

INSTRUMENT FLIGHT RULES (IFR) FOR AH-64A APACHE

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Figure 1

Abstract

The objective of this test was to improve the instrument flight rules (IFR) and instrument meteorological conditions (IMC) capability of the AH-64A Apache helicopter. The test aircraft differed from a production aircraft in that it had a Garmin GNS 430 installed in the pilots station and a Sandel SN3308 Navigation installed in the pilots and copilot station replacing the horizontal situation indicator and radio magnetic indicator respectively. Two very high frequency (VHF) omni directional range (VOR)/Glideslope blade antennas were mounted horizontally on the left and right sides of the tailboom at approximately flight station (FS) 460. The GPS antenna was mounted on the left side turtleback door at approximately flight station (FS) 295. Overall Apache pilot workload in an IFR environment is satisfactory

and flight safety is enhanced with a significant increase in situational awareness. Airspace information displayed on the AH-64A IFR equipment, increased flight safety and situational awareness for the crew. The Garmin GNS 430 turn anticipation feature increases AH-64A flight safety in adverse wind conditions by providing cues to keep the aircraft on the desired course. The AH-64A IFR equipment suite installed on the aircraft costs less than \$100,000 per aircraft and has potential to significantly enhance the flight safety and situational awareness in the cockpit and can take the AH-64A long into the future.

Background

In August 2002 the U.S. Army European Commander identified a mission needs requirement that the AH-64A Apache Helicopters be capable of flying under

Instrument Flight Rules (IFR) in accordance with the requirements of the European airspace system. (figure 1) The AH-64A Apache helicopter is currently qualified for IFR and flight under instrument meteorological conditions (IMC). IFR navigation is limited to a single Airborne Direction Finder (ADF). On August 16, 2002 the AH-64A Apache Program Manager (PM) through the U.S. Army Aviation and Missile Command (AMCOM) Commander, requested that the Aviation Applied Technology Directorate (AATD) procure, install, and qualify (flight test) an add-on navigation and approach system to provide a near term (6 month) improved IFR/IMC deployment capability for the AH-64A Apache helicopters.

Objective

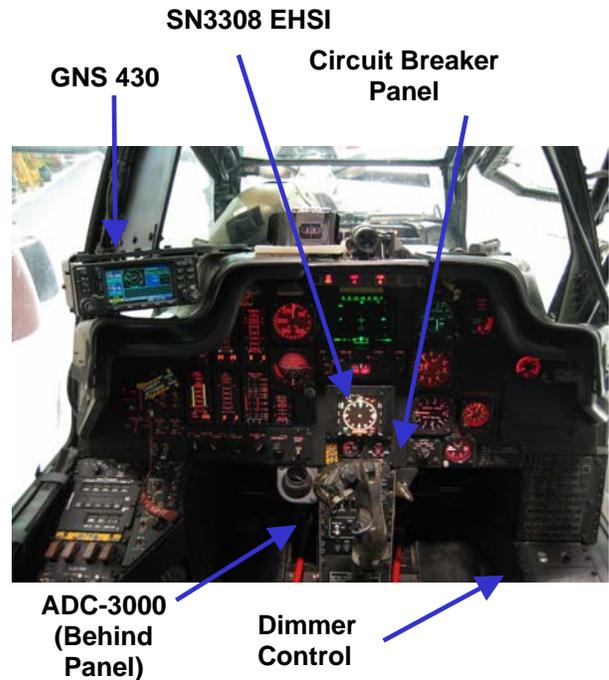
The objective of this test was to improve the IFR and IMC capability of the AH-64A Apache helicopter. The test aircraft, Army Serial Number (ASN) 89-00214 differed from a production aircraft in that it had a Garmin GNS 430 installed in the pilots station and a Sandel SN3308 Navigation installed in the pilots and copilot station replacing the horizontal situation indicator and radio magnetic indicator respectively. Two very high frequency (VHF) omni directional range (VOR)/Glideslope blade antennas were mounted horizontally on the left and right sides of the tailboom at approximately flight station (FS) 460. The GPS antenna was mounted on the left side turtleback door at approximately flight station (FS) 295.

Equipment

The equipment suite that was installed for the improved AH-64A IFR system consisted of the following TSO (technical standard order)-compliant commercial off the shelf (COTS) products (figure 2 and 3):

- Garmin GNS 430 COM/NAV System
- Sandel SN 3308 Electronic Flight Instrumentation System (EFIS)
- Goodrich ADC-3000 air data system

The GNS 430 System is an integrated, panel mounted instrument, which contained a VHF Communications Transceiver (not used in this installation), a VOR/ILS receiver, and a Global Positioning System (GPS) Navigation computer. The installed Garmin equipment



**Pilot Station
Figure 2**

consisted of a GPS antenna and GPS Receiver, VOR/ILS/Glides Slope (GS) receiver and VOR/ILS/GS antenna. The primary function of the VOR/ILS Receiver portion of the equipment was to receive and demodulate VOR, Localizer, and Glide Slope signals. The primary function of the GPS portion of the system was to acquire signals from the GPS system satellites, recover orbital data, make range and Doppler measurements, and process this information in real-time to obtain the user's position, velocity, and time. Provided the Garmin GNS 430's GPS receiver was designed to meet the accuracy specifications for:

- VFR/IFR enroute, terminal, precision, and non-precision instrument approaches (GPS, Loran-C, VOR, VOR-DME, ILS, NDB, NDB-DME, RNAV) operation within the U.S. National Airspace System in accordance with AC 20-138.
- North Atlantic Minimum Navigation Performance Specification (MNPS) Airspace in accordance with AC 91-49 and AC 120-33.

- AC 90-96 and in accordance with AC 20-138, and JAA AMJ 20X2 Leaflet 2 Revision 1, provided it was receiving usable navigation information from the GPS receiver.

Navigation is accomplished using the WGS-84 (NAD-83) coordinate reference datum. Navigation data is based upon use of only the GPS operated by the United States of America.

The Sandel SN3308 Navigation Display is an advanced microprocessor controlled airborne multipurpose electronic display, which is FAA approved under technical standard order TSO-C113. The SN3308 employed an active matrix liquid crystal (AMLCD) projection display. It is designed to combine the functions of the Horizontal Situation Indicator (HSI), Long-Range Navigation (GPS) Map Display, GPS Annunciators and External Mode Switches.



Copilot Gunner
Figure 3

The digital and analog interface properties of the unit provided for compatibility with the Garmin GNS430. The SN3308 received resolved heading information from the aircraft Heading And Reference System (HARS) and ADF bearing from the aircraft ANARN-149(V)3. The SN3308 is designed to display the downloaded flight plan data from a connected GNS 430 GPS receiver. The moving map database for the SN3308 as well

as the internal operating system software were field uploadable through the use of a portable computer equipped with a Windows operating system and an RS-232C Serial Port.

Testing and Results

The purpose of Apache IFR effort was to qualify the installed equipment in the AH-64A helicopter for IFR and IMC flight. A total of 45 flight hours were flown during the period of 25 November 2002 through 28 February 2003. Test participants included AATD, AMCOM Aviation Engineering Directive (AED), Aviation Technical Test Center (ATTC) and the Directorate of Evaluations and Standards (DES). The aircraft was flown in accordance with the limitations of the interim statement of airworthiness qualification (ISAQ), the operator's manual, and the AATD airworthiness release (AWR). The aircraft and subsystem components were tested to the requirements of the Airworthiness qualification Plan (AQP) developed by AED.

The general test approach was to evaluate the areas of form, fit and function, Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC), navigation performance, mission suitability, and human factors/workload assessment. The sequence of testing was to first demonstrate functionality to include on-board EMI/EMC testing and an acceptable performance level followed by mission suitability testing. Mission suitability testing started in a simulated day IMC condition (back seat only) and progressed to actual IMC test flights. During mission suitability testing the pilot test group was expanded from two experimental test pilots to include pilots representative of fleet experience levels.

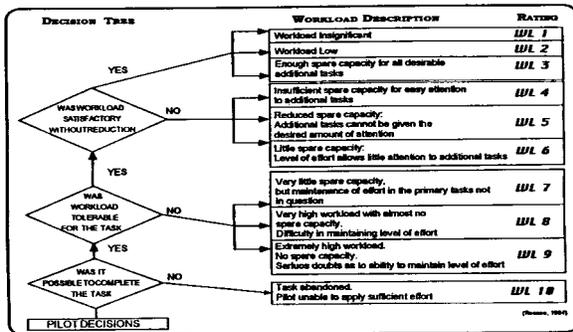
An evaluation of the pilot's ability to meet desired/adequate performance was assessed as part of the suitability testing. The aircraft external configuration for navigation performance testing was two 230-gallon external tanks mounted inboard, and two M-261 rocket pods mounted outboard on the wing pylons. This configuration was used as a worse case representation for the navigation antenna reception. The aircraft external configuration for all other flights was flown with empty M-272 missile launchers inboard, and M-261 rocket pods outboard on the wing pylons. No specific gross weights or center of

gravity were targeted. Simulated IMC was accomplished by installing a Field of View (FOV) restriction in the pilot's station, which prevented external reference. Component performance tests for the installed equipment were developed using AC 29-2C, Airworthiness Guidance for Rotorcraft Instrument Flight as a guide. Mission suitability assessment tasks were developed in coordination with ATTC and using Test Plan, MH-60S/SH-60R Instrument Meteorological Conditions Flight Certification, Naval Air Test Center, as a guide.

A subjective assessment technique was used to evaluate pilot workload with the operation and use of the installed equipment. Workload assessments were performed during the mission suitability portion of the test. Subjective measures required the pilot to judge and report a perceived experience of workload imposed by performing a particular task. The general tasks for workload evaluation are listed below.

- (a) Enroute Navigation
- (b) Execute Precision Approach
- (c) Execute Non-Precision Approach
- (d) Enter a Flight Plan
- (e) Modify a Flight Plan
- (f) Change VOR frequency

These tasks were evaluated while performing the instrument take off, area navigation, VOR approach, GPS approach, ILS approach, and during the precision approach radar (PAR) maneuvers. Evaluated tasks a, b, and c, above, were performed in a normal operational mode as defined by the pilot executing the task and the copilot assisting with flight management/call-outs as directed



Bedford Workload Scale
Figure 4

by the pilot. Tasks d, e, f, and g were performed in two ways; initially by transferring flying duties to the copilot and executing the task and subsequently by maintaining the flying duties in addition to completing the task. The tasks were evaluated using the Bedford Workload Scale (figure 4).

System performance tests conform to the requirements of the specific tests detailed in the FAA AC-29C, Airworthiness Guidance For Rotorcraft Instrument Flight. The EMI/EMC test was conducted and there were no anomalies detected during this test.

A limited handling qualities evaluation was conducted to determine the affects of the VOR antenna installation on the tailboom of the flight vehicle. The VOR antennas had no apparent affect to the flying qualities of the aircraft. The GPS and VOR/Localizer/ILS systems met the requirements detailed in AC-29C.

The GPS rotor modulation testing was performed on the ground by varying the main rotor speed and observing the effects to the satellite tracking and signal strength of the Garmin 430. The main rotor speed was adjusted from 90 percent to 104 percent. The rotor modulation did not affect the Garmin 430 GPS signal performance.

The Field of View (FOV) was evaluated concurrently with mission maneuvers in day and night conditions. The FOV was similar to an unmodified AH-64A. The GNS 430 provides a minor obstruction above the left side glare shield but does not impact safe operation of the aircraft in all modes of flight to include Nap Of the Earth (NOE) and terrain flight. The Field of View of the AH-64A modified with the IFR equipment is satisfactory.

A qualitative and quantitative night vision goggle (NVG) evaluation of the Sandel 3308 and Garmin 430 displays was conducted from the co-pilot gunner (CPG) station using the AN/ANVIS 6V1 NVG's. Results of the quantitative NVG compatibility indicate that the test items have no measurable effect on Snellen acuity when viewing outside the cockpit through ANVIS-6 goggles from either the pilot or the CPG crew stations.

The AH-64A IFR equipment was evaluated for crew access and operation as installed in the pilot and CPG stations. For both the Garmin GNS 430 and the Sandel, the control knobs and buttons were easy to reach, actuate and identify based upon tactile feel, size, shape and location. Access to and manipulation of the Garmin GNS 430 control knobs was not a problem except one of eight pilots noted that it was difficult to access with the left slide-out glareshield extended. With a gloved hand the Sandel 3308 was subject to potential inadvertent button activation. The Sandel 3308 bezel control buttons required minimal force to push and activate. The buttons were located close to each other and did not provide tactile feel feedback when activated. However, visual feedback on the Sandel 3308 display made it readily apparent that there was an inadvertent button activation. These were minor annoyances that can be overcome through minimal training and as the operator becomes more experienced with the system. The AH-64A IFR equipment flight crew interface was satisfactory.

Suitability tests were performed during specific phase of flight; Enroute, Terminal, Approach, Missed Approach, and Holding.

Eight subject pilots flew the AH-64A IFR equipment during IFR suitability testing. Day IMC conditions were simulated with FOV restrictions installed on the canopy. The FOV restrictions prevented the pilot from maintaining any visual references outside the cockpit and essentially simulated zero visibility and zero ceiling weather conditions. Tests were conducted with wind varying from 5 knots up to 40 knots. Turbulence varied from stable to occasional moderate turbulence. Most evaluation flights were conducted with light turbulence. Seven specific maneuvers were flown which encompassed the entire spectrum of IFR flight. The maneuvers were instrument take off, area navigation, holding, and approaches using VOR, GPS, ILS, and precision approach radar (PAR). The information displayed to the pilot provided suitable reference system for flying in an IMC environment. All subject pilots attained at least adequate task performance and most pilots attained desired performance. The maneuvers were performed safely and within standards stipulated within the AH-64A Aircrew Training Manual (ATM) Training

Circular (TC) 1-214. Workload assessments were conducted concurrently with maneuver execution. Workload was assessed as low with pilot ratings predominantly at WL3. All the ratings ranged from WL2 to WL5. Overall, the AH-64A IFR equipment is intuitive to operate and provided clear data to safely fly in an IMC environment with significantly increased situational awareness from the unmodified AH-64A.

The AH-64A IFR equipment was evaluated while conducting ITO maneuvers during day simulated IMC, night IFR, and day IMC conditions. Weather conditions varied from calm to adverse (greater than 15 knots) winds and turbulence. Winds varied from 6 knots to 15 gusting to 20 knots. The ITO task was conducted from the ground as per the AH-64A ATM. Eight pilots flew this maneuver. All pilots accomplished the ITO maneuver with desired performance. The desired performance standards were +/- 5 deg of heading, +/-2 deg of pitch attitude, and 500 fpm +/-100 fpm rate of climb. Pilots safely and easily performed the task. Workload ratings ranged from WL 3 to WL 5. The average workload rating was WL 3.8 and the lowest and most frequently assigned workload rating was WL 3. During the most adverse weather conditions, the pilot reported that maintaining desired performance standards was easy due to the handling qualities of the aircraft and the flight information displayed on the Sandel 3308 EFIS. Typically, pilot attention was focused on the task to maintain the desired heading, pitch attitude, and rate of climb. Consequently, pilots were not using the Garmin GNS 430 during this maneuver. Of the newly installed IFR equipment, only the Sandel 3308 EFIS display was incorporated into the pilot's instrument scan. The Sandel 3308 provided heading information to the pilot in a standard and simple format that allowed for quick comprehension. The AH-64A IFR system provided clear indications to the pilot and allowed for the aircraft to smoothly transition from the ground to a forward flight condition in IMC. The AH-64A IFR equipment is satisfactory for instrument take off.

The AH-64A IFR equipment was evaluated while conducting IFR area navigation during day simulated IMC, night IFR, and day IMC conditions. IFR area navigation consisted of tracking course lines, tracking to intercept

course lines, or changing course direction as waypoints were crossed. Eight pilots flew the AH-64A IFR equipment while conducting IFR navigation. Seven pilots accomplished the IFR area navigation task with desired performance and one pilot achieved adequate performance. The desired performance standards were +/- 5 deg of heading, +/-5 knots airspeed, +/-50 ft altitude, and 1 course deviation indicator dot. The adequate performance standards were +/- 10 deg of heading, +/-10 knots airspeed, +/- 100 ft altitude, and 2 course deviation indicator (CDI) dots. Using the AH-64A IFR equipment was easy and intuitive. All pilots assigned a low workload rating of WL 3. The Sandel 3308 EFIS display provided outstanding cueing for course interception and tracking. Coupled with the Garmin GNS 430, situational awareness was significantly increased and provided the pilot simple and effective information for aircraft position determination along navigation routes. Additionally, the AH-64A IFR system increased flight safety and situational awareness by providing the pilot information about the location of Class B, C, and D airspace which minimized the possibility of pilots inadvertently entering congested airspace without clearance. The low workload ratings and increased safety associated with the AH-64A IFR equipment significantly improve the AH-64A capability to area navigate while flying IFR. The AH-64A IFR equipment is satisfactory for IFR area navigation. Airspace information displayed on the AH-64A IFR equipment is an enhancing characteristic and will increase flight safety and situational awareness.

The AH-64A IFR equipment was evaluated while conducting IFR holding during day simulated IMC, night IFR, and day IMC conditions. Wind at test altitude varied from 5 knots up to 40 knots with a direct cross wind to the inbound and outbound legs. IFR holding consisted of entering the holding pattern using either a direct, parallel or tear drop entry patterns based upon the direction the aircraft approached the holding fix. Additionally, up to four complete circuits were made with most pilots executing three complete holding pattern circuits. IFR holding patterns were conducted using one minute inbound legs and over a VOR using both VLOC and GPS modes. Eight pilots flew the AH-64A IFR equipment while conducting IFR holding. Four pilots accomplished the IFR area navigation task

with desired performance and four pilots achieved adequate performance. The desired performance standards were +/- 5 deg of heading, +/-5 knots airspeed, +/-50ft altitude, and 1 CDI dot. The adequate performance standards were +/- 10 deg of heading, +/-10 knots airspeed, +/-100 ft altitude, and 2 CDI dots. Both entry into IFR holding and the holding procedures were easy and intuitive using the AH-64A IFR equipment with low overall workload. The average workload rating was WL 3.8. The lowest workload rating was WL 3 and the highest was WL 5. The AH-64A IFR equipment significantly increased pilot's situational awareness of the aircraft's position relative to the IFR holding pattern. This made it very easy to determine the proper entry pattern procedure and cross wind corrections while in the holding pattern circuit. Even during adverse wind conditions, when cross wind corrections up to 30 degrees were required, the information displayed to the pilot is sufficient to quickly determine the amount of cross wind correction needed. The AH-64A IFR equipment is satisfactory for IFR holding.

The AH-64A IFR equipment was evaluated while executing a non precision VOR Instrument approach during day simulated IMC, night IFR, and day IMC conditions. Eight pilots flew the AH-64A IFR equipment while conducting a VOR approach. Six pilots accomplished the IFR area navigation task with desired performance and two pilots achieved adequate performance. The desired performance standards were +/- 5 deg of heading, +/-5 knots airspeed, 1 CDI dot, and +/-50ft of the minimum decision altitude (MDA). The adequate performance standards were +/- 10 deg of heading, +/-10 knots airspeed, 2 CDI dots, and +/-100 ft altitude of MDA. Both pilots who obtained adequate performance maintained desired performance parameters except airspeed, which reduced to 80 knots from 90 knots while executing the missed approach. When the missed approach was initiated, aircraft torque was increased from 35 percent to 65 percent to for climb power. Within 10 seconds and with no significant longitudinal cyclic movement, airspeed reduced by 10 knots. This task performance deviation was not related to the AH-64A IFR equipment. The average workload rating was low at WL 3.5 and all the ratings ranged from WL 3 to WL 5. Performing the non-precision VOR approach

was intuitive and similar to other aircraft with VOR capable equipment installed. The AH-64A IFR equipment provided both traditional bearing and course deviation indications as well additional situational awareness data that kept the pilot aware of his exact location throughout the entire maneuver. The low workload and increased situational awareness significantly increases the capability of the AH-64A to perform non-precision approaches. The AH-64A IFR equipment is satisfactory for VOR approaches.

The AH-64A IFR equipment was evaluated while conducting GPS approaches during day simulated IMC, night IFR, and day IMC conditions. Eight pilots flew the AH-64A IFR equipment while conducting a GPS approach. All eight pilots accomplished the task with desired performance. The desired performance standards were +/- 5 deg of heading, +/-5 knots airspeed, 1 CDI dot, and +/-50ft of the MDA. The average workload rating was low at WL 3.3 and all the ratings ranged from WL 2 to WL 5. Performing the task was similar to flying a standard NDB approach in an unmodified AH-64A except the AH-64A IFR equipment provided significantly improved situational awareness. The information provided by both the Garmin GNS 430 and Sandel 3308 display is very useful and easy to understand. The pilot had quick reference to all necessary information to properly execute the GPS approach, and consequently, the AH-64A IFR equipment effectively reduced pilot workload. Additionally, the Garmin GNS 430 provided a turn anticipation feature. This feature provided cues to turn prior to upcoming waypoints to keep the aircraft on the prescribed course and heading upon completion of the turn. The turn anticipation feature used ground speed, current heading, and the next leg's heading to calculate when to prompt the pilot to turn. Typically, the Garmin GNS 430 provided indications to turn early at approximately 1 nautical mile away from the selected waypoint. At this point, if the pilot turned towards the next heading at a standard turn rate, the aircraft was correctly aligned and on course upon achieving the new heading. These turn anticipation indications were easy to understand and allowed the pilot to execute the approach efficiently and accurately with only small, if any, track corrections upon turning to new course headings. The low

workload and increased situational awareness significantly increases the capability of the AH-64A to perform GPS non-precision approaches. The AH-64A IFR equipment is satisfactory for GPS approaches. The Garmin GNS 430 turn anticipation is an enhancing characteristic and will increase flight safety in adverse wind conditions by providing the pilot cues that help keep the aircraft on the prescribed course.

The AH-64A IFR equipment was evaluated while conducting ILS approaches during day simulated IMC, night IFR, and day IMC conditions. Eight pilots flew the AH-64A IFR equipment while conducting an ILS approach. All eight pilots accomplished the task with desired performance. The desired performance standards were +/- 5 deg of heading, +/-5 knots airspeed, 1 CDI dot, and +/-50ft of the decision height (DH). The average workload rating was low at WL 3.8 and all the ratings ranged from WL 3 to WL 5. Due to the precise nature of an ILS approach, the aircraft can be flown closer to the ground in IMC conditions and requires more precise altitude and course control. The AH-64A IFR equipment provides an outstanding reference system for maintaining desired precise altitude and course alignment throughout the ILS approach. The CDI sensitivity is adequate for this aircraft. Glide slope and course deviation needles were easy to read and follow. The needle response is properly scaled to the aircraft's actual position, and the needle indications were neither too sensitive nor overly damped. The low workload and increased situational awareness significantly increases the capability of the AH-64A to perform ILS precision approaches. The AH-64A IFR equipment is satisfactory for ILS approaches.

The AH-64A IFR equipment was evaluated while conducting PAR approaches during day simulated IMC, night IFR, and day IMC conditions. Five pilots flew the AH-64A IFR equipment while conducting a PAR approach. Four pilots accomplished the task with desired performance, and one pilot obtained adequate performance. The average workload rating was low at WL 3.8 and all the ratings ranged from WL 3 to WL 5. Performing the PAR approach is easy. The Sandel 3308 EFIS display provided satisfactory aircraft horizontal and situational information. Both the 360

degree and 70 degree arc view were satisfactory for precise heading control. Most pilots considered it easier to make fine heading adjustments using the 70 degree arc view than the 360 degree view while receiving final approach guidance.

Workload while using the AH-64A IFR equipment was evaluated during day simulated IMC, night IFR, and day IMC conditions. Pilots made workload assessments during all phases of IFR flight (ITO, RNAV, VOR approaches, GPS approaches, ILS approaches, and PAR approaches). Workload ratings ranged from WL 2 to WL 5. The highest workload ratings resulted while the pilot attempted to perform multiple tasks. All tasks were completed safely; however, programming the Garmin is a possible distraction for the pilot from the primary duties of aircraft control. Performing operations on the Garmin GNS 430 and flying the aircraft while attempting to maintain specific aircraft altitude, airspeed, and ground track parameters resulted in an increase of workload. As workload ratings increased with the additional task of programming the Garmin GNS 430, some pilots decided to transfer the controls to the Copilot Gunner (CPG) until the programming was complete. Additionally, there were data points where task performance degraded from desired to adequate and were directly attributed to the pilots divided attention between flying the aircraft and programming the Garmin GNS 430. Alternatively, workload was minimized when the pilot transferred the controls to the CPG, pre-programmed the Garmin GNS 430 prior to take-off, maintained pitch attitude with the heading attitude stability (HAS) system, or elected not to fully program the Garmin GNS 430. In the last case raw VOR, GPS, or NDB data displayed on the Sandel 3308 was used to perform the IFR task as it was not necessary to fly the AH-64A in an IFR environment with a complete flight plan and approach loaded into the Garmin GNS 430. For most of the pilots, the workload increase and division of attention was similar to flying the aircraft and simultaneously changing a radio frequency or the transponder squawk code. Interaction with the Garmin GNS 430 while flying the aircraft and maintaining desired task performance required the pilot to know exactly which function to perform and the exact sequence of buttons to push. Any

confusion about how to operate the GNS 430 drove the workload up. In all cases, maintaining control of the aircraft is not in question and the workload while using the AH-64A IFR equipment is satisfactory.

All flight functions operated correctly as per the Garmin operator's manual. The Garmin computed ETA and the EGI ETA were identical throughout the flight. The Garmin GNS 430 and the Sandel 3308 IFR equipment met the requirements for IFR qualification.

Conclusion

Overall Apache pilot workload in an IFR environment is satisfactory and flight safety is enhanced with a significant increase in situational awareness. Airspace information displayed on the AH-64A IFR equipment, increased flight safety and situational awareness for the crew. The Garmin GNS 430 turn anticipation feature increases AH-64A flight safety in adverse wind conditions by providing cues to keep the aircraft on the desired course. The AH-64A IFR equipment suite installed on the aircraft costs less than \$100,000 per aircraft and has potential to significantly enhance the flight safety and situational awareness in the cockpit and can take the AH-64A long into the future.

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