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Evolution of the night flight inspection concept: technology and operational procedures

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ABSTRACT

The integrated use of vision enhancement systems and synthetic environment presentation may lead to widespread night flight inspection operations. This will greatly alleviate "interference" with commercial operations during daytime at busy airport and airspaces. The technology is mature enough to start thinking seriously about standard operating procedure for night flight inspection operations. Technical and procedural issues, at the operational level, are considered and discussed in order to take full advantage from the use of enhanced and synthetic vision systems.

INTRODUCTION

The possibilities offered by this kind of technology are already well know by operators and the advantages in terms of approaches completed to a safe landing are clear, but the real plus of EVS and SVS in the Flight Inspection field of operations is the improved Situational Awareness during night flight, allowing for efficient and safe flight during the less congested nighttime. As discussed in another paper[1] the difference between commercial operations and flight inspection operations account for the conceptual difference among the use of the vision enhancement technology. In fact the purpose of the enhancement is not weather related but situational awareness related, for there is no need to perform flight inspection in marginal weather, but the enhancement is necessary to obtain the required level of situational awareness with respect of aircraft position and surrounding obstacles in good weather at night.
In the military world IR sensor have been used successfully since the sixties, but only recently this technology has been made available on the civil market (millimeter wave radar is at present under development).

Brief technical description: IR sensor, MMWR and SVS

At the basis of IR sensing lies the proportional relation between the temperature of an object and its emitted thermal energy, a quantity we can measure with a IR detector and present on a screen after proper processing. The IR spectrum may be further subdivided for the purpose of observing specific phenomena and sensors may use cooled or un-cooled technology, but the details, even if interesting, are not relevant with the purpose of this document.
The MMWR is a millimeter radar able to obtain a better penetration of certain weather phenomena, such as heavy rain or blowing sand, because water droplets/sand particles are smaller in diameter than the wavelength, allowing the system to "see through". At present the main limitation is the limited resolution of the processed image, but technology is improving fast and integration with IR imaging is able to provide an ideal solution in almost any condition. The main disadvantages are related to antenna dimension that at present is too big to fit in light or medium jets.
Synthetic Vision Systems uses a different approach to the same problem. With precise positioning obtained from the navigation sensors and an obstacle/terrain representation (coming from a database) presented to the crew, the SVS offers the possibility to maintain an high degree of situational awareness. Improvements in 3D graphic and the implementation of high resolution displays in the cockpit account for the technology we need to integrate all the available resources to obtain the level of situational awareness required to operate at night, in good weather[2] and perform the complex flight profiles required by the flight inspection of a specific navaid.

Why vision enhancement?

First of all it is important to define the term "vision enhancement system" as intended in this document: "an integrated system used to provide increased situational awareness to the flight crew during night (or day) flight inspection activities which uses a combination of sensors including, but not limited to, IR sensors, MMWR and SVS, together with specific standard operating procedure".
The reason for using a vision enhancement system is crystal clear: in today's congested airspace flight inspection cannot provide another element of "flow disturbance", so most of the flight inspection work will probably be done at night, at least when the navaid is located at or near a busy airport. This will require development of a new set of operational requirements and new procedures for the flight inspection crew. The operational requirements will call for a properly equipped aircraft and, among other things, for an aircraft with low noise signature (very often airports are surrounded by noise sensitive areas densely populated, at least in Europe). Training and operational procedure will be revised accordingly as specified in the following paragraphs.
As a by-product (a very important and strategic one) the flight inspection service provider may expect an increase in overall efficiency, a reduction in flight time for a given check and, in general, more productive operation[3]. Technology implementation costs will be quickly absorbed.

Aircraft configuration

The first step towards the night flight inspection operation is to properly configure the aircraft avionics. It is not interest of the authors to suggest any type of aircraft but consideration should be given to the fact that the best suited aircraft seems to be a mid-size turbofan powered aircraft which combines internal capacity, endurance and low noise. Furthermore if operated at lower weight flexible thrust may be used during low passes and consequent go around, minimizing acoustic impact.
Avionics configuration should include IR sensor(s), HUD and SVS and EFB. Given the cost of HUD only one unit should be installed in the captain position[4]. MMWR is not recommended unless bad weather penetration is a requirement for purposes other than flight inspection.
Data fusion between IR and flight data (and eventually MMWR) should be presented on the HUD and repeated on pilot request on the PNF PFD or MFD. On the PFD/MFD integration of real time IR/MMWR imaging and 3D SVS graphic terrain/obstacles will provide the PNF with the "big picture" situational awareness, while the PF will concentrate on flying the profile. Electronic Flight Bag will avoid head down time looking for paper charts (approach and departure plates and airways will be presented on the navigation display). An important feature not to be underestimated is the what we called the "flight inspection profile generator", meaning that all flight profiles required must be presented as guidance command on the HUD[5]. Autopilot coupling is a requirement as well, thus permitting precise tracking of the profile and lowering at the same time pilot workload.

Standard Operating Procedures (SOPs)

Company procedures must endorse night operations and provide appropriate guidance to the crews, which are composed by pilots and system engineers (depending on company policies both may be Navaids Flight Inspector). Procedure must be set on the following areas:
1. Ground (before the flight)
• Flight crew and ground staff (including ATC) briefing and flight planning
• System compatible failures (a specific MEL for night flight inspection operation)
• Cockpit preparation and HUD/EFIS layout
• SVS database and positioning system check (inertial, GNSS, etc.)
• Meteorological conditions
2. Airborne
• PF, PNF and SO roles and responsibilities
• Standard callouts

• Normal procedures
• Contingency procedures
• Emergency procedures
3. Ground (after the flight)
• Data collection, recording and storage
• Critical results communication

Some of the points are self-explanatory, others need few words to be spent. Two aspects needs more in depth analysis: "PF and PNF roles and responsibilities" and "Critical results communication". Normally the roles and the responsibilities of the crew members are well established during standard operation. What is peculiar about flight inspection is that almost all the profiles flown are non-standard and sometimes outside the obstacles protection envelope provided by definition when following published procedures. This requires an increased level of crew alertness during the day and it is easy to understand that even a greater level of alertness will be required at night, should the technology of vision enhancement not be used. The PF will be tasked with the handling of the aircraft and will track the profile taking advantage of the HUD presentation and autopilot coupling, while the PNF will help maintaining the "big picture" situational awareness, general spatial position consciousness and ATC communication, giving support to the PF as needed. The SO will provide essential data exchange, and navaid adjustments request, where required, to ground staff (applicable with real time automatic flight inspection systems).

The communication of critical results is taken into account because sometimes appropriate offices and/or officers may not be available at night. In case of findings requiring an immediate action (suspending/reopening procedures, deactivating/reactivating critical navaids, etc.) a procedure shall be established to allow proper flow of information to the interested parties (NOTAMs, etc.).

Training

To obtain the expected results training is of paramount importance, and not only related to the flight deck crew, but to the organization as a whole entity. To maximize the operational benefits everybody should be trained to highest standards: pilots should undergo specific training every 6 months (included in the standard simulator training) and should maintain currency and proficiency according to company rules complementing the existing mandatory requirements from the various CAAs. SOs should also undergo recurrent training to maintain an adequate level of theoretical knowledge to complement the skill acquired during field operations.

Flight Inspection Service Provider organization

Organizing crew rostering, aircraft availability, maintenance, flight planning support and coordination may be challenging. 24 hours a day operations may otherwise solve many operational problems. It is not the purpose of this document to provide an in-depth evaluation of this specific problem, but there are many examples that can be used to set up an efficient organization.

Human factor considerations

There are two major points of interest when assessing human factors relevant to this type of operations: technology integration and fatigue. Assuming a good level of confidence in the technology employed and proper crew training one of the most crucial aspect is the possibility of complacency. This is a "classic" in advanced technology cockpits where everything seems under control and the feeling of reliability and safety given by the system reduces the level of attention of the crew members and their situational awareness. CRM training and strict adherence to SOPs will alleviate the problem.

Fatigue is another important factor and must be considered carefully. In the aviation community there is an increased attention on the subject that has been recognized as a factor or contributing factor in many incident and accident. To mitigate the impact of fatigue as a factor of risk shorter shifts should be assigned to crew operating at night and if possible a bidding system should be established to assign night shifts on a voluntary basis[6]. Rest periods should be properly calibrated. This is just an overview of a more vast argument, but these are not problems specifically related to the flight inspection activity. In some cases in fact the continuous exposure to particular conditions (low level flight, for example) may prove to be a valuable asset in critical moments because reactions to threats come automatically and instinctively.

Risk assessment and mitigation

Apart from human factors, already discussed, even if briefly, there are some "what if" that must be evaluated. An Hazard and Operability study, along with a Human Factor case should be done with a group of experts to look at the possible issues. There are few families of risk that must be taken into account to proceed with the evaluation. Technical issues, human factor issues, environmental issues, all must be considered. In general terms technical issues have technical and/or procedural mitigation such as systems redundancy and proper application of abnormal or emergency procedures, while human factor issues may be mitigated through training and CRM/TRM and in some instances by company policies. Environmental issue must be divided in two parts, the first one operational and linked to weather and the second one more focused on pollution and noise. Weather is dealt with rules and procedures, but noise and pollution are a direct consequence of the type of aircraft used. As reported in a previous paragraph turbofan equipped aircraft are probably better suited for the job.

Pilot report

To assess the real possibilities of EVS (IR cooled and un-cooled sensors) a flight test has been arranged. The flight took place at night, departing from Nashua, N.H., USA, just after sunset. Weather condition at the moment of start up were 10 miles visibility and a high overcast, with winds from the West at 15 knots. Moon conditions: almost new moon (according to the U.S. Naval Observatory only 7% of the moon was illuminated, but moonset at 16:05 Easter Standard Time, combined with the overcast, gave us no moonlight and good test conditions). Start up procedures were standard. EVS set up was straightforward: switch it on and wait about 4 minutes for the sensor to reach the appropriate temperature (this procedure may require up to 10 minutes). The aircraft has also an un-cooled IR sensor that is promptly available upon start-up (this is a light weight, low cost sensor aimed at the general aviation market, but performance are limited). During taxi with the EVS switched on apron and taxiway layout, lighting and markings were clearly visible. Obstacles such as service trucks, cars, light poles and even men were easy to spot. After the usual before take off checks we were ready for departure. Centerline tracking on take off was easy even with no centerline runway lights. Once airborne we set course to a nearby airport (Keene) for an ILS approach, followed by a low pass at 50 ft. All obstacles were clearly visible and the streets pattern, small lakes and trees were perfectly identifiable even if the area of the approach was in complete darkness. After the go-around we set the heading inbound a mountain that has no lighted areas. The natural obstacle was perfectly visible on the EVS, but impossible to see to the naked eye. After another approach to a different airport (Manchester International) and a final low pass at our departure airport we landed and taxied out using EVS to track down the taxiway centerline. After few minutes of use the pilot has the impression that EVS is a natural extension of his own senses and a "must-have" in the cockpit. HUD with EVS overlay is a winning combination, but there are few limitations. Strong crosswind may require a drift correction exceeding the field of view of the system (about 15° each side of the longitudinal axis of the aircraft). Furthermore certain obscurants are difficult or impossible to penetrate with IR sensor (heavy rain, for instance), nevertheless the EVS offers a degree of situational awareness simply impossible otherwise.

Given the set of rules that we laid down for this kind of operations (VMC, light crosswind, no significant weather phenomena) the limitation listed above will be hardly a concern for the flight inspection crew of the future. The system tested represent the state of the art of the IR technology, but the HUD that we had on board was an experimental unit aimed at the general aviation market: distinctively better results can be obtained when combining state of the art IR sensors with high end HUDs

CONCLUSIONS

It is clear to the skilled observer that in today's air transport system any delay imposed to the airlines in not acceptable nor tolerable. Even the temporary and sometime very limited disturbance given by the flight inspection aircraft is day after day less justifiable. Night flight inspection operations on a regular basis seems to offer a good solution[7], but some requirements must be satisfied in order to proceed in this direction. To maintain a sufficient degree of situational awareness certain technologies must be implemented to enhance the natural vision and spatial position consciousness of the pilot. Training and new SOPs must be provided. Change of habit in crew shifts may prove difficult for some organizations: good industrial relations will help to solve the problem, together with appropriate rostering techniques. Relevant advantages are expected for the flight inspection service provider in terms of efficiency and overall profitability (technology implementation costs must be compared with the effective needs to assess overall efficiency increase and potential revenues increase). The technology used is proven and reliable and should not constitute a risk, but at the moment only the FAA has issued a formal certification for EVS systems (EASA will follow with its own set of rules, that will be harmonized with the FAA, shortly). This kind of implementation is strongly recommended for the service providers that are in the process of renewing their fleet: EVS and the possibility to operate at night may provide an edge over competitors in the future. The concept has been demonstrated during a dedicated flight test.

Fig. 1. HUD and MFD

LIST OF ACRONYMS AND ABBREVIATIONS

ATC	Air Traffic Control
CAA	Civil Aviation Authority
CRM	Crew Resource Management
EFB	Electronic Flight Bag
EFIS	Electronic Flight Instrument System
GNSS	Global Navigation Satellite System
HUD	Head Up Display
IR	Infrared
MEL	Minimum Equipment List
MFD	Multifunction Display
MMWR	Millimeter Wave Radar
Navaid	Electromagnetic Navigation Aid
NOTAM	Notice To Airmen
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
SO	Flight Inspection System Operator
SOP	Standard Operating Procedure
SVS	Synthetic Vision System
TRM	Team Resource Management
VMC	Visual Meteorological Conditions

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REFERENCES

1. F. Maracich, E. M. Feliziani: "Enhanced Vision System (EVS) and Synthetic Vision System (SVS) for Night Flight Inspection Operations: a Possible Solution", 13th IFIS - Montreal, 2004.
2. Night VMC as applicable must prevail during the entire flight, as a mitigation factor for both technical failures and crew workload.
3. An increase in personnel cost may be expected, easily offset by the increased efficiency and overall profitability.
4. To avoid an increase in pilot workload a company policy should be provided to allow the PF to be seated on the left seat. This will allow both pilots to maintain proficiency on the system. If the company follows more stringent rules about flight crew member position on the flight deck and if night operations are supposed to became prevalent a two HUD units installation is recommended.
5. The HUD symbology shall reflect this option activated by the crew with a distinctive mark, such as a "flight inspection flag" that will disappear when normal navigation is selected and reappear every time "flight inspection navigation" is again required. This is important to avoid selection of improper profile during normal flight.
6. This system is in use with major airlines and works with a very good level of satisfaction. Not all the organizations will be able to apply this kind of approach, due to number of available personnel and other considerations. Where applicable this system may provide good industrial relation and an high level of internal harmony.
7. It is quite evident that a traffic distribution assessment must be made before starting night operations at any given location. For instance there is no purpose in doing night operations at a busy cargo hub where traffic peaks are distributed over the nighttime. In such cases is better to operate during the day using other delay mitigation techniques, i.e. operational coordination (E. M. Feliziani, F. Maracich: "Advantages in employing an operational coordinator during flight inspection activities", 12th IFIS - Rome 2002, and E. M. Feliziani, F. Maracich: "Flight Inspection in Busy Terminal Area: How to make it more cost-effective?", 14th IFIS - Toulouse 2006).