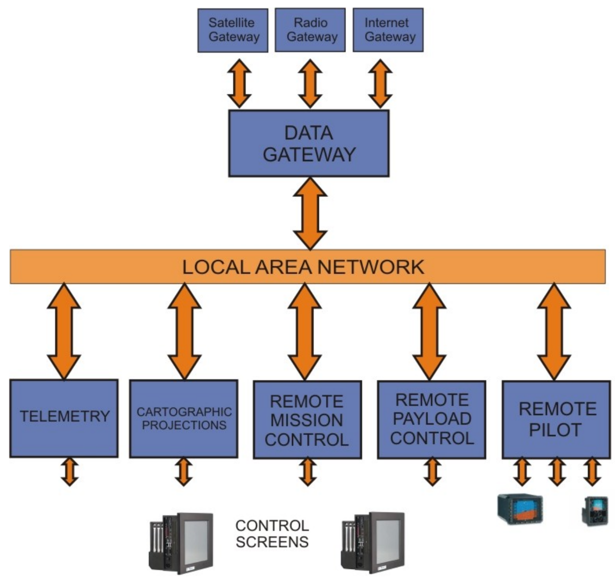

Figure 3: ICARUS avionics Architecture

Figure 3 shows the avionics architecture based on services proposed by ICARUS group in previous works. This proposal makes indifferent (from a logical point of view) the location of the services/functions.

Current Flight Inspection activities are fare away from being an isolated experiment. These activities are conducted without disturbing the aerial traffic.

From the point of view of an UAS, this scenario could be seen as an assortment of flying units, some of them collaboratives, some other not so collaboratives. From the point of view of the rest of airspace users, an UAS is seen as a potential menace. Another menace for the rest of users is the lack of services of flight inspection for unscheduled maintenance of radio navigation aids.

With this perspective, operations could not be planned statically, requiring more agile systems [Alberts12]. System agility depends on the system capacities to be considered:

- Robust
- Resilient
- Responsive
- Flexible
- Innovative
- Adaptive

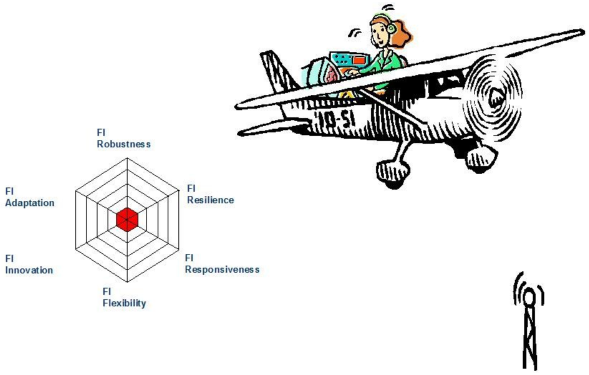

Figure 4: Current Architecture agility

Figure 4 shows in a qualitative manner the agility of current FI architecture. This agility is presented as reference for introducing the advantages of ICARUS FI architecture.

Objectives

This proposal has as its masterpiece the study of the technological and regulatory constraints of radionavigation flight inspection using the UAS technology. This use allows the separation of the flight inspection in two segments:

I. Air Segment. Includes the elements essentials in the air, particularly antennas, elements of measurement, collection /storage of data.

II. Ground Segment. Includes all those not strictly necessary for the ongoing inspection, electronic spare parts, as well as the capability to carry comfortably personnel and ground equipment.

Such separation could now be translated into proper use of telecommunications capabilities available to us so that the platform could be seen from the viewpoint of the mission, as a network of computers interacting in a common mission.

Figure 5 shows the ICARUS proposal for flight inspection architecture. Comparing with figure 2 could be appreciate the split of the Flight Inspection platform in the two segments mentioned before.

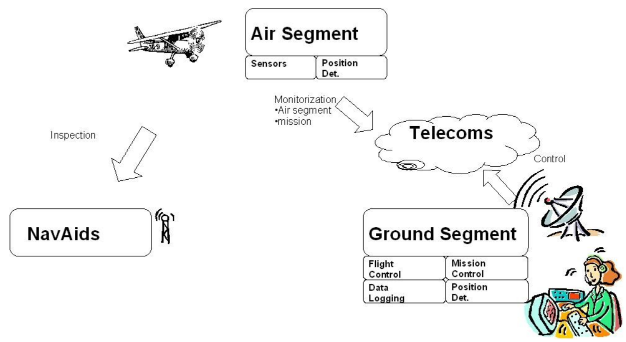

Figure 5: ICARUS FI proposal

Thanks to the separation into two segments, the Air Segment could be resized, replacing the existing aircrafts (large, expensive of acquire and to maintain) by UAS adjusted to the real needs in Flight Inspection: to carry sensors in the area to observe. This would bring flights the inherent characteristics of these devices: lower cost of the platform, lower operating costs, increased availability, etc.. Benefits that would revert in an air transport system more affordable (lower costs per flight test).

The different technical objectives identified in this proposal are:

- To design an UAS payload able to inspect Radio Navigation Aids both day and night.
- To design a mechanism for transmitting this information to a base station (from Air segment to Ground Segment) in real time or near real time without lost of information in case of communications link lost.
- To develop systems that use precise positioning systems complementary to those that are inspected.
- To design a mission planning system that allows its efficient use and exploitation by non-specialist.
- Integration of all the systems in a Flight inspection system.

First approach for accomplish these requirements will be the viability evaluation including a simulation of the concept.

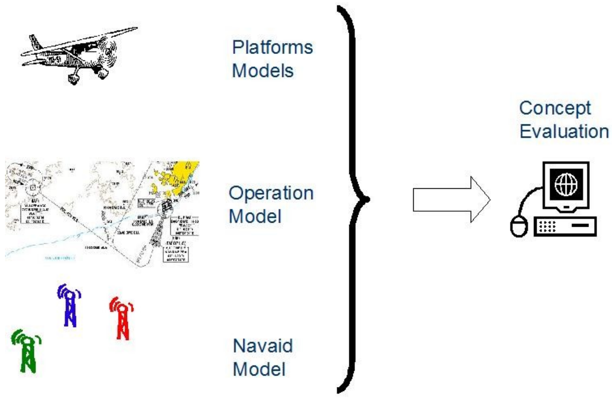

Figure 6: Viability Evaluation

Figure 6 shows the modelization envisaged for the viability assessment. Safety assessment and regulation survey has been omitted from the picture for simplicity purposes, keeping the technical and operational aspects as part of the simulation.

An additional optimization resulting from the separation into two segments of the platform inspection, is the simultaneous use of several aerial vehicles reporting to the same Ground Segment station.

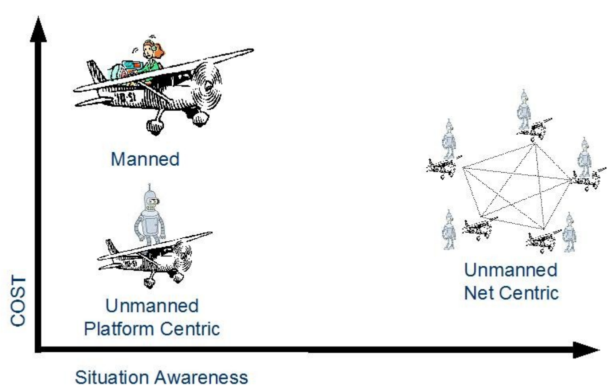

Figure 7: Platform architecture tradeoff

As seen in figure 7, the change of platform is translated into lower costs (both acquisition and operational) for similar levels of situation awareness. This cost contention could be used to add more units of Air segment integrating a sensor network or adding redundancy to the Flight inspection system.

By this provision different areas could be simultaneously inspected, reducing the number of coordinated actions with air navigation and decreasing the time that an area is disabled by being inspected. E.g. different runway headers in a single airport inspection.

This simultaneous use of different vehicles in the air segment modifies also the agility of the Flight Inspection service. This concept used in Command and Control [Alberts 12] summarizes the benefit of ICARUS proposal beyond the cost containment.

The agility enhancement is better understand when analyzing the effect on its components:

Robustness: The ability to maintain effective FI across a range of tasks, situations, and conditions. Robustness could be improved through use of specialized platforms.

Resilience: The ability to recover from or adjust to loss of FI capability due to misfortune, damage, or a destabilizing perturbation in the environment. Resilience could be improved through redundancy in the net of UAV.

Responsiveness: The ability to react to a change in the environment in a timely manner. Redundancy could improve Responsiveness with appropriate logistics.

Flexibility: The ability to employ multiple ways to succeed and the capacity to move seamlessly between them. The split in two segments allows to change the air segment keeping in a transparent manner for the flight inspectors of the ground segment.

Innovation: The ability to do new things and the ability to do old things in new ways. Icarus proposal is itself innovative. Additionally, the network perspective allows the change of nodes for new ones, keeping the network structure.

Adaptation: The ability to change work processes, composition of a structure and/or relationships between and among constituent entities. Distributed perspective of ICARUS proposal (for flight inspection and for avionics architecture) enhances the adaptation in different levels compartmenting the functionality (for avionics and for flight inspection platform).

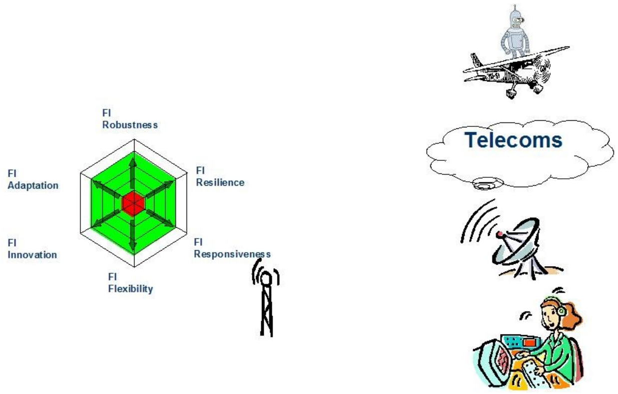

Figure 8: ICARUS FI architecture agility

Figure 8 shows, in a qualitative manner, the envisaged improvement in agility thanks to the change of platform architecture.

Last but not least, with this proposals we intend to provide a project that benefits different actors involved in the achievement of a peaceful integration of UAVs in airspace:

- Aeronautic industry
- Research center (University).
- Navigation Services Providers
- Airports owners

The principal benefit for Aeronautic industry comes from the future capability of reducing costs in flight inspection allowing lower taxes.

For the Navigation Services providers and for the airport owners the benefit of a cheaper mean for flight inspection is obvious. This benefit becomes a synergism as implies all the actors in the same objective: integration of UAVs in airspace. This synergism is extensive to different points of view (telecoms, ATC, logistics, operational safety...)

Conclusions

Replacement of current flight inspection platforms by UAVs should improve the flight inspection in different ways:

Cost reduction. Thanks to lower costs of acquisition of smaller aircrafts, to its operations and also thanks to a better employment of Human resources.

Agility improvement. Improvement of prices allows to employ different strategies. e.g: apply redundancies, geographical distribution of air segments, fast replacement of damaged air units, fast acquisition of new units for new needs...etc

Figure 9 shows the envisaged enhancement (from a qualitatively point of view) thanks to the change of platform architecture. The more evident is the cost reduction (due to the smaller aircrafts acquisition, its operation , efficient use of human resources ...). The agility improvement allows the system to affront changing environments .

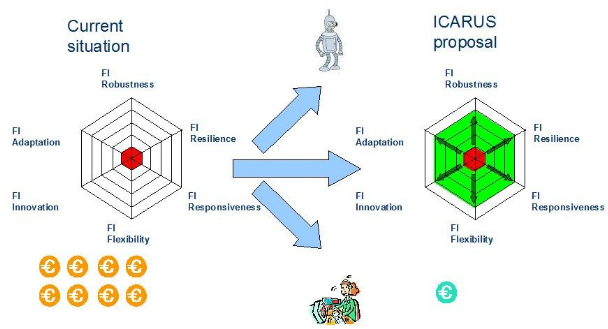

Figure 9: Flight Inspection Agility Enhancement

Another benefit of ICARUS proposal is the synergism that could be obtained from the different actors (ANSP, Industry, research centers) having the common objective of using an UAV for in flight Inspection purposes.

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Disclaimer

Work partially supported by:

Spanish Ministry of Education grant: TIN2007-63927.

Spanish Ministry of Industry grant: SAE-20081098