DESIGN OF A DISPLAY FOR ALERTING COCKPIT AUTOMATION FUNCTION CONFIGURATION CHANGES

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Abstract

The evolution of automation on the modern airliner flight deck has resulted in a "stack" of functions that has been incrementally "layered" over time to support the flight crew in performing the mission. The stack includes automation functions for: (1) Stability Augmentation and Engine Control for instantaneous control of aerodynamic control surfaces and engines, (2) Autopilot and Autothrottle for tactical control of the trajectory, and (3) Flight Management for strategic flight plan path management and optimization. By engaging/disengaging these functions there are up to 16 combinations of automation function configurations that can be engaged at any time. Due to the evolutionary development of the flight deck, the engagement status of the *combination of functions* is annunciated in an adhoc, distributed fashion across the flight deck displays. There is no single display of the consolidated automation function configuration.

Analysis of the accident scenarios for Controlled Flight into Stall (CFIS) accidents identified a category of accident in which an automation function (e.g. Autothrottle) autonomously dis-engaged without flight crew action. This resulted in the automation flying the aircraft into an aerodynamic stall. Without salient notification of the *engagement status change*, the flight crew's ability to mitigate the scenario in a timely manner was curtailed.

This paper describes the requirements, design and test plan to provide a single synoptic display of the consolidated automation function configuration status. The display appears whenever a configuration change occurs, otherwise it remains hidden. The implications and limitations of this design are discussed.

1 INTRODUCTION

The dominant category of aircraft accidents are classified as Loss of Control (LOC) accidents [1]. Within the LOC category is a class of accidents classified as Controlled Flight into Stall (CFIS) [2]. CFIS accidents are characterized by aircraft that experience an aerodynamic stall with a mechanically, electronically, structurally sound aircraft. Within the CFIS category there are two sub-categories of CFIS accidents:

(1) *No Active Speed Control:* the automation is coupled but no longer actively commands controls to the airspeed target. The selected guidance/control mode does not actively control to the airspeed target. Examples include "dormant throttles" (OZ214) and "land mode" (TK1951).

(2) *Silent De-coupling the Automation (i.e. disengagement)* resulting in no active speed control. Examples include silent "Autothrottle disconnects" (AAL903, ThompsonFly). There are also accident scenarios in which the automated airspeed protection (also known as Alpha-floor) is autonomously turned off. Examples include QZ851, AF447, XL Germany.

Mitigation of the "no active speed control" scenario is discussed in Sherry, Mauro, Trippe [3], [4]. The focus of this paper is the mitigation of (silent) disengagement of the automation functions whereby the configuration of the automation functions on the flight deck results in no active speed control.

This paper is organized as follows: Section 2 describes the flight deck automation "stack" and the alternate possible engagement configurations. Section 3 describes the CFIS accident scenarios related to flight deck automation configuration. Section 4 derives requirements for a consolidated annunciation of the flight deck automation configuration. Section 5 describes the design of the flight deck automation configuration display. Section 6 describes the design of an experiment to test the efficacy of the display. Section 7 provides Conclusions and discusses the implications and limitations of the design.

2 FLIGHT PATH MANAGEMENT AND FLIGHT DECK AUTOMATION CONFIGURATION

The flight deck of a modern airliner is a "human-machine system" with responsibility for managing the mission including, but not limited to, the management of the aircraft trajectory for origin to destination. This function, performed by various combinations of flight crew and automation functions, coordinates the movement of the aircraft control surfaces and propulsion to achieve a sequence of target altitudes, speeds and headings that constitute the segments of the departure, enroute, arrival and approach procedures in the mission flight plan.

The combination of **control surfaces** and engine controls are adjusted in a coordinated manner to maintain aerodynamic lift and thrust (i.e. energy) for the desired trajectory defined by target altitude, speed, and heading.

The combination of **target altitudes, speeds and headings** are coordinated to meet the requirements of the active leg of the flightplan or ATC instruction.

The **active leg of the flightplan** is based on the flightplan that includes the navigation procedures (e.g. SIDs, airways, STAR, Approach, …), airspace restrictions due to traffic and weather, traffic separation, and other safety, traffic flow management, and business considerations.

The flight crew are responsible for the overall conduct of the flight including the (a) mission flight plan, (b) targets and control modes for each segment of the flight plan and (c) control surface/propulsion commands for each target control mode combination.

Chronological Architecture of Flight Deck Automation Functions

Each of the flight crew tasks is supported by flight deck automation functions and their associated displays that have evolved over time. The evolution of has resulted in the "stacking" of functions that is found in the modern airliner (Figure 1). The stack includes:

(1) stability augmentation and engine control for instantaneous control of control surfaces and engines,

(2) tactical control of the trajectory to the targets,

(3) strategic flight plan path management through automated selection of the targets and control modes.

As the flight deck automation has evolved there are two alternate sources of **targets and control modes**, and two alternate sources of **elevator, aileron/rudder, and thrust commands** (Figure 1).

Sources of Targets and Control Modes

The *Flight Management System (FMS)* provides a means to define the flight plan and provides calculations for optimum speeds and route of flight to achieve fuel-burn, time of arrival, and time-enroute objectives. The flight crew interact with the FMS functions through a Multi-function Control and Display Unit (MCDU) and can visualize the flight plan on the Navigation Display (Figure 1).

The FMS automatically selects the appropriate targets and control modes based on the current aircraft position relative to the targets required for the current flight plan segment. The automatic selection of Altitude and Speed targets, and pitch and thrust control modes is known as Vertical Navigation or VNAV. The automatic selection of Heading/Course targets, and roll control modes is known as Lateral Navigation or LNAV.

The other source of targets and control modes is the *Mode Control Panel (MCP)*. The flight crew can select Altitude, Vertical Speed, Airspeed and Heading/Course targets directly via knobs and wheels. The flight-crew can also select the control mode via push-buttons on the MCP. When the flight crew select targets and modes on the MCP, it is fair to say they are following a flight plan or navigation procedure, albeit not the exact flight plan in the FMS.

The flight crew determine whether to fly the VNAV or LNAV targets and control modes or to use the MCP selected targets and control modes by selecting the VNAV and LNAV buttons on the MCP. When VNAV or LNAV buttons are <u>not</u> selected, the

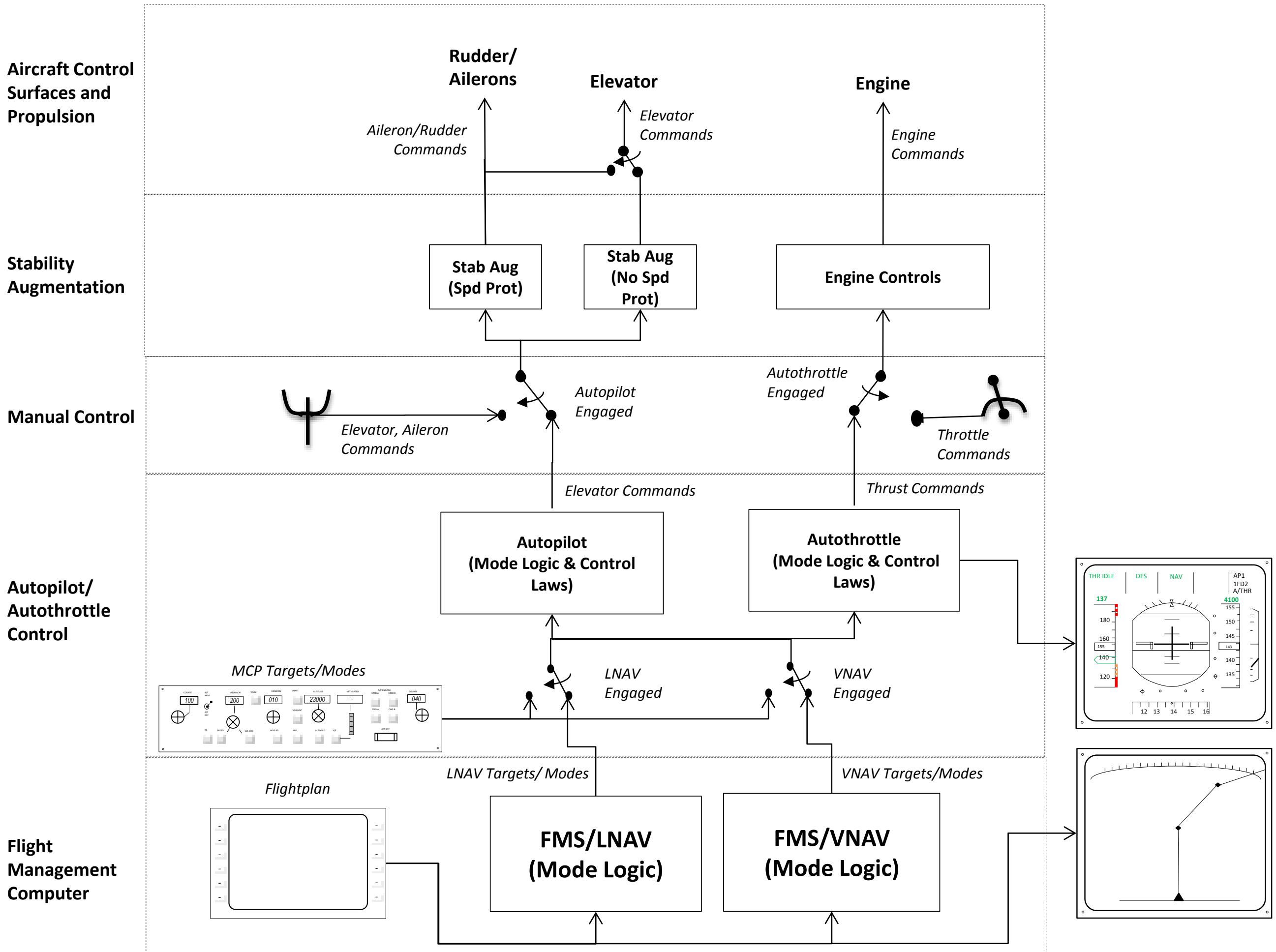

FIGURE 1: Chronological architecture of the modern airliner flight deck automation functions with switches (shown as two-pole switches) for selecting the source of targets and control modes, and for selecting the pitch, roll and thrust commands.

targets and control modes come from the MCP, otherwise from the FMS.

VNAV/LNAV, also known as PROF/NAV on some aircraft, represent "mega-modes" as they automatically select the control-modes for pitch, roll and thrust.

Sources of Commands

The *Autopilot -Autothrottle*, or Flight Guidance and Flight Control (FG/FC) System convert the targets from the FMS or MCP into commands to the control surfaces (e.g. elevators, ailerons, and rudder) and to the propulsion system such that the aircraft achieves the specified targets. These commands are coordinated in such a way that the aircraft maintains aerodynamic stability and remains within the safe operation regime at all times with passenger comfort considerations.

An alternate source of commands is via *the side-stick/yoke* and *throttle lever*. Likewise, when the flight crew command pitch, roll and thrust using the stick and the throttle lever, it is fair to say they are following a flight plan or navigation procedure, and maintaining aerodynamic stability, albeit not the exact flight plan in the FMS or by the same energy strategy in the Autopilot/Autothrottle.

The status of the Autpilot and Autothrottle engaged switches determine the source of commands.

The propulsion and control-surface commands are converted to actuator commands by Flight

Control & Stability Augmentation and Full Authority Digital Engine Control systems. These systems compensate for non-linearities in the aerodynamics and engine performance.

Flight Deck Automation Function Configuration

The FMS targets and control modes are used by the Autopilot when the VNAV and LNAV mega-modes are selected. When VNAV and LNAV are engaged the flight planning, guidance and control automation is considered to be in the "managed" configuration (Figure 1). When LNAV or VNAV are no longer selected, the Autopilot uses the targets and control modes from the MCP.

When the Autopilot, and/or Autothrottle are no longer selected, the Engine Controls and Stability Augmentation use the commands from the stick and throttle lever.

As a consequence, the combination of LNAV, VNAV, Autopilot and Autothrottle selections can result in flight deck automation can be configures in 16 combinations (Table 1).

TABLE 1: Flight deck Automation Function Configuration combinations for LNAV, VNAV, Autopilot and Autothrottle

Automation Function Configuration				Source of Targets		Source of Commands		
VNAV	**LNAV**	**AP**	**AT**	**Alt, Airspeed, ROC/D**	**Heading /Course**	**Pitch**	**Roll**	**Thrust**
Eng	Eng	Eng	Eng	MCDU	MCDU	AP	AP	AT
	Eng	Eng	Eng	MCP	MCDU	AP	AP	AT
Eng		Eng	Eng	MCDU	MCP	AP	AP	AT
		Eng	Eng	MCP	MCP	AP	AP	AT
Eng	Eng		Eng	MCDU	MCDU	S&R	S&R	AT
	Eng		Eng	MCP	MCDU	S&R	S&R	AT
Eng			Eng	MCDU	MCP	S&R	S&R	AT
			Eng	MCP	MCP	S&R	S&R	AT
Eng	Eng	Eng		MCDU	MCDU	AP	AP	ThL
	Eng	Eng		MCP	MCDU	AP	AP	ThL
Eng		Eng		MCDU	MCP	AP	AP	ThL
		Eng		MCP	MCP	AP	AP	ThL
Eng	Eng			MCDU	MCDU	S&R	S&R	ThL
	Eng			MCP	MCDU	S&R	S&R	ThL
Eng				MCDU	MCP	S&R	S&R	ThL
				MCP	MCP	S&R	S&R	ThL

Display Flight Deck Automation Function Configuration

The incremental evolution of the flight deck automation functions over time is reflected in the *flight deck user-interface which does* ***not*** *reflect the functional architecture* (i.e. the stack), and does **not** *have single display of the consolidated automation function configuration.*

For the flight crew, the primary source of information on aircraft energy-state is the Primary Flight Display (PFD). The modern "glass" PFD is an integrated version of the federated "steam gauge" displays used in older aircraft that used one gauge for each parameter. Information about the automation function engagement status, targets, and modes has been layered into the PFD. Many of the features of the PFD were designed prior to the evolution of the automation and were *not explicitly designed to support tasks associated with monitoring complex automation for inappropriate commands*.

The PFD, see Figure 2, is organized as follows. The center section of the display is an attitude indicator (AI). The top of the AI has a bank indicator. To the left of the AI is an airspeed tape. To the right of the AI is the altitude tape and vertical speed

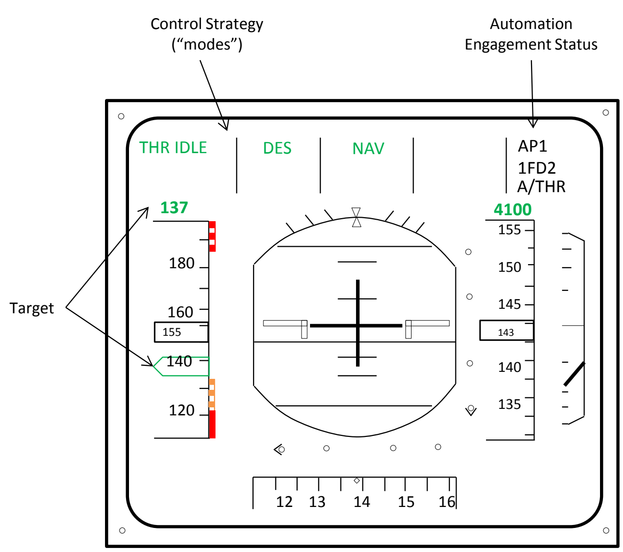

FIGURE 2: Example of a generic Primary Flight Display (PFD). that was designed prior to evolution of flight deck automation

indicator. Below the AI is a partial compass rose that displays the aircraft heading. Above the AI is the Flight Mode Annunciator (FMA).

The FMA displays the control modes for each of the roll, pitch and thrust axes (Figure 2). It also displays the status of the Autopilot and Autothrottle. Some FMAs use labels to indicate VNAV and LNAV status (e.g. VNAV-PATH). Other FMAs use color codes to indicate VNAV and LNAV engagement (i.e. magenta)

The PFD does not explicitly display whether the automation is controlling to the targets and the labels displayed on the FMA are sometimes ambiguous. These issues may have contributed to several CFIS incidents and accidents [4].

The Mode Control panel is the input device for pilot manual selection of the targets and modes, *and* for coupling (i.e. engaging the automation functions). The MCP also does not provide a visual indication of the automation "stack" or the consolidated status of the automation configuration (Figure 3.)

3 CFIS ACCIDENTS AND FLIGHT DECK AUTOMATION CONFIGURATION

In several recent accidents and incidents a structurally, mechanically, and electronically sound commercial airliner decelerated through the minimum safe operating speed (1.3 VStall) to the stick-shaker stall speed.

Each of these "Controlled Flight into Stall (CFIS)" accidents and incidents followed a unique sequence of events [2]. However, the sequence of events exhibited a general pattern in which: (1) a triggering event (e.g., sensor discrepancy, and/or erroneous flight crew entry) resulted in (2) an effect on the automation (e.g. a mode change, change in automation Function engagement status, or inappropriate target), that led to (3) an inappropriate automation command that in turn, (4) resulted in a speed envelope violation.

In each of these cases, the flight crew was not able to intervene in a timely manner because (1) the triggering event was not annunciated or if it was annunciated, the consequences of the triggering event were ambiguous, (2) the changes in the automation states were not explicitly annunciated on the flight deck, (3) the inappropriate command was not salient and (4) the resulting deceleration was masked by an appropriate trajectory maneuvers.

Automation Function Engagement Status

In several cases, the automation autonomously disengaged, no longer coupling the automation commands to the control surfaces and engines (Table 2). The American Airlines (AAL) 903 incident is an example of this scenario. AAL 903 was instructed to hold at 16,000' due to a weather cell on the arrival procedure. The aircraft decelerated and leveled-off as it made the turn into the holding pattern. During the turn and level-off, with the A/T commanding idle thrust, the A/T autonomously disengaged. Without the A/T coupled to the engines, and the thrust at idle, the aircraft decelerated well below the minimum safe operating speed (1.3 VStall) before the stick-shaker got the flight crews attention.

A sample of CFIS accidents associated with change in Flight deck Automation Function Configuration is provided in Table 2.

Mitigating Flight deck Automation Function

FIGURE 3: Example of Mode Control Panel (MCP) that hides the "stack" architecture with LNAV and VNAV buttons at the same "level" as mode buttons and A/T and A/P engagement switches.

Configuration CFIS Accidents

The VNAV, LNAV, A/P, and A/T status are annunciated on the push-buttons on the MCP (Figure 3). In some MCP designs the position of a toggle switch also indicates the status of the A/P. The main source of flight deck automation function configuration status is the PFD (Figure 2). There are several designs of PFD but in some form they all display the A/P and A/T status as labels, and the VNAV, LNAV status as either labels (e.g. VNAV-PTH), or by color (e.g. magenta for VNAV, LNAV).

In some flight deck designs the disengagement of the A/P or A/T results in a Caution/Warning annunciation that can only be extinguished by the flight crew action of pressing the Caution/Warning button. In modern glass flight decks a slew of error messages may also appear on the Synoptics displays associated with A/P or A/T dis-engagement (e.g. AF 447 sensor discrepancies that lead to A/P and A/T status change).

TABLE 2: Sample of CFIS accidents associated with change in Flight deck Automation Function Configuration

Accidents and Incidents	Maneuver	Effects of Triggering Events on Automation
AAL 903	Decelerating entering a holding pattern at FL160	Autothrottle no longer engaged for speed control
ThomsonFly, Bournemouth ThompsonFly, Belfast ThomsonFly, not specified	Decelerating on approach	Autothrottle no longer engaged for speed control
Midwest 490	Climb	Autopilot no longer engaged for speed control
JetStar 248	Decelerating on approach	Autothrottle no longer engaged for speed control
Air France 447	Cruise (Coffin Corner)	Autopilot and Autothrottle no longer engaged for speed control. Also speed protection turned off.
AirAsia 8501	Cruise (coffin Corner)	Autopilot and Autothrottle no longer engaged for speed control. Also speed protection turned off.
XL Germany	Descending	Speed protection turned off

4 REQUIREMENTS AND DESIGN OF FLIGHT DECK AUTOMATION FUNTION CONFIGURATION DISPLAY AND ALERTING

To address issues associated with CFIS and other classes of accidents, researchers have developed concepts to improve the detection, recognition, and diagnosis of this speed deviation. For example, concepts that would increase the salience of the low speed condition [5], provide additional displays to anticipate the low speed condition [3], [4], manage aircraft energy [6, 7, 8, 9, 11], and eliminate ambiguity in mode labels [10] have been proposed. None of these proposals explicitly address the scenario related to automation function status as result of autonomous decoupling..

Requirements

To address the automation decoupling scenario the following requirements for an Automation Function Configuration (AFC) display have been established:

1. AFC shall identify the status of the source of targets and control modes for Lateral and Vertical (includes speed) trajectories
2. AFC shall provide status in one location (not distributed across the flight deck)
3. AFC shall provide visual cues to the flight crew (and possibly aural/haptic as well)
4. AFC shall identify manual selection and deselection as well as autonomous deselection
5. AFC shall identify unlikely combinations of status

Design

1 Display the source of the targets and control modes for LNAV, VNAV, A/P, A/T and Stability Augmentation (Speed Protection)

2 Identify sources that are not used

3 Display the un commanded configuration status changes
4 Display anomalous configurations

5 SPECIFICATION OF THE FLIGHT DECK AUTOMATION FUNCTION CONFIGURATION DISPLAY

A wire-frame of the synoptic flight deck automation function configuration is shown in Figure 4. The wire-frame depicts the flow of information through the automation functions with "switches" for sources of targets and control modes, sources of commands, and for automated speed protection. Note: the stick and throttle lever are shown to over-ride the pitch, roll, and thrust commands from the Autopilot and Autothrottle.

The diagram is color coded according to the logic defined for the graphic objects in Figure A-1 in the Appendix. The color code identifies the source of the targets and modes: magenta for VNAV, LNAV source, green for MCP source, and white for stick/rudder and throttle inputs. When a source is decoupled it is gray.

The AFC is not displayed until a configuration change occurs and then pops-up on the synoptic display as if to say "is that what you wanted to happen. Click OK to Continue."

If the transition was autonomous (i.e. not pilot selected), the sections of the display that changed flash for 3 seconds. For example if VNAV transitions from engaged to not engaged, the graphic objects that changed to magenta flash for 3 seconds. Likewise if the Autothrottle is disengaged, the graphic objects that changed to gray flash for 3 seconds. If the transition was pilot selected there is no flashing.

The AFC is hidden and the synoptic display returns to previous page when the pilot touches the display or selects an OK button. One option is to require pilot verification only for autonomous configuration changes (e.g. an autonomous Autothrottle disconnect). When the pilot pushes a button (e.g. VNAV), the AFC is displayed for 5 secs and then automatically returns to the previous display.

The AFC can be displayed at any time by pilot selection on the synoptic display options input device.

A sample display is illustrated in Appendix 5

6 DESIGN OF EXPERIMENT

Null Hypothesis: Operators with the AFC Display shall perform the same or worse than operators with the standard Flight Deck displays.

A human-in-the-loop experiment was designed to evaluate the efficacy of the AFC Display. Airline pilots currently flying Boeing aircraft will recruited to participate in an simulator study comparing a traditional flight deck design (used in the Boeing 777) and an enhanced flight deck design designed to alert the pilot when airspeed is not being controlled by the autoflight system due to a change in the Automation Function Configuration.

Participating pilots will be seated in the left seat performing the role of Pilot flying (PF) with confederate pilot serving as Pilot Monitoring (PM).

Reaction time will be used to determine whether the AFC Display will have any effects because reaction times are more sensitive measures of performance than error rates. The pilots will be instructed to indicate automation function configuration changes path by explicitly verbalizing the change in status. . The pilot's reaction time from the time that the decoupling occurred until the pilot explicitly identified the decoupling will be recorded.

Eight scenarios will be used for normal operation and 8 scenarios depicted a problem. Half of the scenarios will depict a traditional Boeing Flight deck and half depict an enhanced Boeing Flight deck with a AFC Display.

The scenarios that will be presented on each type are counterbalanced across the participants. The order of presentation, traditional first or enhanced first, will also be counterbalanced.

Two sets of 8 situations will be produced, set "A" and set "B." For each situation, two versions were constructed. One depicted the situation progressing normally. The other depicted a decoupling of the automation. Each pilot will view all

16 situations with 4 situations from each set depicting a normal flight and 4 depicting a decoupling.

For half of the pilots, set A scenarios were depicted on a traditional flight deck and set B scenarios were depicted on an enhanced flight deck. For the other half of the pilots, the relation between sets and flight deck type will be reversed. Prior to being shown the enhanced flight deck scenarios, the enhancements will be described to the pilots and they will be shown 4 practice scenarios.

For each flight scenario, the pilot subject will first be shown a brief written description of the scenario along with ATC-like instructions in italics that described what would happen in the upcoming slides. For example, "Inbound to KJFK RWY 31R; maintain 1900 feet; heading 285 to intercept the localizer; cleared ILS RWY 31R." If the scenario placed the pilot's aircraft on an approach, the participants were also shown an approach plate with

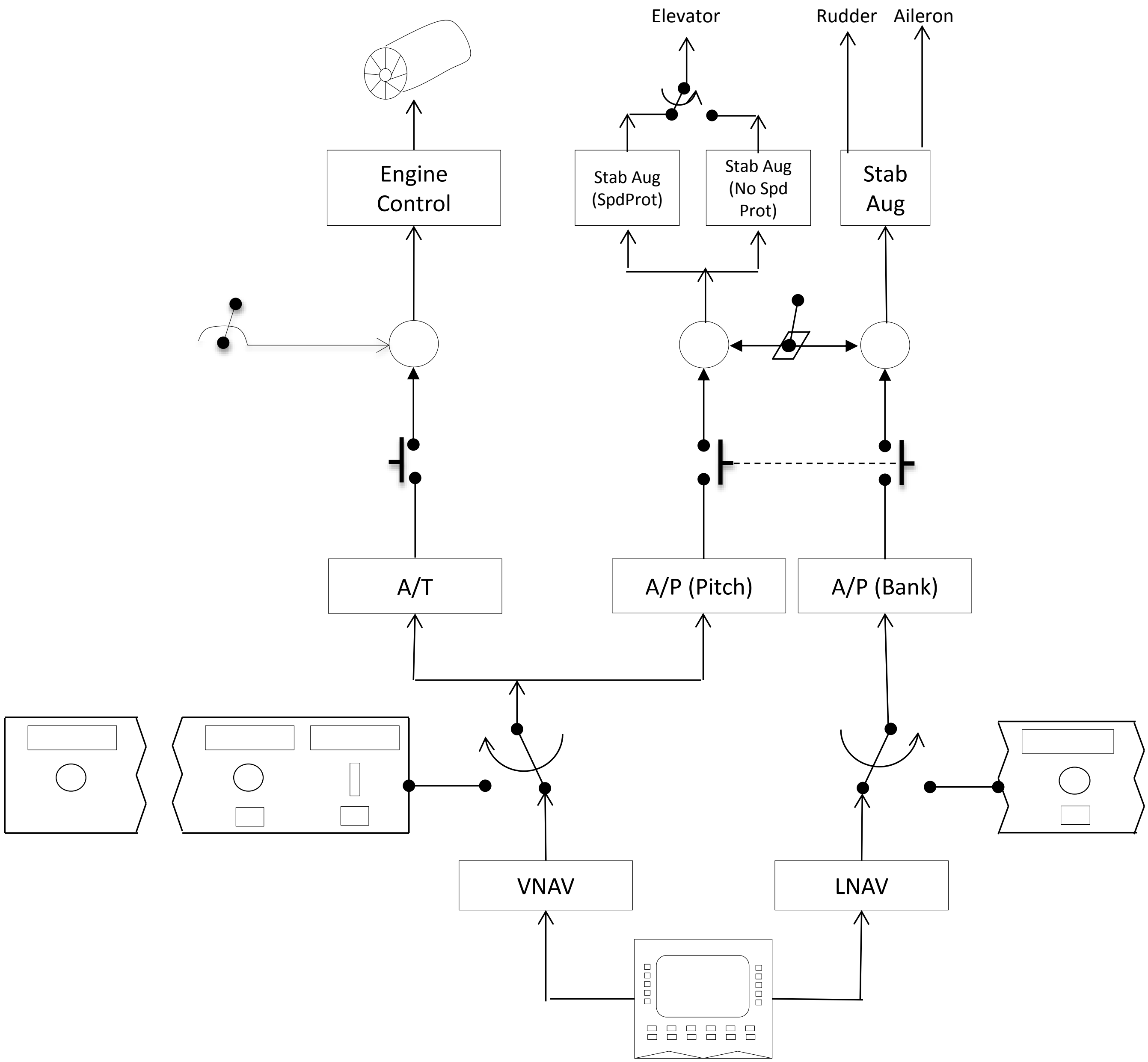

FIGURE 4: Wire-frame of the synoptic flight deck Automation Function Configuration display

the approximate vertical and lateral position of the aircraft indicated.

After the description the pilots were instructed to fly the procedure.

Scenarios:

Climb with Energy Management Disconnect: Aircraft climbing to Crz FL 350. ATC requests expedite climb. Confederate pilot uses Vertical Speed mode and sets Climb rate in excess of rate possible with available thrust (e.g. 5500 fpm). Airspeed decays and Autopilot and Autothrottle silently disengage.

Cruise Disconnect/Weather: Cruise in turbulence with weather reroutes. Aircraft in "coffin corner" with small range between VMO and VMIN. Aircraft decelerating when Autopilot and Autothrottle silently disengage.

Cruise Disconnect/Aircraft System Malfunction: Cruise in turbulence with weather and aircraft system malfunction messages that pilots are diagnosing. Aircraft in "coffin corner" with small range between VMO and VMIN. Aircraft decelerating when Autopilot and Autothrottle silently disengage.

LNAV not re-engaged. Cruise flightlevel weather and traffic avoidance taking place simultaneously. VNAV and LNAV engaged. ATC requests route change that is coordinated and entered into MCDU flight plan by confederate pilot (PM). The re-route has large course change in 10nm (e.g. 60 degrees). LNAV is re-enagaged. ATC requests course change for traffic. PM uses Heading mode and

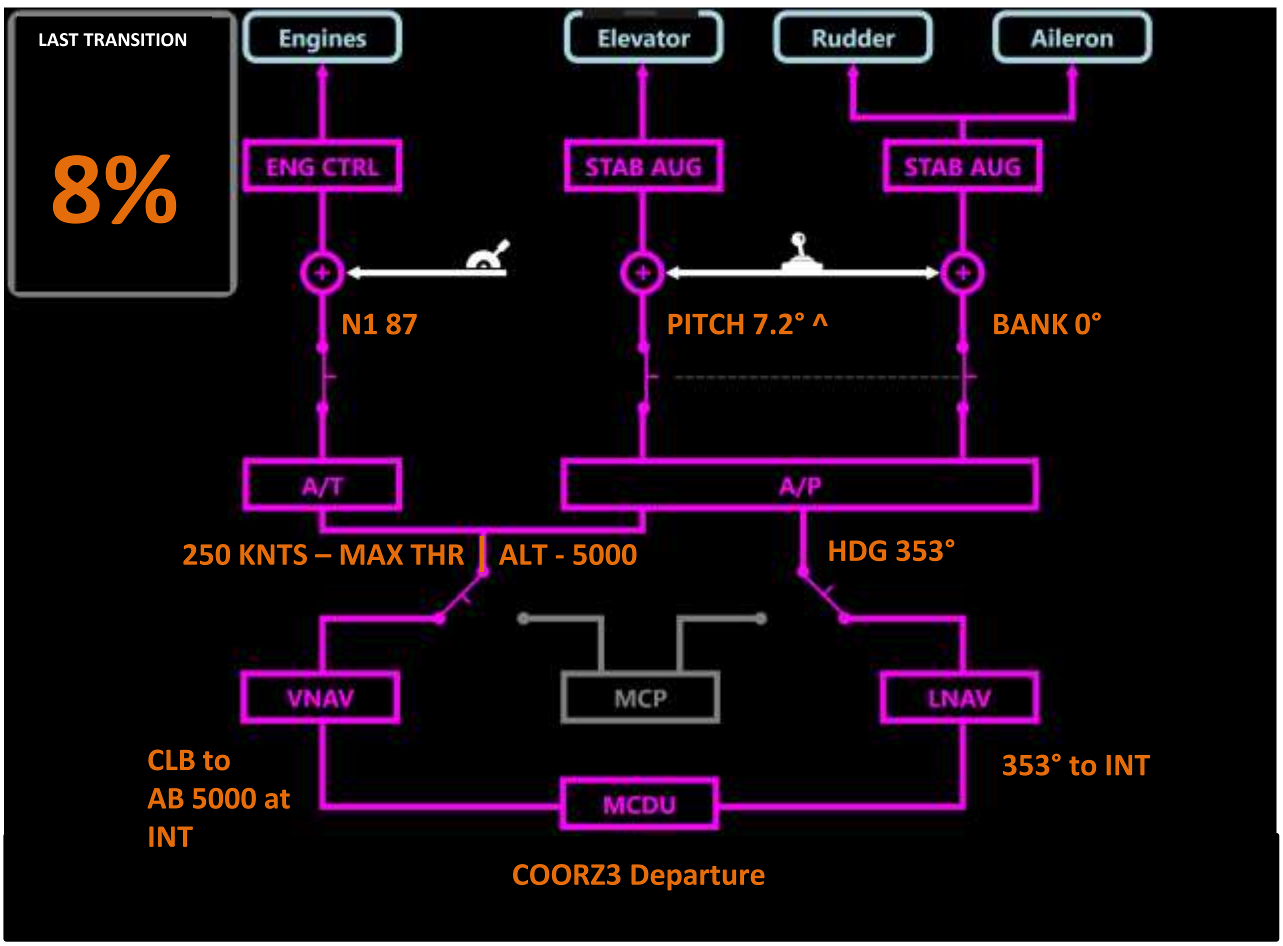

FIGURE 5: AFC display for VNAV/LNAV/AP/AT with: (1) probability of last transition display, (2)

"accidently" does not re-engage LNAV. The aircraft does not make the course change.

VNAV not re-engaged. Descending on VNAV path with several crossing restrictions and speed restrictions. ATC requests lateral path offset for traffic. Heading mode used to fly procedures turn (360 degree) that causes VNAV to *silently* disengage. Aircraft misses crossing restriction.

Deceleration to Max Endurance Hold Speed. Flight descending to destination airport from FL 350. When passing through FL200, the flight is instructed by ATC to hold at waypoint 10 nm away and level-off at FL160. During the turn into the hold, while the aircraft is decelerating to the Max Endurance speed, with the throttles at idle, the Autothrottle is *silently* disconnected.

Deceleration to Approach Landing Speed. Flight is descending on an extended glideslope from 3000'AGL and 9 nm from the destination runway. While the flight is decorating to the approach speed on the glide path with the throttles at idle, the Autothrottle is *silently* disconnected.

Go Around. Overfly Missed Approach point and initiate a Go Around. During rotate and pitch-up phase, Autothrottle is *silently* disconnected.

7 CONCLUSIONS

This paper describes the requirements, design and tests to provide a single synoptic display of flight deck automation function configuration status. This display is designed specifically to provide situation awareness to the flight crew of rare events when the automation function (e.g. Autothrottle) autonomously dis-engages without flight crew action and without salient notification of the *engagement status change*. This curtails the flight crew's ability to mitigate the scenarios in a timely manner.

Preliminary experiment results show that the display is effective in bringing pilot attention to the transition. The display did not have an adverse effect on pilot cockpit operations. Experiment subject feedback identified several candidate additions to the display:

(1) the probability of the last transition (based on historic data). See Figure 5.

(2) the probability of the next transition (based on historic data).

(3) the flight plan intentions, targets and control modes and the commands. See Figure 5 and Figure 6.

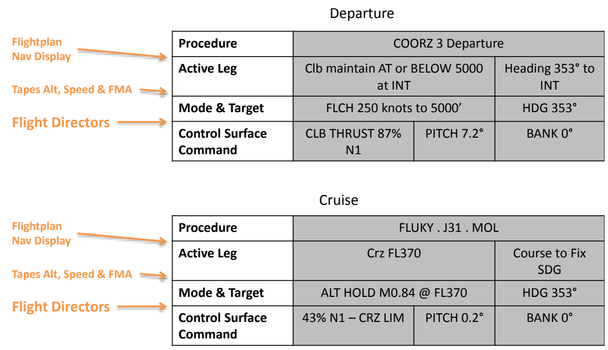

FIGURE 6: Intention, Target/Control Mode, and Command Display

Experiment subject feedback also commented on the utility of the display for training purposes.

Other Related Issues

Pitch and thrust are cross-coupled and also, together determine the energy-state of the aircraft. However, the A/P and A/T have their own vertical stacks and no interconnection. If these stacks were truly integrated, the combined automation system could much more readily project energy states. For example, the system could identify situations such as Scenario 1 above well before they became critical.

Current FMAs also identify modes that are "armed for conditional engagement". This information could be incorporated into this display.

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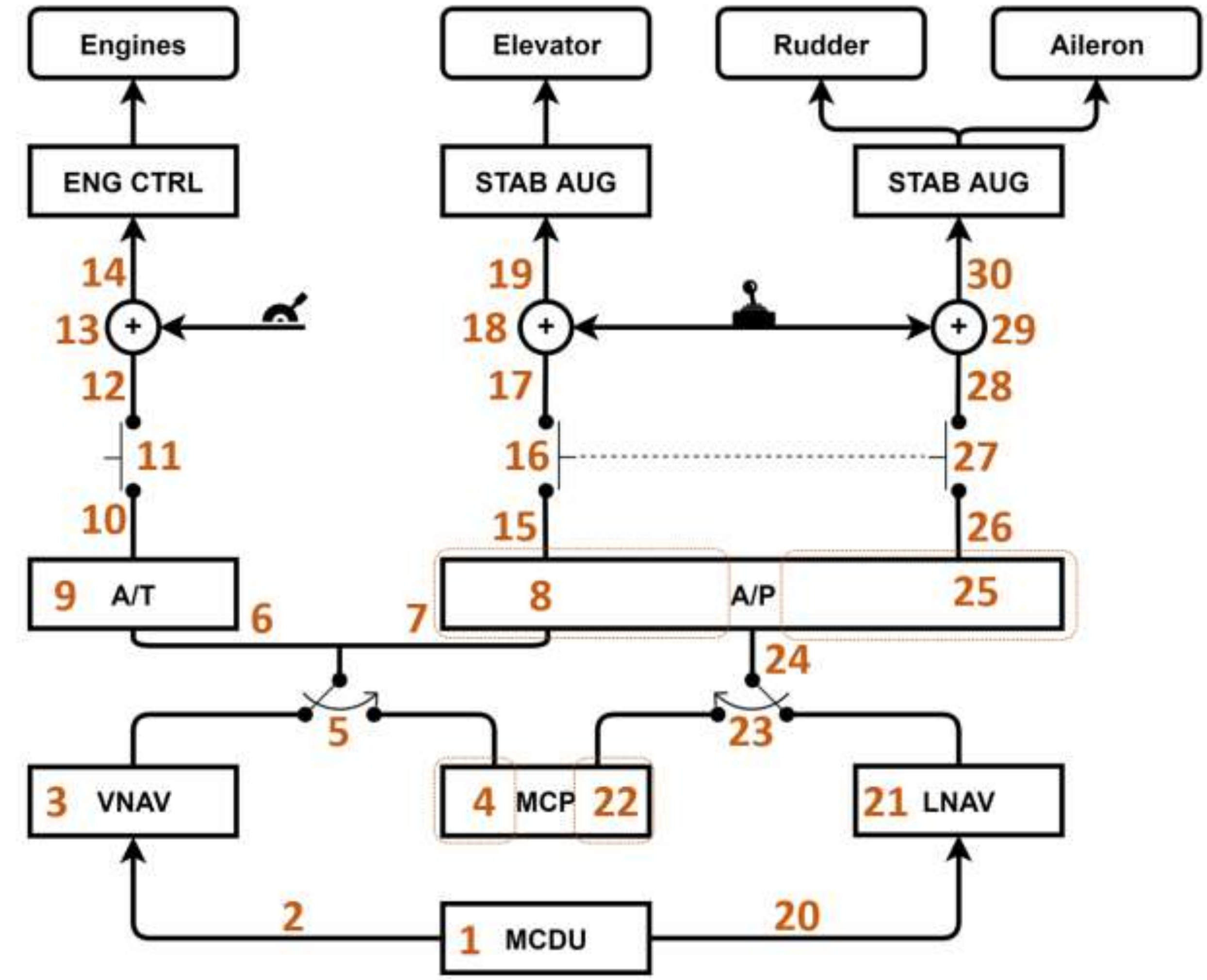
APPENDIX A



VNAV		On	On	On	On	On	On	On	On
LNAV		Off	Off	Off	Off	On	On	On	On
A/P		On	Off	On	Off	On	Off	On	Off
A/T		On	On	Off	Off	On	On	Off	Off
	MCDU	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta
	MCDU to VNAV	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta
	VNAV Box	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta
	Vert MCP	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray
	VNAV MCP Switch	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta	Magenta

	VNAV to AT	Magenta	Magenta	Gray	Gray	Magenta	Magenta	Gray	Gray
	VNAV to AP	Magenta	Gray	Magenta	Gray	Magenta	Gray	Magenta	Gray
	AP Pitch Box	Magenta	Gray	Magenta	Gray	Magenta	Gray	Magenta	Gray
	AT Box	Magenta	Magenta	Gray	Gray	Magenta	Magenta	Gray	Gray
0	AT Box to AT Switch	Magenta	Magenta	Gray	Gray	Magenta	Magenta	Gray	Gray
1	AT Switch	Magenta	Magenta	Gray	Gray	Magenta	Magenta	Gray	Gray
2	AT Switch to AT Circle	Magenta	Magenta	Gray	Gray	Magenta	Magenta	Gray	Gray
3	AT Circle	Magenta	Magenta	White	White	Magenta	Magenta	White	White
4	AT Circle to Engine	Magenta	Magenta	White	White	Magenta	Magenta	White	White
5	AP Pitch Box to AP Switch	Magenta	Gray	Magenta	Gray	Magenta	Gray	Magenta	Gray
6	AP Pitch Switch	Magenta	Gray	Magenta	Gray	Magenta	Gray	Magenta	Gray
7	AP Pitch Switch to AP Circle	Magenta	Gray	Magenta	Gray	Magenta	Gray	Magenta	Gray
8	AP Pitch Circle	Magenta	White	Magenta	White	Magenta	White	Magenta	White
9	AP Pitch Circle to Stab Aug Elev	Magenta	White	Magenta	White	Magenta	White	Magenta	White
0	MCDU to LNAV	Gray	Gray	Gray	Gray	Magenta	Magenta	Magenta	Magenta
1	LNAV Box	Gray	Gray	Gray	Gray	Magenta	Magenta	Magenta	Magenta
2	Lat MCP	Green	Gray	Green	Gray	Gray	Gray	Gray	Gray
3	LNAV MCP Switch	Green	Gray	Green	Gray	Magenta	Magenta	Magenta	Magenta
4	LNAV to AP Bank	Green	Gray	Green	Gray	Magenta	Magenta	Magenta	Magenta
5	AP Bank Box	Green	Gray	Green	Gray	Magenta	Gray	Magenta	Gray
6	AP Bank Box to AP Switch	Green	Gray	Green	Gray	Magenta	Gray	Magenta	Gray
7	AP Bank Switch	Green	Gray	Green	Gray	Magenta	Gray	Magenta	Gray
8	AP Bank Switch to AP Circle	Green	Gray	Green	Gray	Magenta	Gray	Magenta	Gray
9	AP Bank Circle	Green	White	Green	White	Magenta	White	Magenta	White

0	AP Bank Circle to Ailerons/Rudder	Green	White	Green	White	Magenta	White	Magenta	White

	VNAV	Off	Off	Off	Off	Off	Off	Off	Off
	LNAV	On	On	On	On	Off	Off	Off	Off
	A/P	On	Off	On	Off	On	Off	On	Off
	A/T	On	On	Off	Off	On	On	Off	Off
	MCDU	Magenta	Magenta	Magenta	Magenta	Gray	Gray	Gray	Gray
	MCDU to VNAV	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray
	VNAV Box	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray
	Vert MCP	Green	Green	Green	Gray	Green	Green	Green	Gray
	VNAV MCP Switch	Green	Green	Green	Gray	Green	Green	Green	Gray
	VNAV to AT	Green	Green	Gray	Gray	Green	Green	Gray	Gray
	VNAV to AP	Green	Gray	Green	Gray	Green	Gray	Green	Gray
	AP Pitch Box	Green	Gray	Green	Gray	Green	Gray	Green	Gray
	AT Box	Green	Green	Gray	Gray	Green	Green	Gray	Gray
0	AT Box to AT Switch	Green	Green	Gray	Gray	Green	Green	Gray	Gray
1	AT Switch	Green	Green	Gray	Gray	Green	Green	Gray	Gray
2	AT Switch to AT Circle	Green	Green	Gray	Gray	Green	Green	Gray	Gray
3	AT Circle	Green	Green	White	White	Green	Green	White	White
4	AT Circle to Engine	Green	Green	White	White	Green	Green	White	White
5	AP Pitch Box to AP Switch	Green	Gray	Green	Gray	Green	Gray	Green	Gray
6	AP Pitch Switch	Green	Gray	Green	Gray	Green	Gray	Green	Gray
7	AP Pitch Switch to AP Circle	Green	Gray	Green	Gray	Green	Gray	Green	Gray
8	AP Pitch Circle	Green	White	Green	White	Green	White	Green	White
9	AP Pitch Circle to Stab Aug Elev	Green	White	Green	White	Green	White	Green	White
0	MCDU to LNAV	Magenta	Magenta	Magenta	Magenta	Gray	Gray	Gray	Gray
1	LNAV Box	Magenta	Magenta	Magenta	Magenta	Gray	Gray	Gray	Gray

2	**Lat MCP**	Gray	Gray	Gray	Gray	Green	Gray	Green	Gray
3	**LNAV MCP Switch**	Magenta	Magenta	Magenta	Magenta	Green	Gray	Green	Gray
4	**LNAV to AP Bank**	Magenta	Magenta	Magenta	Magenta	Green	Gray	Green	Gray
5	**AP Bank Box**	Magenta	Gray	Magenta	Gray	Green	Gray	Green	Gray
6	**AP Bank Box to AP Switch**	Magenta	Gray	Magenta	Gray	Green	Gray	Green	Gray
7	**AP Bank Switch**	Magenta	Gray	Magenta	Gray	Green	Gray	Green	Gray
8	**AP Bank Switch to AP Circle**	Magenta	Gray	Magenta	Gray	Green	Gray	Green	Gray
9	**AP Bank Circle**	Magenta	White	Magenta	White	Green	White	Green	White
0	**AP Bank Circle to Ailerons/Rudder**	Magenta	White	Magenta	White	Green	White	Green	White

FIGURE A-1: Color code for each graphic object in the display.