ADVISORY SYSTEM WITH VOICE ALERTS FOR HELICOPTER IMPLEMENTED IN FS2004 SIMULATOR MODEL

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Abstract

The advisory system with voice alerts tailored for a helicopter implemented in the Microsoft FS2004 flight simulator model comprising the GPWS (Ground Proximity Warning System) and additional flight, basic engine and fuel level parameters was developed. Variants of such systems common for airliners and business jets are not common in a helicopter yet. With this advisory system that takes into account specific characteristics of a helicopter we wanted to enable initial feasibility evaluation of the advisory system and spread awareness for benefits and necessity of use of such systems in a helicopter. GPWS modes for a helicopter are implemented in accordance with the recent RITA research project by the FAA for the HTAWS (Helicopter Terrain Awareness Warning System).

SUSTAV SA GOVORNIM UPOZORENJIMA ZA HELIKOPTER PRIMIJENJEN NA MODELU ZA FS2004 SIMULATOR

Sažetak

Razvijen je sustav upozoravanja namijenjen za helikopter implementiran na modelu za Microsoft FS2004 simulator koji uključuje GPWS (Ground Proximity Warning System) i dodatne parametre leta, osnovne parametre motora i razine goriva. Varijanta ovakvih sustava uobičajena je na komercijalnim i mlaznim poslovnim zrakoplovima, ali još uvijek nije prisutna kod helikoptera. S ovim sustavom upozoravanja koji uključuje specifičnosti helikoptera željeli smo omogućiti inicijalnu evaluaciju prikladnosti ovakvog sustava te proširiti spoznaju o pogodnostima i potrebi korištenja sustava u helikopteru. Modovi GPWS sustava za helikopter implementirani su u skladu s nedavno od strane FAA pokrenutim RITA istraživačkim projektom za HTWAS (Helicopter Terrain Awareness Warning System).

1. INTRODUCTION

Helicopter safety is still far from desired (see comparison in Table 1, year 2004, [1]).

Table 1: Accident rates for U.S. air transportation

Type of transport	Accident rate / 100,000 hours	Fatal accident rate / 100,000 hours
U.S. Civil helicopters (all types)	8,09	1,48
U.S. Turbine civil helicopters	5,11	1,21
U.S. Air Carier (Part 121)	0,132	0,011

Main causes of fatal accidents with an appropriate technical remedy that may prevent accidents for particular causes are listed in the Table 2, [2]. The proposed advisory system consists of three subsystems: the GPWS, monitoring of flight parameters, basic engine parameters and fuel level. The system is implemented for the FS2004 flight simulator model of an Agusta A-109C helicopter. The A-109C is a high performance twin turbine engine helicopter, one of the most successful in its class during the course of its 25 year history. Choice of an A-109C was based on a retractable gear and available basic helicopter add-on model [3] for a FS2004 flight simulator.

Table 2: Top Operational Causes of Fatal Rotorcraft Accidents 1994 - 2004

Cause	N	Remedy
Wire/Object Strikes	30	OCAS/SVS/ NVG/WSPS
Flight into Terrain/Water IMC/Nigh	25	GPWS/HTAWS/ SVS/NVG
Flight into Terrain/Water VFR	14	
Unknown	7	ASAP, FDR, HUMS & HOMP Monitoring
Low Rotor RPM	5	
Abrupt Control Movement	4	
Tail Rotor Strike / Loss of Control	3	
Personnel Walk into Rotor	3	
Loss of Tail Rotor Effectiveness	2	
Over Gross Weight	2	

Abbrev.: OCAS - Obstacle Collision Avoidance System, SVS – Synthetic Vision System, NVG - Night Vision Goggles, WSPS – Wire Strike Protection System, GPWS - Ground Proximity Warning system, HTAWS - Helicopter Terrain Awareness and Warning System, ASAP – Airline Safety Action Program, FDR - Flight Data Recorder, HUMS - Health and Usage Monitoring System, HOMP – Helicopter Operations Monitoring Program

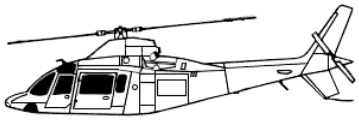

Fig. 1. Agusta A-109C helicopter used in a FS2004 flight simulator with an advisory system

2. GPWS

The helicopter GPWS has some new modes and some usual GPWS modes modified (Fig.1-12, adopted from [2]). Most figures are self-explanatory.

2.1. Mode 1 - Excessive Descent Rate

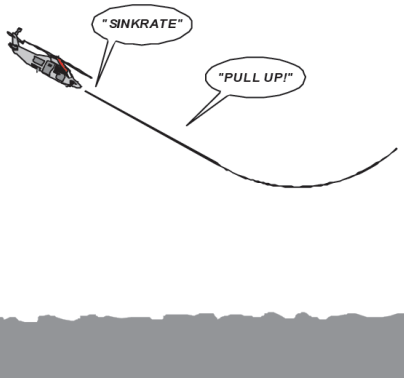

Fig. 2. Mode 1: Alert is triggered by the combination of Descent Rate (Pressure Alt) Vs Clearance (Radio Alt)

2.2. Mode 2 - Excessive Terrain Closure

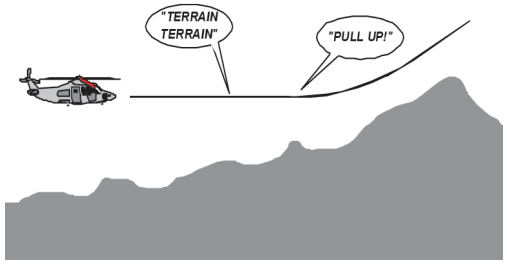

Fig 3. Mode 2: Alert is triggered by the combination of Closure Rate (Radio Alt) Vs Clearance (Radio Alt)

2.3. Mode 3 - Descent After Takeoff

Fig. 4. Alert is triggered by the combination of Altitude (Pressure Alt) Loss Vs Clearance (Radio Alt)

2.4. Mode 4A - Terrain Clearance - Gear Up

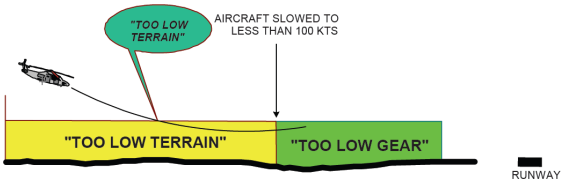

Fig. 5. Mode 3: Alert is triggered by combination of Clearance (Radio Alt) Vs Airspeed & Flight Phase

2.5. Mode 4A - Terrain Clearance - Gear Up Autorotation

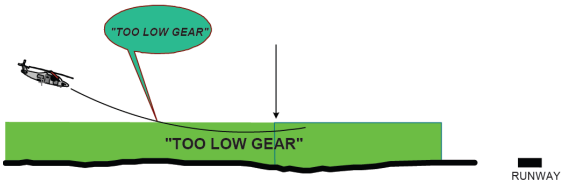

Fig. 6. Mode 4A: Alert is triggered by the combination of Clearance (Radio Alt) Vs Airspeed & Flight Phase

2.6. Mode 4B - Terrain Clearance - Gear Down

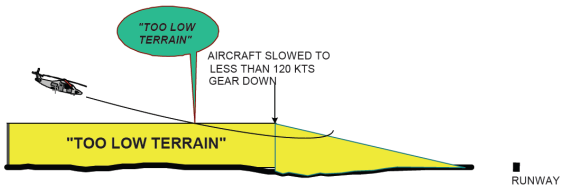

Fig. 7. Mode 4B: Alert is triggered by the combination of Clearance (Radio Alt) Vs Airspeed & Flight Phase

2.6. Mode 4C - Takeoff Into Raising Terrain

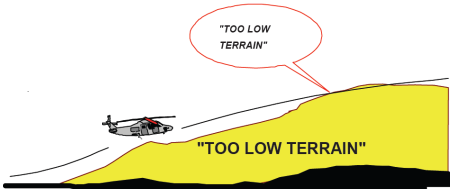

Fig. 8. Mode 4C: Alert is triggered by the combination of Clearance (Radio Alt) Vs Airspeed & Flight Phase

2.8 Mode 5 - Descent Below Glideslope (Soft and Hard)

Warnings are useful during an ILS approach.

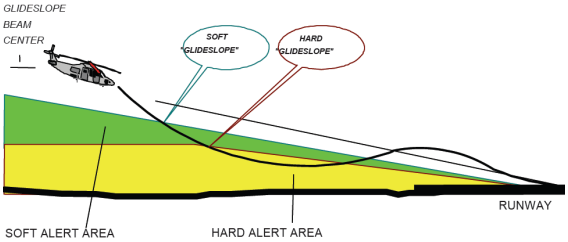

Fig. 9. Mode 5: Alert is triggered by the excessive glideslope deviation

2.9. Mode 6 - Bank Angle

The excessive bank angle may be dangerous and lead to loss of control. The threshold depends on the altitude (35º above 50 feet and 15º below).

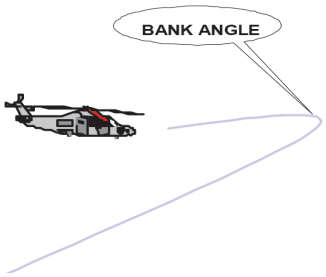

Fig. 10. Mode 6: Alert is triggered by the aircraft specific bank angle

2.10. Mode 6 - Altitude Callouts Autorotation

Callouts during a descent through predefined altitudes (500, 400, 300, 200, 100, 50, 40, 30, 20, 10). During autorotation terrain warnings are suppressed.

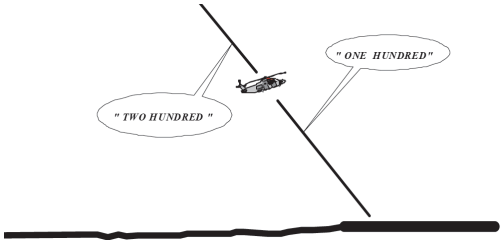

Fig. 11. Mode 6: Alert is triggered by the Radar Altitude.

2.11. Mode 6 - Altitude Callouts Normal Operation

A descent through predefined altitudes (500, 400, 300, 200, 100, 50, 40, 30, 20, 10) + (approach) minimums. During a normal operation terrain warnings are not suppressed.

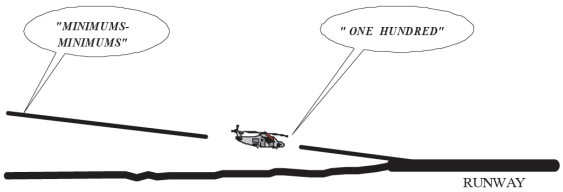

Fig. 12. Mode 6: Alert is triggered by the Radar Altitude.

2.12. Mode 6 - Tail Strike

This mode warns the pilot of possible tail strike due to high pitch attitude at low altitude. The condition may develop during approach slowdown and landing.

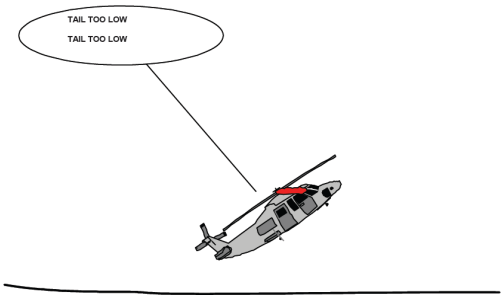

Fig. 13. Mode 6: Alert is triggered by the combination of aircraft Pitch and Radar Altitude.

2.11. Benefit of full TAWS instead of GPWS

It would certainly be beneficial to have a full TAWS with look-ahead capability instead of a simpler GPWS. Such system could warn the pilot of a rapid rising terrain (cliffs). However, since a helicopter typically operates at lower altitudes, this requires a very large and frequently updated high resolution terrain and obstacle database. Discrepancies in a terrain database could generate false alerts and "nuisance" warnings that may negatively impact crew's response to a valid alert.

3. MONITORING FLIGHT PARAMETERS

Advisory system monitors following parameters:

3.1. Overspeed (high IAS)

Alert is triggered for the indicated airspeed above the predefined limit (airspeed limit beyond which structural damage could occur [4]).

3.2. Low Rotor RPM

Alert is triggered for a rotor RPM below the predefined limit (doesn't produce sufficient lift [4]).

3.3. Rotor vortex Warning (Rotorwash)

This is a condition when a helicopter may be in a vertical descent with up to maximum power applied, and little or no cyclic authority (Fig 14, adopted from [4]). The alert is triggered by the combination of a low IAS and vertical speed (descent) above the predefined limit.

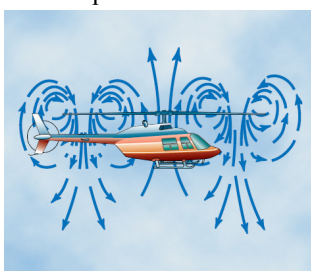

Fig. 14. Rotor vortex

4. MONITORING BASIC ENGINE PARAMETERS

Monitoring basic engine parameters is intended to alert the pilot that the operating limit is being approached.

4.1. Oil Pressure

Alert is triggered by an oil pressure below the limit, intended to prevent engine damage and failure.

4.2. Oil Temperature

Alert is triggered by temperature above the limit, intended to prevent engine damage and failure.

4.3. Transmission Torque

Alert is triggered by torque above the limit if the pilot is operating under unfavorable torque that increases wear, only acceptable during emergency.

4.4. Engine Exhaust Gas Temperature EGT

Alert is triggered by EGT above predefined limit. Prevent engine damage, particularly during startup.

4.5. Engine Gas Producer Speed - N1

Alert is triggered by N1 above the predefined limit.

5. MONITORING FUEL LEVEL

5.1. Low Fuel

Alert is triggered by the fuel level below the limit. Warning is intended to prevent fuel exhaustion accidents.

6. INTERACTION WITH FLIGHT SIMULATOR

Each aircraft within a FS2004 flight simulator consists of an aircraft.cfg file and model, (instrument) panel and sound folders (Fig. 15.). The model includes aircraft flight dynamics. Sound includes various .wav files that are combined for producing engine and environment sounds (wind etc.). The panel consists of numerous gauges.

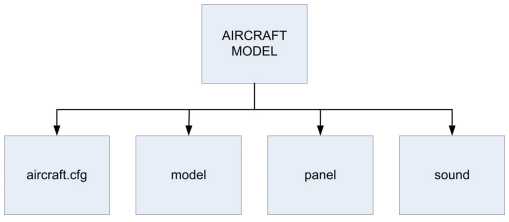

Fig. 15. Structure of aircraft model in FS2004

Gauges are organized in windows (panel can have more windows, Fig. 16.)

7. ADVISORY SYSTEM GAUGE

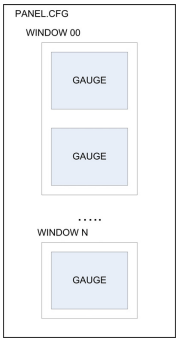

Fig 16. Panel structure

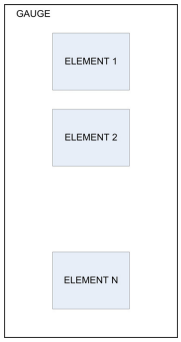

Fig. 17. Gauge structure

Gauges consist of one or more elements (Fig. 17) realized using the XML language that interacts with FS2004 system variables. The XML code is interpreted by the FS2004 [5]. Reversed Polish Notation is used in rule definition.

At the beginning of the gauge code line specifies how often to process elements (usually several times per second).

The advisory system gauge is built upon the available airplane GPWS gauge [6] with some GPWS modes modified, some modes removed and some modes added to suit a helicopter.

Additional flight parameters, engine parameters and fuel level elements are added. Here is an example of an element that implements one rule (Low Rotor RPM):

```
<!-- Rotorspeed -->
<Element>
  <Select>
    <Value>
      (A:ROTOR RPM PCT,percent) 90 &lt;
      if{
 1 (&gt;L:GPWS_Sound_RotorSpeed,number) }
    </Value>
  </Select>
</Element>
```

The condition has to be met for an aural alert to be played through the sound messages gauge [7] call. More rules can be implemented with additional elements.

To prevent simultaneous aural alerts, simple prioritization is built into the gauge, so only the most important alert is played. In the GPWS, aural alert for a lower mode has higher priority than alert for a higher mode.

8. PREPARATION OF VOICE ALERTS

Messages are recorded as .wav files that are played by invoking the sound gauge [7] when

particular condition(s) is/are fulfilled. Original Honeywell or CoolEdit recorded (sample rate 11025 Hz, resolution 16 bit) files are used. Recorded files are first edited for beginning and end of a message, then subjected to an amplitude normalization (120% to extend a dynamics of recorded signal) as shown in Fig. 19 - Fig. 21.

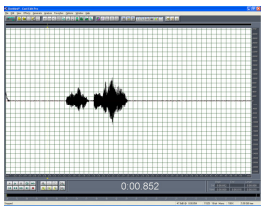

Fig. 18 Initial recording

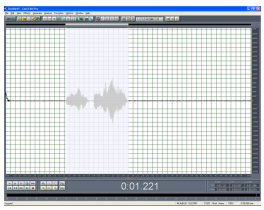

Fig. 19 Placing markers

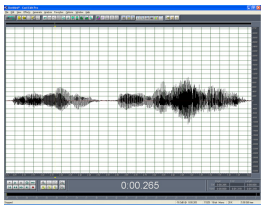

Fig. 20 Message only

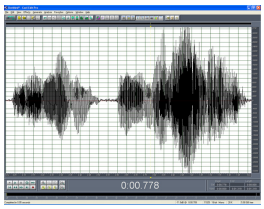

Fig. 21 Normalization

9. EVALUATION TESTS

Table 3: Pilot's questionnaire

Voice Alert	Practical value of alert				
	1	2	3	4	5
GPWS					
Mode 1 - Excessive Descent Rate				+	+++
Mode 2 - Excessive Terrain Closure		++		++	
Mode 3 - Descent After Takeoff	+	+	+		
Mode 4A - Terrain Clearance - Gear Up		+	+	+	
Mode 4A - Terrain Clearance - Gear Up Autorotation		++			++
Mode 4B - Terrain Clearance – Gear Down		+++			+
Mode 4C - Takeoff Into Raising Terrain	+	+	++		
Mode 5 - Descent Below Glideslope (Soft and Hard)	++	+		+	
Mode 6 - Bank Angle	+++	+			
Mode 6 - Altitude Callouts Autorotation			++	++	
Mode 6 - Altitude Callouts Normal Operation	++	++			
Mode 6 - Tail Strike		+	++		+
Benefit of full TAWS instead of GPWS		++	++		
FLIGHT PARAMETERS					
Overspeed (high IAS)		++	+	+	
Low Rotor RPM				+	+++
Rotor Votrex Warning (Rotorwash)	+	++			+
BASIC ENGINE PARAMETERS					
Oil Pressure		++	+		+
Oil Temperature		++	++		
Transmission Torque		+	+		++
Engine Exhaust Gas Temperature - EGT		+		+	++
Engine Gas Producer Speed - N1		++		+	+
FUEL STATUS					
Fuel Level (Low Fuel)		+		++	+

Practical value of an alert is assessed using following scale: 1 - no use at all, 2 - small use, 3 - some use, 4 - great use, 5 – indispensable.

Evaluation of implemented concepts has been carried out by four experienced helicopter police (MUP - Ministry of Interior) pilots. Most important alerts according to Table 3 are GPWS Mode 1: Mode 1 - Excessive Descent Rate, GPWS Mode 6 - Altitude Callouts Autorotation, Low Rotor RPM, Engine Exhaust Gas Temperature – EGT and Fuel Level (Low Fuel). Least important alert is Mode 6 - Bank Angle followed by Mode 6 - Altitude Callouts Normal Operation.

10. CONCLUSION

It is our opinion that safety of a helicopter could be substantially increased with the introduction of an advisory system that will monitor terrain clearance, flight, engine and fuel parameters and warn the pilot of imminent dangers that otherwise may remain overlooked. Other expected benefits are maximizing available performance and reduced maintenance costs. Inadvertently exceeding normal operating limits is a direct cause of higher operating costs, premature component failure and accidents. Implementing the advisory system with the FS2004 simulator enabled us to design such system at practically no cost and evaluate benefits of a system at no risk. Wire strikes still remain a problem that could only partially be addressed with the TAWS. For additional safety a hot wire detector (prevention of wire strikes into "live" wires) should be included to diminish occurrence of this kind of accident. Passive solution like wire cutters should also not be forgotten.

11. LITERATURE

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[2] J. Arnold, HTAWS, Federal Aviation Administration, Heli-Expo 2006, February 28, 2006

[3] A. Devins, T. Jorgensen and S. Hanley, Gmax Agusta A109, FS2004 helicopter add-on

[4] Rotorcraft Flying Handbook, U.S. Department of Transportation, Federal Aviation Administration, 2000

[5] N. Pike, XML Gauge Programming for FS2004, Chapters 1-4, 2005

[6] R. Barendregt, Ground Proximity Warning System (GPWS) FS2004 Gauge V3.3, 3 June 2005

[7] D. Dawson, Freeware Sound Gauge - dsd_xml_sound3.gau, 6 November 2006