Paper 127

The Impact of Civil Tilt Rotor Aircraft on the Air Traffic Management Environment - A Virtual Engineering Assessment

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Abstract

Modelling and Handling Qualities of the Future European Civil Tilt Rotor ERICA are now well advanced under the 5^{th} and 6^{th} framework European Commission funded projects, ACT-TILT and NICETRIP. This has allowed a first assessment of the impact of the introduction of the civil tilt rotor ERICA, into the existing Air Traffic Management environment; this concept of operations assessment is the study of this paper, where real-time Air Traffic Control and fixed-wing traffic simulations based at SICTA (Naples) were coupled with real-time piloted tilt rotor simulations of ERICA at NLR (Amsterdam), Eurocopter France (Marignane) and the University of Liverpool.

The tilt rotor approach scenarios were made to a Milan Malpensa airport simulation environment which has two parallel runways. During the networked-simulation exercise, fixed-wing traffic operated to and from only one runway (runway 35L), while the tilt rotors made Simultaneous Non-Interfering (SNI) approaches, parallel to the fixed-wing operations, either to a Point-in-Space (PinS approach) or to a designated Final Approach and Take off area (FATO approach), as well as departures. The procedures were developed using advanced Navigation systems such as GBAS and SBAS, which were designed with proper Required Navigational Performance.

To accomplish the trial objectives, it was vital that the air traffic controllers could see all aircraft on scope and communicate in real-time with the ERICA crew flying the ERICA aircraft simulations. This involved many technical challenges, where aircraft geocentric position and orientation data had to be sent from each player to a central hub at NLR using DIS (Distributed Interactive Simulation). The data were then relayed back to all participants allowing all air traffic in the scenario to be visualised in each simulation (up to 40 individual aircraft). The voice-over-internet-protocol (VOIP) communication software was developed by SICTA and allowed communication with tower, ground and delivery controllers.

Substantial information and data were gathered and analysed through video, pilot and controller questionnaires and time history recordings during a successful simulation trial week.

Nomenclature

ARTS	Aerodrome Real Time Simulator	IFR	Instrument Flight Rules
AGL	Above Ground Level	ILS	Instrument Landing System
ADF	Automatic Direction Finder	LPV	Localizer Precision with Vertical guidance
	Air Traffic Controller	MAHF	Missed Approach Holding Fix
ATCo	Air Traffic Management	MDA	Minimum Descent Altitude
ATM	ConTRol Zone	MSL	Mean Sea Level
CTR	Data Interface System	NICETRIP	Novel Innovative Competitive Effective Tilt Rotor Integrated Project
DIS	Descent Point	PinS	Point-in-Space
DP	Enhanced Rotorcraft Innovative Concept Achievement	R/T	Radio Telephony
ERICA	final Approach Fix	RFMS	Research Flight Management System
FAF	Final Approach and Take-Off area	RTS	Real-Time Simulator
FATO	Flight Management System	SBAS	Space-Based Augmentation system
FMS	Ground-Based Augmentation System	SNI	Simultaneous Non-Interfering
GBAS	Helicopter Pilot Station	SPHERE	Simulation Pilotée Hélicoptère pour l'Etude et la REcherche
HPS	International Civil Aviation Organisation	TP	Turning Point

Introduction

A key target of SESAR (Single European Sky ATM Research) is that the future ATM system must safely and efficiently accommodate tilt rotor demand and assist all airspace users for the whole flight, from pre-departure operations to arrival at the stand.

Modelling and Handling Qualities of the Future European Civil Tilt Rotor ERICA are now well advanced under the 5th and 6th framework European Commission funded projects, ACT-TILT and NICETRIP. This has allowed a first assessment of the impact of the introduction of the civil tilt rotor ERICA, into the existing Air Traffic Management environment utilising 3 helicopter real-time simulators, located at Eurocopter, Marignane (France), the University of Liverpool (Great Britain) and at the National Aerospace Laboratory NLR at Amsterdam (The Netherlands), as well as one real-time ATC simulator at Sicta in Naples.

The tilt-rotor used in the simulations is the ERICA model illustrated in Figure 1, developed in the European tilt-rotor projects ACT-TILT and currently NICETRIP.

Figure 1 ERICA tilt rotor

It is characterised by rotating nacelles at the wing tips, with half the outer-wing sections also being able to rotate independently to reduce downwash on the wing in hover and low speed. The 10 tonne aircraft has been designed to have a cruise speed of 250Kt at 7,500m (25,000ft) and is powered by a 'beefed-up' version of the PW 127 (20% increased power output). The two engines drive 2 cross-shafted 4-bladed rotors with a diameter of 7.4m (Ref. 1).

Approach procedures

The assessment was performed to a virtual Milan Malpensa airport, which has two parallel runways (Ref. 2). There are a number of operational restrictions at this airfield, due to the presence of a military airport and existing Cameri CTR operations. Therefore, to accommodate the operation of tilt-rotors at the airport the procedures are designed such that they do not interfere with existing air traffic and are called Simultaneous Non-Interfering Operations (SNIOps).

Two new tilt rotor steep approach procedures were designed for tilt rotor operations at Malpensa airport, with steep glide slopes (9° and 6.48°) on the final segment to test the suitability and capability of such procedures. The first is an approach to a dedicated Final Approach and Take-Off area (FATO) which is illustrated in Figure 2, while the second is a Point-In-Space (PinS) approach, where the visual segment is also displayed in Figure 2, (Ref. 3).

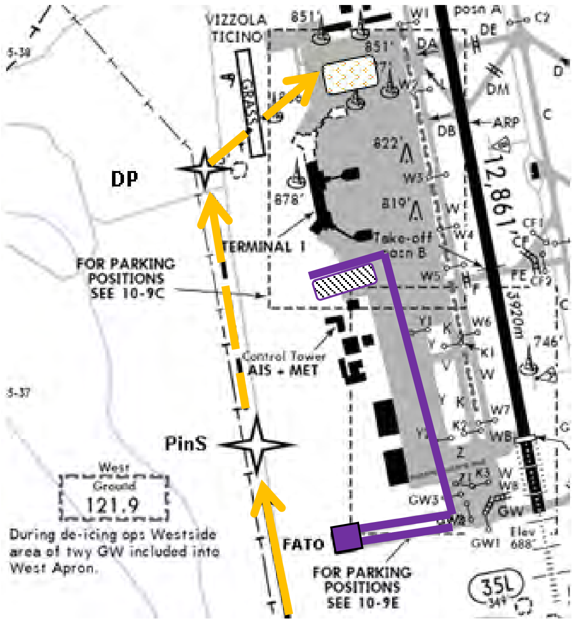

Figure 2 Visual segment of PinS procedure and FATO relative to the runways at Malpensa (plate modified from Ref. 2)

FATO approach

The Final Approach and Take-Off area (FATO) was placed to the west of the threshold of runway 35L, illustrated in Figure 2. The central landing area of the 100*x*100m FATO was marked by a single letter 'H'. When the tilt rotor landed, it had to taxi to the designated parking bay near the control tower, (see the purple-lined -area in Figure 2 via one of the two taxiways (one for departure and the other for arrivals) which connect the FATO with taxiways K and Y on the main apron.

Figure 3 and Figure 4 illustrate plan and profile views of the FATO procedure. The approach procedure is of the class LPV (Localiser Precision with Vertical guidance) with SBAS (Space-Based Augmentation System) to augment the GPS navigational accuracy in order to achieve near Cat 1 accuracy. The decision altitude is 200 ft AGL. The missed approach is a straight continuation to a turning point, from where a left turn is made towards the Romagnano (RMG) locator.

The final approach glideslope to the FATO was selected to be 9º as illustrated in Figure 4. This steep approach provides a small noise footprint and good obstacle avoidance capability. However, considering the combination of the steep glideslope and a maximum descent rate of 800 ft/min, the maximum airspeed during the final descent on the glideslope is limited to 50 knots. This is about 20 knots below the minimum-power speed of Erica in helicopter mode, making speed control difficult because of the associated speed instability (known as "*flying on the backside of the power curve*").

The approach began at an altitude of 5000 ft, so as to be 1000 ft above ILS traffic on the initial approach and to avoid any conflict with that traffic.

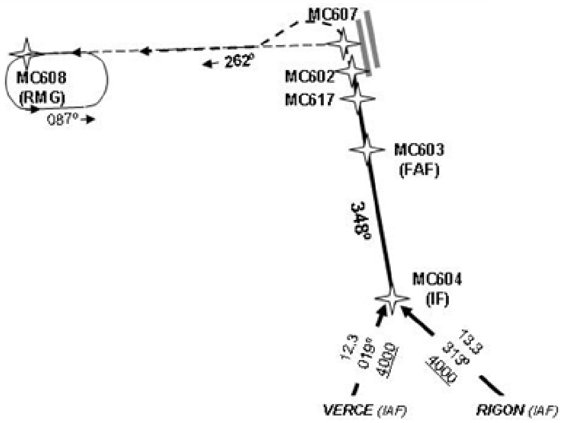

Figure 3 FATO procedure plan view

The missed approach procedure, if required, starts at the decision altitude of 200 ft AGL or at waypoint MC602, whichever comes first, as illustrated in Figure 3. A straight track of 348º is to be flown towards waypoint MC607 (a fly-over waypoint), after which a left turn is to be made to intercept a track of 262º from MC607 to the MAHF (Missed Approach Holding Fix) 'RMG' (Romagnano, waypoint MC608), while climbing to an altitude of 4000 ft MSL.

This missed approach route is identical to the new departure route for the tilt-rotors, i.e. the tilt-rotor is to proceed to the fly-over waypoint MC609 directly from take off, and then follow the missed approach route from there, usually having been cleared to a higher altitude of 5000 ft MSL.

PinS approach

This is effectively an approach towards an easily identifiable object or "aiming" point on the ground as marked in Figure 2 (in this case a highway roundabout). The IFR segment ends at a 'Point-in-Space' (PinS). Decision height is 250 ft AGL if vertical guidance is available, otherwise the Minimum Descent Altitude (MDA) of 270 ft AGL. The glideslope of this procedure is 6.48º. Initial approach altitude is 5000 ft AGL. Final approach course is also 348º magnetic, and is parallel with the ILS 35L.

When reaching the PinS the tilt-rotor is to level off, then decelerate to 50 knots, continuing straight ahead (visually) at MDA towards a Descent Point (DP). At DP, initiate final descent and land on the apron for taxiing to one of the 3 helispots located on the main tarmac. A schematic of the visual path of the PinS along the airport is shown in Figure 4 (dashed line).

A profile view of the approach is shown in Figure 5. Vertical guidance is by SBAS, and makes this approach an LPV approach.

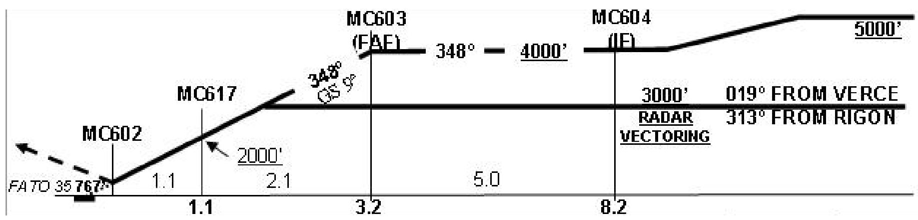

Figure 4 Profile view of the FATO procedure

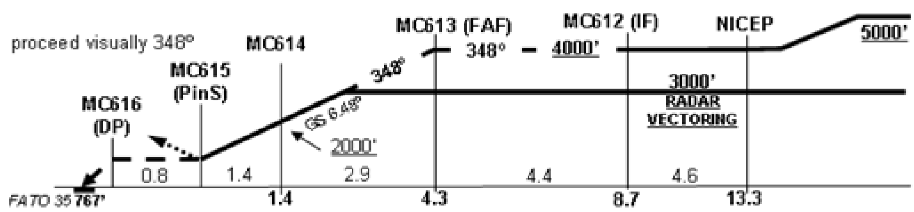

Figure 5 Profile view of the PinS procedure

The final turn needed at the DP is about 60º, i.e. considerably more than allowed by ICAO (30º). During the evaluation and testing of this turn (in daylight conditions) no objections arose from the pilots. For the missed approach the same turning point 'TP' as for the FATO procedure is used.

Therefore, after the PinS, the aircraft is required to make a small turn to the right to a track of 353º as the PinS procedure final approach track is slightly offset to the left of the FATO final approach track.

In the visual database a few light masts on the tarmac north of the control tower were removed in order to provide obstacle clearance. According to the ICAO definition of the PinS procedure [2] the lateral protection areas for the final segment (and also the visual segment) have a semi-width of 0.8 NM. Applying this to the Malpensa situation would have meant a large (0.8 NM) lateral separation between the PinS final approach track and the airport control tower, this being the main obstacle, or else a high MDA of approximately 500ft AGL. The lateral separation, however, is limited due to the presence of the Cameri CTR. The ICAO definition, however, applies to a rotorcraft using a "basic GNSS" receiver. In the case of the future tilt-rotor Erica, it is assumed that it will operate with a GNSS, augmented with SBAS (Space-Based Augmentation system). This will allow a reduction in the lateral protection area semi-width to at least 0.2-0.3 NM, which is the lateral separation that applied to this procedure at Malpensa airport. With this assumption the PinS approach can be oriented as described. The approach minimums could be reduced to 246 ft AGL.

Experiment design

Early in the experiment definition, NICETRIP partners opted to connect the 3 real-time simulation platforms available with the ATC simulator.

NLR: HPS

The Helicopter Pilot Station is a fixed-base simulator at NLR, Amsterdam, which had recently been upgraded (October 2009) and is pictured in Figure 6. The upgrade consisted of elevating the pilot cockpit upon a pedestal (3m high), adding a frame and replacing the 3 visual projection boards by a half-cylindrical wall.

Figure 6 NLR HPS Simulation Facility

Four image projectors provide visual scenery with a 70º vertical x 180º horizontal field-of-view. Four programmable EFIS displays make up the instrumentation in the cockpit. The flight control forces are generated by a digital control loading system designed by MOOG.

Eurocopter: SPHERE

SPHERE is a fixed-base simulator, located at EC Marignane premises, used for research and development purposes. It can be used to simulate any rotorcraft configuration including the tilt-rotor. The visuals are projected onto the internal surface of an 8-m diameter dome, inside which the simulation cockpit is located which is illustrated in Figure 7.

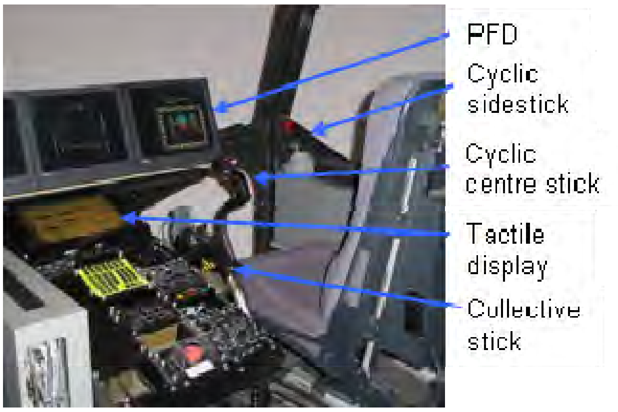

Figure 7 Eurocopter SPHERE Simulation Facility

The spherical screen provides an 80° vertical x 180° horizontal field of view. The flight controls are Fokker helicopter-type inceptors, whose force-deflection characteristics are adjustable. The cockpit panels consist of six instrument panels plus a virtual panel (for configuration of the auto-pilot, interface with the mission computer, landing gear command). A large panel of visual cues is available: good weather, rain (three levels), clouds with transition, fog, wind. The main adaptations for the trials were mainly related to flight mechanics model upgrades (engine model, thrust/power management, landing gears, VRS, enhanced ground effect), cockpit devices, pilot displays, data exchanges through DIS protocol and audio set communication with SICTA platform.

UoL: HeliFlight-R

The HELIFLGHT-R at UoL is pictured in Figure 8. Some of the key features, discussed further in Ref. 4 are:

- 6-axis DOF electrically actuated motion platform
- HD projectors with automatic edge blending and geometry correction
- 220x70 degree field of view
- 2 pilot crew station with additional instructor station

- 4-axis fully programmable control loading system that back-drives the pilots' controls
- View refreshing frequency: 30 Hz – 60 Hz is expected for these evaluations.
- Engine and NR sound effect: This is currently implemented on the tilt rotor simulation model at UoL based upon engine RPM.
- Flight Control: FOKKER flight controls system including capability to modify loads in real time. Cockpit devices: six touch screens to display MFDs and other symbology plus virtual panel (ex. AFCS panel).
- Real time architecture: ARTIST or RISE environment can be used for simulations. Flight state refreshing frequency: 60 Hz.

Figure 8 UoL HELIFLIGHT-R Simulation Facility

Sicta: ARTS

ARTS, Aerodrome Real Time Simulator, is an A-SMGCS simulator for small-scale aerodrome simulation. It is mainly an integration platform also usable for small-scale real time simulations and prototyping sessions considering Tower, Ground and Runway controllers in the loop. It is composed of ground system infrastructure (e.g. route planning and surface collision alert), ground surveillance and a simulated environment for navigation and piloting of mobiles (aircraft and vehicles).

The real-time validation platform is built from two macro-modules: PP/Navigation module and TWR (A-SMGCS) module. The first one is an ATC real-time simulation facility for human-in-the-loop simulation letting to reproduce aircraft/vehicles activities on the airport surface, as well as on the final approach and initial climb segment, following ATCos clearances/instructions. Pseudo-pilots/drivers, sitting in a dedicated room, can communicate with the ATCos via a simulated radio transmission line. TWR (A-SMGCS) module is an ATC real-time simulation facility for human-in-the-loop simulation reproducing the Malpensa TWR equipment/facilities. This module can reproduce all the Tower CWPs available in the Malpensa TWR: CDD (Clearance-Delivery Dispatcher), GEC (Ground Executive Controller) and TEC (Tower Executive Controller).

The Audiolan module is an ATC real-time simulation facility for simulating the radio communication between ATCos and Pseudo-pilots. It can simulate a point-to-point communication, between ATCos, and a frequency communication between ATCos and pilots. It can record the voice communication that occurred and can be enhanced in order to record Instantaneous Self Assessments.

Connecting the Simulators

To accomplish the trial objectives, it was vital that the air traffic controllers could see all aircraft on scope and communicate in real-time with the ERICA crew flying the ERICA aircraft simulations. This involved many technical challenges, where aircraft geocentric position and orientation data had to be sent from each player to a central hub at NLR using DIS (Distributed Interactive Simulation, Ref. 5). The data were then relayed back to all participants allowing all air traffic in the scenario to be visualised in each simulation (up to 40 individual aircraft).

Communication between the ATCos and pilots was achieved by Voice Over Internet Protocol (VOIP) using Audioset software (Figure 9) provided to all players by SICTA. The software requires a Virtual Private Network (VPN) between the players to ensure there are no communication breaks between the partners. The VPN was also used for simulation management and coordination, where during the simulation exercise; the simulation manager from each player maintained contact through a chat window. This was especially useful for coordinating when players entered the simulation.

Figure 9 Audioset (Provided by SICTA)

The Audioset software depicted in Figure 9 works by the pilot in the cockpit selecting communication with an ATC based upon flight profile. The options in this example are ATC1 for the control tower, ATC2 for ground taxi and finally ATC3 for departure. The frequency was assigned by an IP address and port number. When an ATC was selected, the pilot could here all chatter on that frequency between the ATCos and other aircraft. To talk to the ATC, the pilot pressed and held the 'push to talk' button.

Stand-alone trials

In order to allow for adjustments and specific, procedure-related tests, the experiment was split into a stand-alone phase and an integrated or networked phase. The stand-alone trials occurred at different times, performed by the different RTS partners. Eurocopter performed their stand-alone trials in October 2009, NLR in December 2009 and UoL in January 2010.

No ATCos were involved in the stand-alone simulation trials. Partners scheduled tests according to their individual objectives, such as:

- refine procedures
- pilot training
- display guidance tuning
- flight procedure development (e.g. nacelle tilt angle and speed schedule display)
- tilt rotor manoeuvre performance and evaluation of the survivability of a vortex wake encounter

Networked Simulation Trials

The date of the integrated trials was defined several months in advance to allow the partners to prepare the simulation set-up. Most of the effort was spent on preparing the data interface and radio communications between the simulators and ATC. Some partners had no previous experience in networked operations and software had to be developed to make the various simulators work together. In the networked simulation trial, the RTSs were connected to the ATC simulator through DIS. Tilt rotor flight data and other fixed-wing traffic data were exchanged, such that each RTS and ATC simulator had information about the whereabouts of all traffic operating in the Malpensa airspace (including ground taxiing traffic). Three pilots participated at each piloted simulation facility. Three ATCos from ENAV took part, acting in turn as clearance delivery controller, ground controller and runway controller ("tower"). For all integrated tests, pseudo-pilots from the ENAV academy drove the fixed-wing traffic which was arriving and departing from runway 35L. The following objectives applied:

- to evaluate the airport's capacity, time delays and effect on them by adding tilt-rotor operations using:
    - a new dedicated FATO for approaches
    - (or) a point-in-space (PinS) for approaches, after which a landing is to be made on the tarmac provided with 3 helispots north of the control tower
    - a new, dedicated departure route
- to evaluate the sensitivity of the ATC system to unexpected events, such as:
    - an unexpected missed approach
    - an occupied landing site (FATO), with possible use of adjacent runway
    - other unusual events to be discussed with the scenarios (see later).

The objectives were evaluated in terms of their effect on ATCo's workload and ATC-pilot interaction (e.g. in terms of no. of R/T messages), airport throughput, etc. Also pilot and ATCo's acceptance of the procedures and workload in the light of possible delays and solutions used by ATC were collected. The main issue here is the interaction between the pilot and the controller when working out various solutions. All tests were made during daylight conditions and with Good visual Environment.

The traffic is built up from zero until the traffic load to be evaluated has developed (this takes about 15 min). Then 1 hour of running, after which the simulation is stopped and the ATCos completed post-scenario questionnaire(s). The pilots also completed an in-cockpit questionnaire after each flight or run during the scenario, as well as a post-scenario questionnaire.

The results of the tests were compared against a baseline scenario, where only fixed-wing flights operate on the standard runway 35L using the ILS approach or standard instrument departures.

Scenarios

Each RTS performed one arrival and departure per scenario. The following scenarios or 'ORG' as duly defined by Sicta (i.e. *organisation* of ATCo, procedure, traffic flow sample, etc.), applied:

1. **ORG A**: Baseline approach procedure (i.e. ILS 35L) applies. No tilt-rotor aircraft are involved.
2. **ORG B**: the FATO procedure applies, with at least 3 tilt-rotor flights arriving and 3 departing per hour per RTS. For departures the newly developed RMG 1F departure procedure for tilt-rotors applies. This departure is equal to the missed approach part of the FATO procedure.
3. **ORG C**: the PinS procedure applies, with at least 3 tilt-rotor flights arriving and 3 departing per hour per RTS. For departures the same RMG 1F departure procedure applies.
4. **ORG D**: both the FATO and the PinS procedure are in operation, with 3 tilt-rotor flights and 3 departures per hour per RTS. ATC decides which of the two procedures applies per arriving flight. In principle, when leaving the initial approach fix to start the approach the crew has already been informed which procedure applies for them, so they can properly set up the

FMS/navigational system and prepare for the approach.

In addition, unusual events were planned, distributed over a number of scenarios. The following types of events were tested:

a) **Communication Failures**: Communication problems between tilt rotor pilot and ATCo were simulated during approach. In this scenario tilt-rotors could follow either FATO or PinS procedure.

b) **Execution of wrong landing procedure:** PinS procedure was executed instead of FATO procedure because of pilot/controller misunderstanding.

c) **FATO occupied**: On landing on the FATO, the tilt rotor simulates an engine failure, blocking the FATO.

Questionnaires were designed for the pilot and ATCo to solicit their response to questions relating to workload and situational awareness in these unusual events (Ref. 6).

Results & discussion

Pilot questionnaire results

Procedures fit/acceptance

With both departures and arrivals having been flown it was possible for the crew to judge whether or not the procedure tested in this scenario was appropriate for the airport. In terms of the *procedure's fit* in the airspace structure a histogram of ratings is given in Figure 10, broken down by the procedures. These results are based on a total of 18 ratings collected.

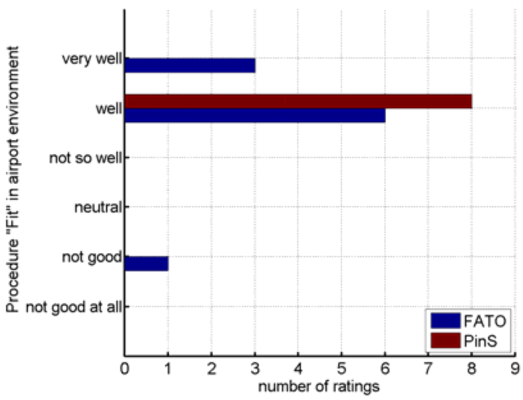

Figure 10 Procedure's "fit" in airport environment

It is clear that the PinS procedure scored slightly better than the FATO procedure, where in one case the "fit" was judged to be '*not good*'. However, the FATO procedure did score a fit rating of '*very well*' 3 times. In terms of the *procedure acceptance*, the PinS procedure was accepted best, and the FATO procedure was accepted well, but slightly less than the PinS, see Figure 11. In one case the FATO procedure was only 'just' accepted, however it was an engineer and not a pilot who gave this rating, so other reasons could perhaps have played a role in his choice.

Pilots commented that the FATO's glideslope of 9º was too steep, resulting in a final approach speed that gave poor speed stability, giving rise to a higher workload. For both the FATO and the PinS procedure a non-precision circling approach part should be added, to allow for the possibility to cross from the FATO or PinS approach and land on the nearby landing runway 35L Also for the PinS procedure a good missed approach procedure *after* the PinS has been past should be defined, in case of a missed approach to be executed when already on the visual segment. Formally a missed approach must have been made at the PinS, but in case of certain meteorological conditions it is arguable that the visual cues are sufficient up to and including the DP point.

For a standard circling approach, in case visual cues are lost, the pilot on the missed approach after a visual segment should turn to the standard missed approach heading of the preceding instrument approach (exceptions granted), and climb away. Such a circling approach part was not specified for the visual segment of the PinS, as it was assumed that, in case of such weather conditions, the pilot would have started the missed approach already at the PinS.

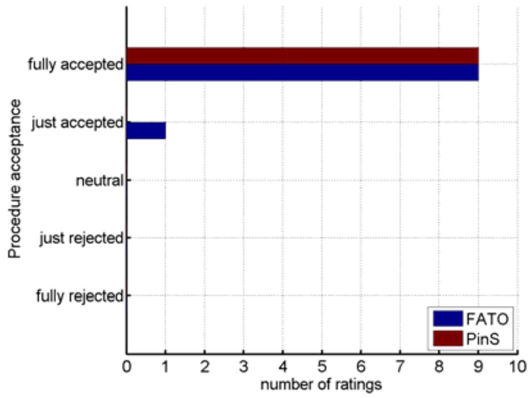

Figure 11 Procedure acceptance

The departure procedure was fully accepted by all pilots, although the pilots commented that the taxi times from stand to the take off position (FATO) were too long, and that the departure direction ("direct to RMG") was not well defined, while an ADF was not on board. This can easily be remedied by re-stating this as "proceed to MC608 via MC607" or similar.

Workload

The pilot rated workload using the McDonnell scale for the "demand on the pilot/controller" (Ref. 2). Since it will likely depend on the type of RTS and scenario/procedures in place, the factorial ANOVA was therefore carried out on the 'demand on the pilot', with as factors 'RTS' (SPHERE, HPS), 'ORG' (B, C and D) and 'Type-of-flight' (departure, arrival). The 'ORG' x 'Type-of-flight' x 'RTS' interaction is shown in Figure 12 for two of the RTSs (HPS and SPHERE).

None of the factors or interactions had any significant effect ($p > 0.1$) on the pilot's workload. On average the pilot's workload was not demanding.

For departures, the workload increased per ORG for the HPS as shown in Figure 12, but this turned out not to be significant ($p > 0.1$). In fact the instrument departure route for all ORGs was the same for the tilt-rotor, so no difference in workload was expected.

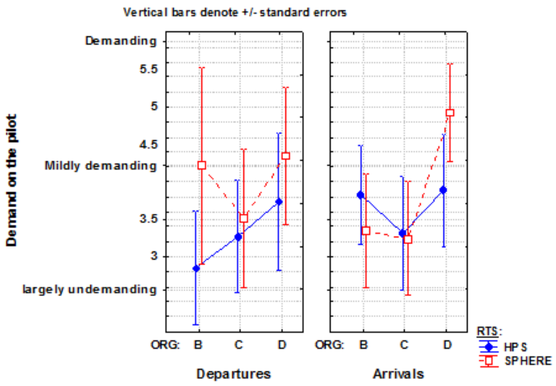

Figure 12 ORG' x 'Type-of-flight' x 'RTS' interaction effect on pilot workload

For ORG B departures the difference in workload between the RTSs was also not significant ($p > 0.1$), although the SPHERE workload was '*mildly demanding*', while for the HPS it was '*largely undemanding*'. For ORG C (the PinS approach) both RTSs had the same workload level. Finally for ORG D arrivals the difference in workload between the RTSs was not significant either ($p>0.1$), owing also to the fairly large spread in ratings (standard error large).

At UoL pilots preferred the PinS approach. Workload was higher on the 9º FATO approach at 50 Kt as the aircraft appeared to be neutrally stable in roll. The descent from 4000 ft appeared to take an unusually long time in helicopter mode. Furthermore no trim wheel/button was available on the inceptor at UoL which caused difficulty in trimming the aircraft, increasing workload.

Departures were less demanding than the approach and descent phase. UoL pilots did not experience a change in workload from ORG B or C for ORG D scenarios.

Situational awareness

The situational awareness of the pilot during the flight through the fixed-wing aircraft riddled airspace is strongly dependent upon the cockpit instrumentation layout, equipment, etc., as simulated per RTS. Therefore the means + std. error distribution with situational awareness is broken down per RTS and per ORG as given in Figure 13. The ORG factor comes in due to the procedure in use, which may give rise to different situational awareness cues.

Situational awareness in the SPHERE RTS varied considerably with scenario. For the HPS it was more or less constant, between '*good*' and '*excellent*'. One of the reasons for the situational awareness being less than '*good*' for the SPHERE was the radio communication that failed or did not function properly.

Pilots at UoL noted that their situational awareness was '*fair*'. Improved instrumentation is required to deliver good situational awareness. Currently the pilot only had glideslope and localiser deviation and distance to defined waypoints.

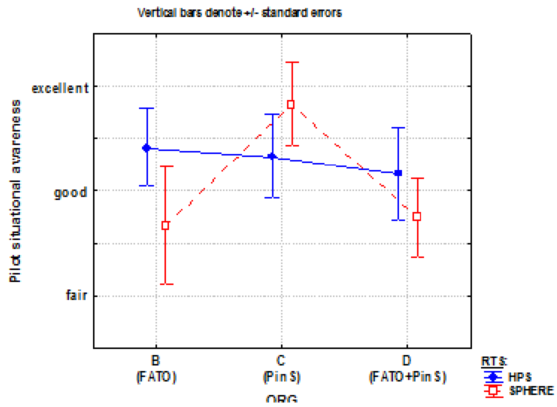

Figure 13 Pilot's situational awareness per ORG and RTS

Unusual Events

Most, if not all of the unusual events turned out to be non-events, at least in the pilot's opinion. In the case of the FATO being occupied, a last minute procedure change to the nearby ILS approach was made to land on runway 35L. The large difference in glideslope angle (7.5º or 9º versus 3º) caused the tilt-rotor to arrive on the ILS approach path far above the ILS glideslope, making the subsequent ILS approach in fact a non-precision approach. Such a change in procedure would only make sense when it is made before the ILS FAF (i.e. at about 10 NM from the airport). When closer to the airport a better solution would be to make a circling approach from or before the DA/H of the FATO/PinS procedure towards the ILS runway.

With another unusual event, the "wrong procedure" for example, an NLR flight was told to "*expect a FATO approach*". Instead a PinS approach was selected and flown. ATC did not notice the flight starting its descent earlier, viz. at 4.3 NM instead of 3.2 NM (see Figure 4 and Figure 5), and cleared the flight to land on the FATO while it was preparing for the PinS visual segment. To the remark of the crew that they were on a PinS approach ATC simply replied with "*OK, that's no problem, room enough*".

Finally in the case of the FATO or helispot being blocked by a tilt rotor with engine failure, all aircraft were instructed to land on the adjacent ILS runway, or vectored around traffic to rejoin the ILS approach.

ATCo questionnaire results

ATCos were asked if they found the FATO and PinS approach:

a) Fully acceptable

b) Acceptable

c) Maybe acceptable/maybe not acceptable

d) Not acceptable

Feedback revealed that all controllers found the FATO approach to be '*acceptable*' while the PinS approach was '*Maybe acceptable/maybe not acceptable*'. The controllers commented that they did not appreciate the PinS procedure, which is characterized by a visual final part requiring more attention from them.

Controllers would prefer that departure procedures designed for tilt-rotor traffic are independent and not-interfering with those of conventional traffic.

Controllers asserted that a tilt rotor having to make a missed approach could be avoided by means of a hovering procedure 0.5NM before the airport. It is only applicable if the tilt rotor at that distance has fully converted to helicopter mode (nacelles at least at 75º). During simulation sessions controllers had the opportunity to experiment with this strategy during the simulation exercise with the unusual event of "*FATO occupied*". A tilt rotor landed on the FATO, but did not vacate it on time, so the tower controller gave the following tilt rotor the instruction to hover at 800' at 1 NM from the airport. When the runway became clear the tower controller subsequently cleared the tilt-rotor to land on the runway-in-use.

Procedures' impact on ATCo's workload

Evaluating the simulation conducted showed that the tilt-rotors presence did not have a strong impact on the controllers' workload. Managing tilt-rotors was, according to the controllers involved, very similar to managing conventional traffic. The ATCos asserted that the transition phase of the tilt-rotor, transitioning from aircraft to helicopter mode, did not have consequences on their task demand. However, they had to take its flight performance into account, especially on final approach, because tilt-rotors are characterized by lower performance than conventional traffic.

The ATCos appreciated that tilt rotors are able to land either as an aircraft or as a helicopter. They asserted that they could support them to better sequence and optimize arriving flights to the airport. In specific circumstances they would prefer a tilt rotor to land as an aircraft, in order not to delay conventional following traffic: If the previous tilt rotor lands as a helicopter on the runway the following conventional traffic must be delayed, e.g. by vectoring, speed reduction or holding, in order to assure proper minima separation, If instead the tilt-rotor lands as an aircraft it maintains aircraft performance on the final approach similar to the following conventional traffic. Controllers stated that this strategy should be applied in specific situations, especially in order to prevent delays.

The ATCos believed that the tilt-rotor parking position should be used exclusively by tilt rotors and at an opportune distance from conventional flight parking positions, in order to guarantee a more efficient and effective ground movement.

Situational Awareness

Notwithstanding some loss of communication and pilots deviating from ATC instructions (probably due to their loss of situational awareness), the controller always maintained awareness of the air traffic situation. Figure 14 shows ATCo feedback about their situational awareness during the simulation session. The data are grouped by organization and by controller position and confirm that controllers maintained a good level of situational awareness. The lowest ranking, if any, was for the tower controller in case of the FATO procedure in use with the tilt-rotors.

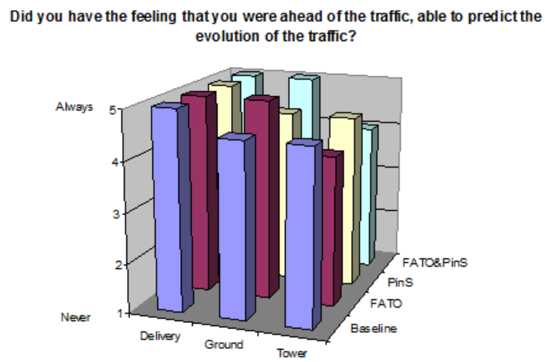

Figure 14 ATCos' feedback about situational awareness

Another aspect of situational awareness is the provision of useful information to the controllers. Figure 15 shows the ATCos' feedback about information requirement with respect to tilt-rotor operations. The data has been grouped by scenario and by controller position.

The data shows that controllers were not always provided with the required information about the tilt rotor. In particular, tower control experienced lack of information in case of the FATO procedure. With the combined FATO & PinS procedures in force this lack of information had apparently been reduced. It is possible that a learning effect is present in the data.

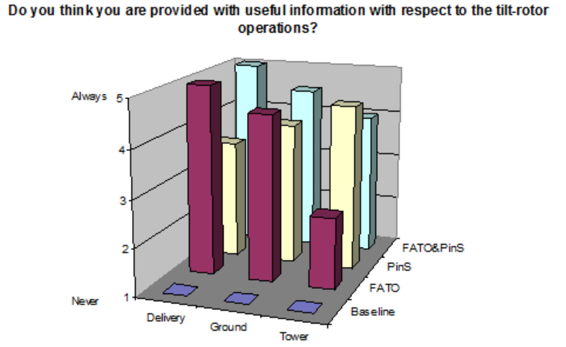

Figure 15 ATCos' feedback about information requirement'

Conclusions & recommendations

In light of the limited scope of the experiment, in terms of modelling, weather, and ATC set-up, the following conclusions and recommendations can be made:

The networked simulation was successful and a unique European achievement: 3 real-time helicopter simulators simultaneously coupled to an ATC simulator in 4 countries. After the initial implementation challenges were overcome, the simulation week ran smoothly, producing good and interesting results. The tilt rotor can very well be introduced in the operational scene of a major busy European airport. Concerning the procedures developed the following conclusions and recommendations can be made.

FATO procedure: ATCos' view

Controllers judged this procedure to be acceptable. They gave suggestions to improve their working method to manage tilt rotors departing/arriving at the FATO. The tilt rotors should be cleared to hold before take off at an intermediate holding position and not on the FATO itself, in order to not occupy the FATO more than needed, especially with incoming tilt rotors at the same time. Similarly an arriving tilt rotor should be considered to have vacated the FATO when it reaches the defined holding point. Therefore, during simulation session controllers gave tilt rotor pilots the instruction to "*hold short of the FATO*" in order to integrate the above proposal in their working methods.

The ATCos asserted that in case of a FATO intrusion (i.e. FATO blocked), it would be preferable to re-route approaching tilt rotors to the PinS procedure, because this solution would involve less changes in decision already made and to traffic management than when letting the tilt rotor land on the adjacent runway.

FATO procedure: Pilots' view

The procedure was well accepted, although the steep glideslope gave problems with speed control. The procedure could be improved by adding a circling-to-land approach to allow landing on the nearby runway in the event of a FATO intrusion, without having to change to ILS procedure. Because of the large difference in glideslope between the FATO and the ILS this change-over is not appreciated. A change-over to the PinS would be much easier.

PinS procedure: ATCo's view

Controllers rated this procedure neither acceptable nor unacceptable ('*maybe/maybe not acceptable*'), experiencing a higher workload on the visual segment after the PinS. Moreover controllers suggested improving the procedure. In particular they asserted that:

- The PinS should be located at least 2 NM before the landing runway, in order to maintain an acceptable level of safety and to assure controller situational awareness, i.e. to have the possibility to prevent an eventual unusual situation.
- A following tilt rotor on a PinS procedure should fly at an altitude higher than the MDA on the visual segment in order to make it perform a missed approach in case of low visibility.

An intermediate holding position should be contemplated for tilt rotors following a PinS procedure. The intermediate holding position should be outside the helispot area.

PinS procedure: Pilots' view

The PinS was an "easy" procedure, due to the less steep glideslope and the wide speed margins that can be handled on the visual segment (50 Kt specified but 70 Kt is also satisfactory). The only area for improvement is the visual segment where tilt rotors were already instructed to change over from tower to ground frequency while still airborne. This should not be done, so that, in case of an unlikely go-around starting between the PinS and the DP, the pilot can report this immediately to the tower controller. With adequate spacing on the approach there is no need for a following tilt rotor to fly at a higher MDA than the preceding tilt rotor.

In case the PinS procedure has to be aborted (e.g. due to some obstruction at the helispots) a circling-to-land procedure, starting at the PinS, should be added in order to be able to land on either the FATO or the runway.

One pilot remarked on the necessity of having a ground marking (e.g. rotating beacon) at the DP for example, in order to identify the visual path more clearly in case of marginal weather and/or pilot unfamiliarity with the airport. In this sense the turn at the DP of about 60º is quite more than the ICAO limit and may pose problems in case of marginal weather or when at night. The issue of proper lighting the helispots at night has not been considered and was beyond the scope of research.

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