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F-14D DISPLAY/SPIN STUDY

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An evaluation of the improvements of the F-14D cockpit configuration was conducted at the Dynamic Flight Simulator (DFS) Facility at NAVAIRDEVCEN in Warminster, PA. The purpose of the study was to demonstrate to selected F-14A pilots, the appearance and operation of the F-14D advanced controls and displays in both controlled and out-of-control flight regimes. Eleven active duty F-14A pilots participated in a two day exercise. Pilots flew Air-to-Air (A/A), Air-to-Ground (A/G) mission segments statically (no G forces) and flat spin recovery segments both statically and dynamically (under G forces). General display questionnaire responses indicate that the major displays, the Head-Up-Display (HUD) and Multifunction displays (MFD'S), were easy to use. It was found through quantitative and qualitative analysis that the HUD Declutter level best for tracking an airborne target and the most preferred format was Declutter I, the best for ground target elimination was Declutter I, and the spin recovery aid most preferred was the F-14D spin arrow. The voice commanded recovery system (VCRS), a verbal spin

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recovery aid, received high ratings for usefulness from the pilots, but should continue to be refined. Spin familiarization was considered by all participants to be valuable for F-14 aircrew. When asked if they would recommend this type of spin familiarization to others, all pilots responded positively, and the majority recommended spin familiarization at least once a tour. Display recommendations include the incorporation of large and centrally located range and Vc readouts for A/A HUD formats, waterline reference bars on all VDI modes, and the examination of the Take-off, Landing, and Navigation display formats during simulated carrier approach.

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INTRODUCTION

BACKGROUND

Tactical aircraft flight simulators generally lack realism in the maneuvering environment. The high forces characteristic of tactical maneuvering are difficult to simulate with conventional motion base schemes. Physical limits and allowable displacements of conventional motion base simulators restrict the magnitude and duration of the forces used for maneuvering cues. The inability of conventional flight simulators to produce representative force cues detracts from the realism of the simulation, particularly for out-of-control flight phases, such as the departure/spin phase.

The F-14 has been shown to exhibit a flat spin mode with yaw rates and longitudinal accelerations in excess of 150 deg/sec and negative 5 Gx (eyeballs-out), respectively, at the pilot's station. These conditions have caused the loss of aircraft and aircrew. Such conditions are extremely difficult to investigate safely in the real aircraft but are well suited to centrifuge simulation (reference 1). For this reason, the Naval Air Development Center (NAVAIRDEVCEN) has developed a total G-force simulation capability known as the Dynamic Flight Simulator (DFS). Using the NAVAIRDEVCEN three degree-of-freedom human centrifuge as a motion and force base, the DFS is capable of simulating the total multidirectional (i.e. 6 degrees of freedom) G-force environment of modern high performance aircraft (reference 2). The DFS is used as a safe platform for evaluating new concepts in crew station design, cockpit displays and controls, restraint systems, aerodynamic configuration and handling qualities. The DFS is currently configured to simulate the F-14D aircraft flight environment. A detailed description of the DFS F-14D cockpit configuration and operation is presented in Appendix A.

PURPOSE

An evaluation of the improvements made to the F-14, incorporated in it's D-version, was conducted in the DFS at NAVAIRDEVCEN in Warminster, PA. The study was performed for three weeks, 20 July and 7 August 1987. The purpose of the evaluation was to demonstrate, to selected F-14A pilots, the appearance and operation of the F-14D advanced controls and displays in both controlled and out-of-control flight regimes. The specific objectives of the project were (1) to examine the ease of use of the F-14D front panel controls and displays (2) to examine various levels of clutter on the Head-Up-Display (HUD) during Air-to-Air (A/A) and Air-to-Ground (A/G) target tracking scenarios and (3) to evaluate three flat spin recovery aids: the F-14A spin arrow format, the F-14D spin arrow format and a Voice-Commanded-Recovery-System (VCRS). The test matrix used for this evaluation varied the order in which display formats were presented to each pilot. This system was implemented to avoid biasing results (i.e., performance or preferences). Analysis of pilot performance measures and questionnaire responses consisted of determining trends/tendencies of participating F-14, with a 95% significance level.

This paper presents the results obtained and provides recommendations for F-14D controls, displays, and departure/spin recovery aids.

METHODOLOGY

SCOPE

Operational capabilities and limitations, as well as the available aerodynamic models, served to impact the scope of this F-14D display/spin study. Thus, the modes of flight were restricted to Air-to-Air, Air-to-Ground, and Departure/Spin. The current DFS F-14D aerodynamic model has no take-off and landing portion, therefore no flights were conducted in that mode. Throughout this evaluation the simulated F-14D was in what is known as a critical stores configuration, commonly referred to as the 2X4 loaded aircraft (two of each: AIM-7, AIM-9, AIM-54A, drop fuel tanks). The F-14D aircraft controls and displays were still under review/development at the time of this study, therefore a freeze in design was initiated to allow for DFS software and hardware implementation. The layouts for the F-14D controls and displays evaluated during this study are presented in Appendix B & C, and simulation discrepancies are listed in Appendix A.

SUBJECTS

Nine active duty F-14A pilots participated in this exercise. Table 1 lists the average flight and trainer times of participants. Each participant experienced Air-to-Air and Air-to-Ground scenarios statically (no G forces), and spin scenarios both statically and dynamically (G forces) during two days at NAVAIRDEVCEN. Familiarization and data collection for this study were conducted on separate days to enhance the participants acclimatization to the centrifuge motion system and it's inherent coriolis forces.

Table 1: Average Aircraft and Trainer Time for Participating Pilots

	Total Flight Time	Last 60 Days
All Aircraft	1553 hours	40 hours
F-14A	972 hours	40 hours
2F95 Trainer	65 hours	2 hours
2E6 Trainer	30 hours	1 hour
2F112 Trainer	21 hours	0 hours

Note: All pilots had previous T-2 spin training in both the classroom and aircraft.

PROCEDURES

During the first day pilots received a short briefing in the morning on the purpose of the exercise and operation of the F-14D simulator. During the remainder of the first day each pilot flew A/A, A/G and spin scenarios statically (no G forces). After completing the static session each pilot flew several representative flight maneuvers and simulated flat spins while under G (-3 Gx). These sessions allowed pilots to become familiar with the flight characteristics of the simulated aircraft and centrifuge control procedures before the data collection began.

On the second day, pilots flew A/A and A/G scenarios statically and flat spin scenarios under three G force levels (-3, -4, -5 or -6 Gx), while real time performance data were collected. At the end of the second day the pilots received a questionnaire pertaining to each mission segment (A/A, A/G, and spin recovery) and a general display questionnaire to record their opinions of the controls, displays and display formats.

MISSION SEGMENTS

Each pilot flew three A/A and three A/G mission segments for each A/A and A/G scenario, respectively. One mission segment was performed for each HUD declutter mode. Clutter is defined by air combat pilots as symbology that may obscure a target or interfere with target tracking. There are three levels or modes of declutter for the F-14D (Normal, Declutter I, Declutter II) which are pilot selectable. The Normal declutter level displays the maximum amount of information and each subsequent declutter level removes information until the minimum amount is displayed under Declutter II. Example HUD formats for each A/A and A/G declutter mode are in Appendix B. Pilots entered and recovered from flat spins under three G-levels (-3, -4, -5 or -6 Gx). During the first flat spin (-3 Gx) each pilot was presented with the standard F-14A spin arrow. This spin was to familiarize the pilot with the -Gx environment. The next three spins were at -4Gx and for each of these, the pilot used a different spin recovery aid (F-14A spin arrow, F-14D spin arrow, and Voice Commanded Recovery System). The last spin was at -5 Gx or -6 Gx and was for the pilot's familiarization. During this spin, the F-14D arrow was presented.

Air-to-Air

Each pilot began the Air-to-Air mission segment at 10,000 feet altitude with a critically loaded aircraft, commonly referred to as the 2 x 4 loading (two of each: AIM-7, AIM-9, AIM-54A, drop fuel tanks). He was instructed to activate the A/A mode of flight, to select the digital HUD format, and to choose the guns weapon mode, which would initiate the required display presentations and pilot scoring algorithms. Initially, the simulated MIG was placed 1000 ft in front of the pilot as it appeared on a computer generated outside scene. Once the mission segment began the MIG's flight profile was generated using previously stored velocities and attitudes. The pilot's task was to tail-chase (track) and acquire (MIG inside the gun reticle) the MIG using the A/A gun track symbology and to fire on the aircraft when it was within range. A hit was scored when the pilot fired at the within range MIG held in the gun reticle. A successful hit was indicated by a break-away X which appeared in the center of the

HUD. Performance measurement in this scenario included (1) time to target acquisition (MIG inside the gun reticle) and (2) percent time the MIG was within the gun reticle from acquisition to kill. Once the pilot scored a hit, the pass ended.

Air-to-Ground

The A/G mission segment included an outside visual scene containing an airport runway and several buildings on either side of the runway. The primary target was a checkerboard painted building located on the right side of the runway and the secondary was a grey hangar on the left side of the runway. The pilot's task was to acquire (target inside the gun reticle) each target and fire on it when within range. A hit was scored when the pilot fired on the targets within range and held in the gun reticle. Each pilot began the mission at a 3,000 ft altitude. He was asked to activate the A/G mode, to select the analog HUD format and to choose the guns weapon mode (manual operation), which would initiate the required display presentations and pilot scoring algorithms. To acquire and hit the first target, each pilot was instructed to maintain a 20 degree dive angle, 250-300 kts airspeed, and complete a strafing pass. After the primary target was hit the pilot was to acquire and fire on the secondary target. Once the pilot scored a hit on each target the data collection ended and the pilot completed the pass with a 4 G pull-up to egress. As in the Air-to-Air mission segment, a break-away X appeared on the center of the HUD when the pilot scored a hit. Performance measurement in this scenario included (1) time to initial target acquisition (target inside the gun reticle) and (2) percent time the target was within the gun reticle.

Spin Recovery

Pilots also experienced five flat spin recoveries using a variety of spin recovery aids. Each spin segments started at 30,000 ft altitude and 184 kts airspeed. Each pilot was asked to initiate a flat spin. This was accomplished by the pilot pulling the aircraft to 30 units Angle-of-Attack (AOA) and slowing the airspeed to 120 kts. The next step was to cross-control the aircraft by the pilot inputting the rudder deflection in the desired direction of the spin and full lateral and aft stick in the opposite direction. At this point, the pilot was instructed to hold the controls until the desired yaw rate/G-force was attained. To recover from each spin, participants followed the Naval Air Training and Operating Procedures Standardization Program (NATOPS) procedures (reference 3) for UPRIGHT DEPARTURE/FLAT SPIN:

1. Stick - FORWARD/NEUTRAL
   LATERAL, HARNESS-LOCK

2. Rudder - OPPOSITE TURN NEEDLE/YAW

IF NO RECOVERY

3. Stick - INTO TURN NEEDLE

4. If engine stalls - BOTH THROTTLES IDLE

IF RECOVERY INDICATED

5. Controls - NEUTRALIZE

6. Recover at 17 units AOA

IF FLAT SPIN VERIFIED BY FLAT ATTITUDE, INCREASING YAW RATE, INCREASING EYEBALL OUT G AND LACK OF PITCH AND ROLL RATES:

7. Canopy - JETTISON

8. EJECT (RIO COMMAND EJECT)

WARNING

Ejection guidelines are not meant to prohibit earlier canopy jettison and/or ejection. If insufficient altitude exists to recover from departed flight the aircrew should not hesitate to eject.

NOTE

At high yaw rates where eyeball out G is sensed, aft stick and full lateral stick into the turn needle may arrest the yaw rate and increase the possibility of recovery. At these yaw rates, the additional differential tail provided by roll SAS on will also increase the possibility of recovery.

RESULTS AND DISCUSSION

PERFORMANCE RESULTS

The A/A mission segment resulted, on the average, in a time to target acquisition that was less for declutter Level I than either Normal or declutter Level II. Although the magnitude of the differences between Level I, Normal, and declutter II are not statistically significant due to sample size and the variability in A/A mission performance from pilot to pilot and from trial to trial, the indicated direction of performance improvement is significant (A/A Level I time < A/A Normal & Level II time). It can then be inferred that the quality of performance was higher for participants using declutter Level I. In contrast, the target was held in the gunsight (acquired) for the greatest percent of time under declutter II, although closely followed by declutter Normal and Level I. These percentages do not vary significantly enough (95% Confidence Interval) to draw conclusions, except to infer that they are statistically equal and do not contradict the time to acquisition results of this segment. Detailed performance results for the A/A mission segment are presented in Table 2 and 3.

The A/G mission segment resulted, on the average, in an acquisition rate that was fastest for declutter Level I followed by declutter Level II and Normal. The magnitude of difference between Level I and Normal is significant (alpha = .10), but not between Level I and II, or Level II and Normal. However, there does exist a significant trend of Level II being less than Normal, and Level I being less than Level II. It can then be

inferred that participant performance was higher using declutter Level I. In contrast, the target was acquired for the greatest percentage of time under declutter Normal, although closely followed by declutter Level I and II. As in the A/A segment, these percentages do not vary significantly enough (95% Confidence Interval) to draw conclusions either, except to deduce that they are statistically equal and therefore do not contradict the time to acquisition results of this segment. Detailed performance results A/G mission segment are presented in Table 2 and 3.

QUESTIONNAIRE RESPONSES

The General Display Questionnaire responses indicated that the Head-Up-Display (HUD), and multifunction displays (MFD's) were, overall, easy to use. The analog/backup instruments received slightly lower ratings than the HUD and MFD's, however, upon further examination, all the backup instruments except the Vertical Velocity Indicator and Angle-of-Attack (AOA) Indicator received favorable ratings. In addition, the general questionnaire requested comments through the following question: "Do you have any suggested changes to display formats, displays or controls ?". Although responses to this question varied greatly, the suggestion or change cited by the highest percentage of aviators (4 pilots) was to include the waterline reference bars on the Normal Take-off, Landing and Navigation (TLN) VDI display format. The current specification requires the pilot to declutter the VDI to obtain the waterline reference bars.

Table 2: Performance Summary for A/G and A/A Mission Segments

	Declutter Level		
Condition	Normal	Level I	Level II
A/A			
Mean Time to Target Acquisition (N \ Std. Dev.)	1.91sec (5\.81)	1.58sec (4\.65)	2.27sec (5\1.25)
Mean Percent Time Acquired (N \ Std. Dev.)	51% (5\30.9)	39% (6\23.2)	58% (5\15.8)
A/G			
Mean Time to Target Acquisition (N \ Std. Dev.)	34.7sec (8\12.9)	22.6sec (7\11.5)	29.7sec (8\10.7)
Mean Percent Time Acquired (N \ Std. Dev.)	89% (8\7.4)	80% (7\22.4)	83% (8\16.4)

Note: All target tracking data is based on a 1 G gun solution.

Table 3: Statistical Test Results (T-test and Sign Test)

Probability of Significant Difference		Normal	Level I	Level II
A/A	Normal	------	50%	40%
	Level I	S (I < N)	------	65%
	Level II *	N (II = N)	S (I < II)	------
A/A%	Normal	------	50%	36%
	Level I	S (I < N)	------	85%
	Level II	N (II = N)	N (II = I)	------
A/G	Normal	------	93%	59%
	Level I	S (I < N)	------	76%
	Level II *	S (II < N)	S (II > I)	------
A/G%	Normal	------	68%	61%
	Level I	N (I = N)	------	24%
	Level II	N (II = N)	N (II = I)	------

Note: S - Indicates positive/significant sign test results.
N - Indicates negative/insignificant sign test results.
* - ANOVA test results indicate different (unequal) values for each declutter level

The ratings for controls focused on the MFD buttons and the Hands-On-Throttle and Stick (HOTAS) cursor. On average, the MFD buttons were easy to use during the static and dynamic sessions. The HOTAS cursor, however received only average ratings, especially for use during dynamic runs. This may be due to the location of the cursor on the outboard throttle lever. Because of this location pilots were required to use their ring finger, which does not have much manual dexterity, to make fine control movements.

The A/A and A/G mission questionnaires, asked the pilots which declutter mode (Normal, Declutter I, or Declutter II) they most and least preferred for target tracking and acquisition. In addition, they were asked to state the reasons for their preferences. Declutter I was the most preferred mode for A/A and A/G target tracking, due to the absence of pitch lines which allowed an unblocked central field of view. However several pilots preferred the Normal mode because of the inclusion of the pitch ladder and heading scale for A/G tracking. Pilots preferred the Normal mode the least for A/A target tracking due to symbology frequently obscuring the target. Declutter II provided very little information for setting dive parameters for A/G attack, and was the least preferred A/G HUD format according to participants. Suggestions for improvements included prominent display of range information and a bomb fall line for predictive tracking. Over half the pilots commented that in all A/A modes, the range and Vc readouts were very small and not in their scan.

The flat spin recovery segment, pilots averaged -5(Gx) for the maximum -Gx experienced. The F-14A and F-14D spin arrows received very positive reviews. The F-14D arrow was selected as the best recovery aid by all 11 pilots giving it the highest possible rating. Those who received exposure to the Voice Commanded Recovery System (VCRS) also gave it high marks for spin recovery assistance. The comments from the VCRS questionnaire indicate that the system would be most effective during a very disorienting spin or when the pilot cannot see the spin arrow. Most pilots would prefer a female voice, or any voice that can be distinguished from other airborne voices (wingman, RIO, etc.) be used in an operational version of the VCRS. All pilots agreed that additional directives such as altitude loss and/or 10K eject call would be useful and should be incorporated in the system. In addition, approximately half the pilots recommended that the VCRS commands be repeated.

A Summary for the general display questionnaire is located in Appendix D. Summaries for A/A, A/G, and Spin Recovery mission segments are located in Appendix E. The results for the VCRS questionnaire are located in Appendix F. The rating scale results are based on a 5 point scale with lower numbers indicating a greater ease of use. The number of pilots selecting a particular scale point is listed below each scale value. The average rating for each item is presented at the right side of the scale. If a rating scale did not fit a question the pilots' comments were recorded and are presented along with the number of pilots agreeing with that comment/response to the right of each. Eleven pilots completed the general display and spin recovery questionnaire. Due to equipment problems only nine of the eleven pilots completed the A/A and A/G mission segments and corresponding questionnaires.

One may question the value of declutter Level II at this point, but there are several factors that may account for lower performance with Level II; (1) the HUD experience level of the aviators, (2) the workload of tasking, and (3) personal combat style of each aviator. The most significant in this experiment appears to be the HUD experience level of an aviator which will tend to correspond directly with display preferences, i.e., low experience causes a desire for increased information (low declutter level) and high experience causes a desire to declutter to the fullest or highest level. Generally, F-14A aviators do not have a high HUD experience level, so they tend to desire increased information (Declutter I over Declutter II). It should follow then that in fleet operations the F-14 aviators will gain HUD experience and declutter Level II will become more useful. During this experiment workload was held constant and combat style was limited to tail chasing, therefore the effect of these variables was minimal.

CONCLUSIONS AND RECOMMENDATIONS

From the summarized performance results and aviator responses, it appears that the objectives of the project were met; i.e., determination of the ease of use of the F-14D front panel displays and controls, the influence of HUD declutter levels on A/A and A/G target tracking (tail-chasing), target acquisition, and the evaluation of various spin recovery aids. It was found that the HUD Declutter level best for tracking an airborne target and the most preferred format was Declutter I, the best for ground target elimination was Declutter I, and the spin recovery aide most preferred was the F-14D spin arrow. It is also evident from the questionnaire results that spin familiarization was considered by all participants to be valuable for F-14 aircrew. When asked if they would recommend this type of spin familiarization to others, all pilots responded positively, and the majority recommended spin familiarization at least once a tour.

Based on the above results and conclusions, the following are recommended:

1. Display the waterline reference bars on all VDI modes not just the decluttered formats.

2. Display a large and centrally located range and Vc readouts for all A/A weapon delivery modes (Appendix G), and re-evaluate the A/A HUD formats for affects of this change at NAVAIRDEVCEN.

3. Switch cage/seam switch with the HOTAS cursor button so HOTAS is on the inboard throttle instead of the present location on the outboard throttle, and evaluate cage/seam switch operation with ring finger in a follow-on investigation.

4. Include a large blade or paddle-type switch for roll SAS for easy activation during spin recovery.

5. Continue to develop and evaluate the VCRS with the following modifications:

   a) an initial warning or message that voice instructions are forthcoming.

   b) a female voice, or any voice that can be distinguished from other airborne voices.

   c) instructions which are repeated at least once, and more than once if there is pilot non- or improper action.

   d) additional messages including altitude above ground level (AGL) remaining and 10,000 ft (AGL) altitude eject command.

6. Incorporate auto-locking restraint system in F-14A and F-14D.

7. Evaluate the Take-off, Landing, and Navigation (TLN) display formats during Night Carrier Approach in the Dynamic Flight Simulator at NAVAIRDEVCEN.

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APPENDIX A: DFS F-14D CONFIGURATION AND OPERATION

DFS OPERATION

The DFS operates from a trim condition. This is achieved by the pilot adjusting first the left throttle, then the right throttle, and finally the pitch trim to attain a trim value less than 1.00 (TRIM on the HSD) when requested by the Experiment Control Station (ECS) Operator. Static (Fixed-Base) operations can only be initiated and terminated by the ECS Operator.

Dynamic (Moving-Base) Operations

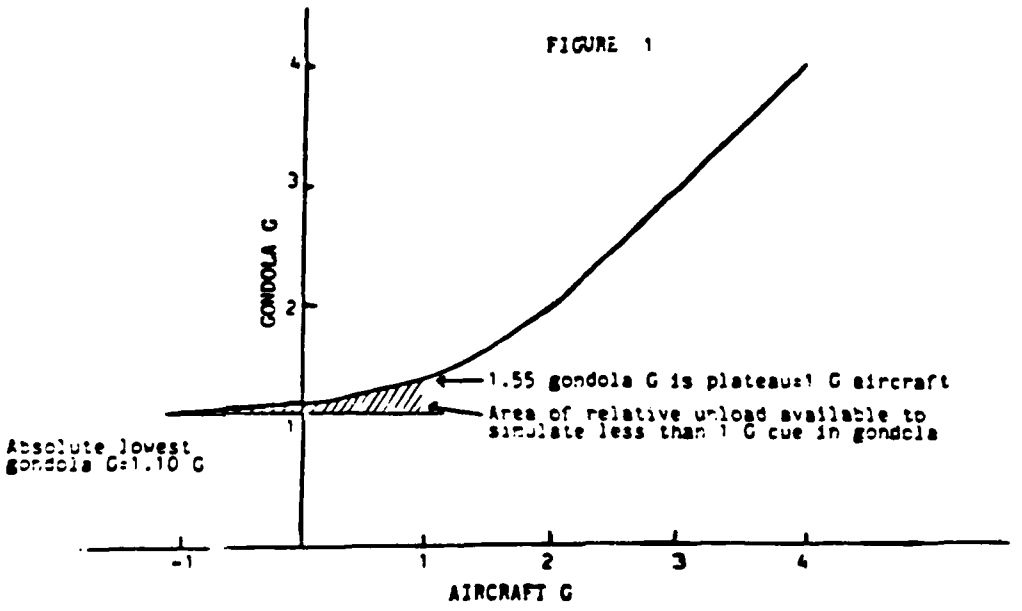
In the REST mode, the gondola will be accelerated to a plateau of +1.25 Gz. In the TRIM mode, the gondola is accelerated to a plateau of +1.55 Gz which will represent +1.0 Gz of the aircraft. All dynamic operations will be initiated from this trim plateau to provide a perception of unloading with forward stick excursions. Above +3.0 Gz, centrifuge accelerations will match aircraft accelerations.

Minor pitch oscillations (1-2Hz) exist between 1.0 and 2.5 Gz that can be aggravated by PIO until the pilot is familiar with the DFS.

The pilot must keep his head still while flying the DFS or, due to the artificially generated force vectors, he will induce a coriolis effect which produces unwanted pitch and roll sensations.

Any DFS run can be terminated by the control room, the flight surgeon, or the pilot (by pushing the bomb button on the control stick).

FIGURE 1



DFS F-14D CONFIGURATION

The following characteristics of the F-14D configuration differ from those of the F-14D airplane:

Cockpit Configuration -

- The ejection seat, control stick, and instrument panel geometrical relationship accurately reflects the F-14D design data. However, the horizontal and vertical consoles are approximately two inches lower than in the airplane and the HUD is located approximately 1 to 1.5 inches higher and at a 8.0° higher angle than the F-14D HUD .
- The DFS HUD combiner glass is larger and located slightly farther away from the pilot than the F-14D HUD.
- The control stick does not accurately represent F-14 damping, breakout and friction characteristics. The stick throws and forces are similar to the F-14.
- The control stick grip is modified version of the original F-14D stick grip; not the latest version. Only the Trim Switch, Weapon Select Switch, and the Trigger are active.
- The weapon select switch is an early F-14D version. In the current version, the short range (SR) position is at 2 o'clock rather than 11 o'clock as in the DFS. The Gun (GN) select is correctly positioned at 5 o'clock.
- The throttle grips are not F-14D grips. However, they are similar in shape. The only active throttle grip switches are the Speedbrake switch and the Cursor Controller.
- The Speedbrake switch is located in the F-14A rather than the F-14D position.
- The cursor breakout force is high. There is an additional, inoperative, cursor controller on the front face of the right throttle grip.
- The three Display Panel pushbuttons (TLN, A/A, and A/G) are always lighted as opposed to lighting when selected.
- Landing Gear - INOP
- Flaps - INOP
- Maneuvering Devices - always extended, no manual operation.
- Wing Sweep - always follows Auto Schedule, no manual operation.
- No aural engine over temp warning.

Cockpit Displays -

- The HUD Field of View (FOV - elevation x assymyth) is different than in the F-14D:

	F-14D HUD		Hughes DFS HUD
Total FOV:	23.5°x30°	<----	22°x30°
Binocular FOV:	18.5°x22.8°	:	20.5°x26°
Continuous FOV:	18.5°x14.5°	:	Not Available
Utilized FOV:	N/A	---->	21°x28°

- The Periscopic TV Camera Sight is not present at the front of the HUD.
- The HUD brightness control knob is not accessible by the pilot.
- Only selected MDRI switches are active.
- The VDI and SMS displays are only selectable on the center MDRI.
- The VDI "cow plops" reflect the F-14A implementation. In the F-14D configuration they will emanate from the center of the screen and radiate toward the lower corners of the display.
- The gunsight implementation is an early design. The current F-14D includes a MultiMode Gun Sight.
- The A/A Sidewinder mode does not include the Sidewinder seeker head positioning cue.

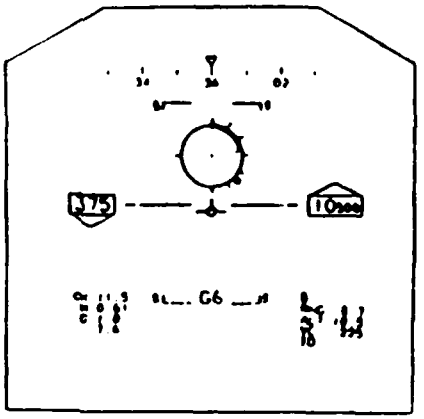
Cockpit Instruments -

- The F-14D engine instrument group will utilize LCD's rather than moving tapes.
- Flap, slat, and gear indicators - INOP
- Trim indicators - INOP
- Nozzle position indicators - INOP
- Fuel Status - INOP, fuel weight constant (8,000 lbs)

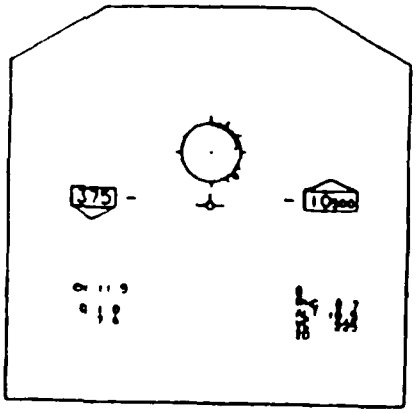
Aerodynamics -

- Similar to F-14 but inaccurate at low angles of attack.
- Lateral sensitivity evident in Cruise flight.

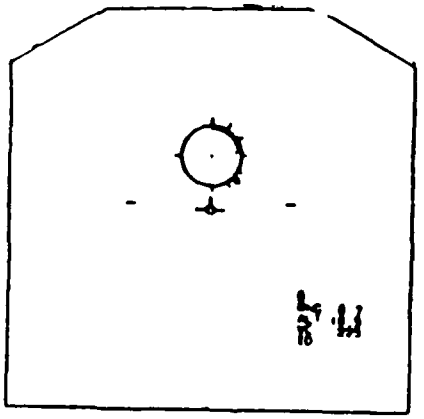
APPENDIX B: DECLUTTER MODES FOR A/A AND A/G HUD FORMATS



a. [illegible]
MANUAL MODE
DIGITAL SELECTED
NO DECLUTTER

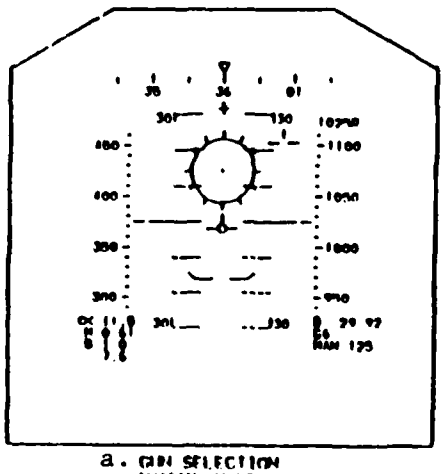


b. [illegible]
MANUAL MODE
DIGITAL SELECTED
DECLUTTER 1

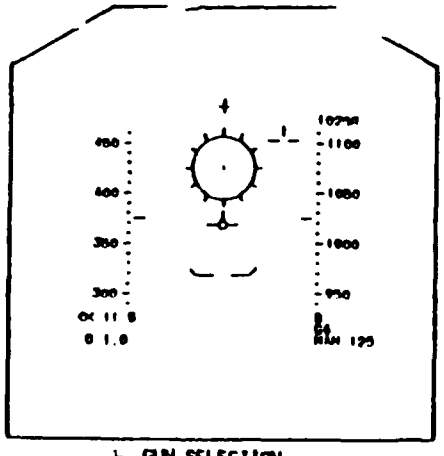


c. [illegible]
MANUAL MODE
DIGITAL SELECTED
DECLUTTER 2

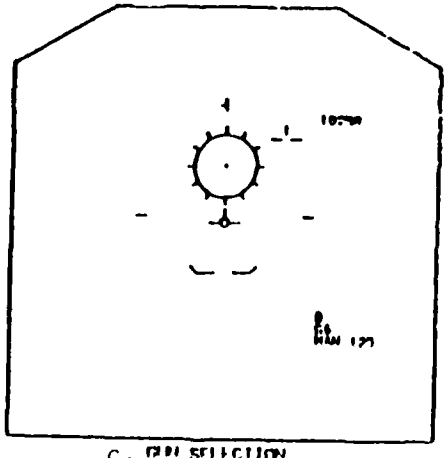
F-14D HEAD UP DISPLAY (HUD) FORMAT
AIR-TO-AIR (A/A) MODE



a. GUN SELECTION
MANUAL MODE
ANALOG READOUT
NO DECLUTTER



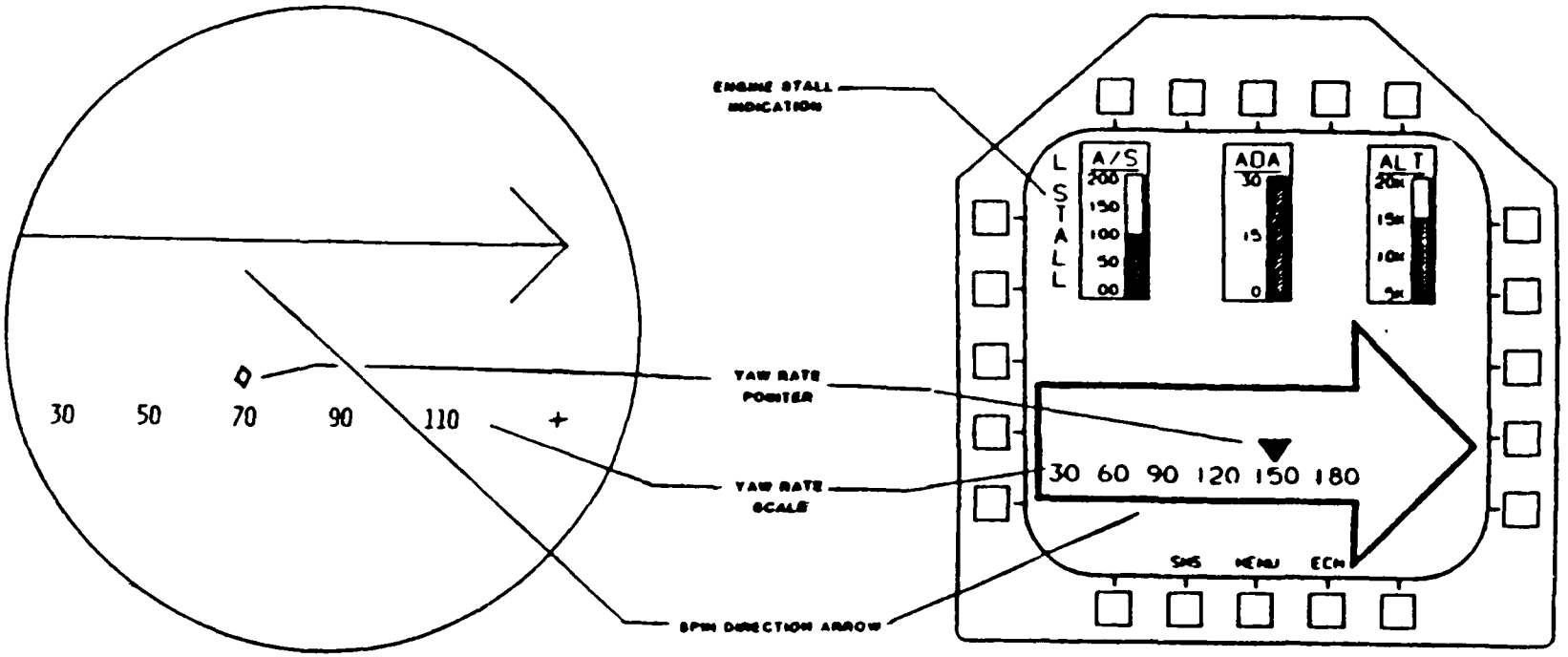
b. GUN SELECTION
MANUAL MODE
ANALOG READOUT
DECLUTTER 1



c. GUN SELECTION
MANUAL MODE
ANALOG READOUT
DECLUTTER 2

F-14D HEAD UP DISPLAY (HUD) FORMAT
AIR-TO GROUND (A/G) MODE

APPENDIX C: SPIN RECOVERY DISPLAYS



a. F-14A SPIN ARROW

b. F-14D SPIN INDICATOR

F-14 SPIN DISPLAYS

APPENDIX D: GENERAL DISPLAY OUESTIONNAIRE RESULTS

GENERAL DISPLAY QUESTIONS

Visual Fatigue/Workload

1. How easy was it to quickly read symbols from the following displays?

Head-Up-Display

Easy	1	2	3	4	5	Difficult
	3	5	3	0	0	Average = 2.0

Multifunction Displays

Easy	1	2	3	4	5	Difficult
	3	6	2	0	0	Average = 1.9

Electro-mechanical/Analog Instruments

Easy	1	2	3	4	5	Difficult
	3	3	4	0	1	Average = 2.4

2. How easy was to cross-check flight control information from the Head-Up-Display using the following electro-mechanical instruments?

Airspeed Indicator

Easy	1	2	3	4	5	Difficult
	6	5	0	0	0	Average = 1.5

Attitude Indicator

Easy	1	2	3	4	5	Difficult
	4	4	2	1	0	Average = 2.0

Altitude Indicator

Easy	1	2	3	4	5	Difficult
	5	4	2	0	0	Average = 1.7

Vertical Velocity Indicator

Easy	1	2	3	4	5	Difficult
	2	3	2	2	1	(1 no response) Average = 2.7

Angle of Attack Indicator

Easy 1 2 3 4 5 Difficult

1 2 3 2 2 (1 no response) Average = 3.2

Symbology Issues

Rate the following display formats along a five point scale:

Excellent 1 2 3 4 5 Poor

	SYMBOL LEGIBILITY						ALPHANUMERICS LEGIBILITY					
Scale:	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.
VDI-Normal	4	5	1	1	0	1.90	5	4	2	0	0	2.00
VDI-Gun Track *	1	4	3	1	0	2.40	4	3	3	0	0	1.90
VDI-Side-winder *	2	4	1	0	0	1.90	2	4	1	0	0	1.90
HSD *	1	6	3	0	0	2.20	2	2	3	2	1	2.80
Stores Manage.	6	5	0	0	0	1.50	5	3	3	0	0	1.80
Spin Arrow	10	1	0	0	0	1.10	8	1	2	0	0	1.50
HUD-Normal	4	5	2	0	0	1.80	5	4	2	0	0	1.70
HUD-Gun Track	3	3	3	1	1	2.45	4	4	3	0	0	1.90
HUD-Side-winder *	2	4	2	0	0	2.00	3	3	2	0	0	1.90
	(Number of Pilots)						(Number of Pilots)					

Note: * indicates missing data

4. Using the following rating scales, rate the ease of quickly obtaining information from the HUD for the following flight control parameters.

Airspeed

Easy	1	2	3	4	5	Difficult
	8	3	0	0	0	Average = 1.3

Altitude

Easy	1	2	3	4	5	Difficult
	7	4	0	0	0	Average = 1.4

Mach Number

Easy	1	2	3	4	5	Difficult
	2	1	4	4	0	Average = 2.9

Angle of Attack

Easy	1	2	3	4	5	Difficult
	0	1	4	3	3	Average = 3.6

Vertical Velocity

Easy	1	2	3	4	5	Difficult
	2	2	4	3	0	Average = 2.7

G

Easy	1	2	3	4	5	Difficult
	0	2	4	3	2	Average = 3.5

Control Issues

5. Rate the ease of changing display formats

DURING STATIC SESSIONS (no g forces)

Multifunction display pushbuttons

Easy	1	2	3	4	5	Difficult
	5	5	1	0	0	Average = 1.6

Hands on throttle and stick cursor

Easy	1	2	3	4	5	Difficult
	2	2	3	3	1	Average = 2.9

DURING DYNAMIC SESSIONS (under g)

Multifunction display pushbuttons

Easy	1	2	3	4	5	Difficult
	1	5	4	1	0	Average = 2.5

Hands on throttle and stick cursor

Easy	1	2	3	4	5	Difficult
	1	4	2	0	4	Average = 3.2

6. Rate the ease of using:

Menu System on the Multifunction Displays

Easy	1	2	3	4	5	Difficult
	3	6	0	1	1	Average = 2.2

Weapons Select Switch on Control Grip

Easy	1	2	3	4	5	Difficult
	7	3	1	0	0	Average = 1.5

7. Rate the ease of using:

Triangular Rate indicators on digital airspeed readout

Easy	1	2	3	4	5	Difficult
	4	4	1	0	2	Average = 2.3

Triangular rate indicators on digital altitude readout

Easy	1	2	3	4	5	Difficult
	4	4	1	0	2	Average = 2.3

7. Do you have any other general comments about the controls, displays and display formats you used in this simulation study?

Roll SAS is hard to find under G. (2 naval aviators)

Turn needle is small and virtually unusable. (2 naval aviators)

Pipper on gunsight is too small for accurate gun sight tracking.

Hard to resolve range of bogey from the tape scale on the A/A gunsight reticle.

Would never use cursor.

New features in TLN mode are outstanding, particularly the Angle-of-Bank indicator and tick marks along the side.

8. Do you have any suggested changes to display formats, displays or controls.

Need fixed aircraft reticle (waterline reference bars) on the basic VDI format to set precise pitch attitudes (4 naval aviators)

MFD cursor control on the outboard throttle requires the use of ring finger for cursor positioning. It is easier to use index finger, for cursor control, which is normally on inboard throttle. (2 naval aviators)

Make altitude/airspeed pointer on analog display more obvious for quick scan.

Rotate control stick handgrip 2-3 degrees counterclockwise for ease of operation.

Eliminate angle-of-attack, IMN and G from HUD display and put on VDI only because they present clutter.

Range scale in lower right hand corner of normal HUD display needs to be bigger and centrally located in A/A mode.

The VDI/TCS functions need to be always available via one button press.

APPENDIX E: MISSION SEGMENT QUESTIONNAIRE RESULTS

A/A Mission Segment Questionnaire

1. Which HUD format (Normal, DCL I, DCL II) did you most prefer for A/A target tracking and acquisition? Why?

Declutter I - 6 naval aviators

Reasons:

Used to less than normal clutter on the HUD.

All data available and easy to read and pitch lines not presented.

Good information without blocking central field of view

No comment

Normal has too much information, Declutter II doesn't have enough.

No pitch lines needed.

Declutter II - 2 naval aviators

Reasons:

Easier to see real world with less information on the HUD.

I wanted less information on the HUD, all I needed was range and Vc.

Normal - 1 naval aviator

Reason:

I could gain a wealth of information plus the readouts didn't get in the way of tracking. I could shift my scan to different sides of the HUD to gain information.

2. Which HUD format did you least prefer for A/A target tracking and acquisition? Why?

Normal - 7 naval aviators

Reasons:

Too much information on the HUD (4)

Never use pitch ladder during A/A tracking

Normal symbology gets in the way of the target

Range and Vc hard to find

Declutter II - 2 naval aviators

Reasons:

Declutter II had insufficient information (2)

3. Using the following rating scales, please rate the ease with which you could obtain the following information using the HUD A/A Sidewinder gun format.

Range Scale	--	Easy	1	2	3	4	5	Difficult
			2	4	0	1	2	Average = 2.70
Maximum Range	--	Easy	1	2	3	4	5	Difficult
			2	2	3	1	1	Average = 2.70
Selected weapon type	--	Easy	1	2	3	4	5	Difficult
			4	4	1	0	0	Average = 1.70

4. Please indicate the display format you preferred (Normal, Declutter I or Declutter II) for the following conditions. If you thought there was no difference between the 3 formats then please indicate in the space provided.

	I	II	Normal	No Difference
a) Ease in viewing the outside scene through the HUD.	1	7	0	1
b) Ease in target tracking	5	3	1	0
c) Ease in deciding when to fire weapon	6	1	0	2
d) Ease in maintaining airpseed	7	0	1	1
e) Ease in maintaining altitude	6	0	2	1
f) Ease in maintaining attitude	2	0	6	1
g) Least amount of eyestrain or visual fatigue	1	8	0	0

5. Do you have any suggested changes to A/A Gun HUD format?

Increase the size of the numbers for range and Vc readouts and place them in a centrally positioned location on the HUD. (5)

The pipper on the gunsight should be made bigger. (2)

Increase the brightness or boldness of circular range tape in gunsight reticle.

Would like director gun reticle with a 25 millimeter ring within the current 50 millimeter ring.

Need to have HUD brightness knob handy.

A/G Mission Segment Questionnaire

1. Which HUD format (Normal, DCL I, DCL II) did you most prefer for A/G target tracking and acquisition? Why?

Declutter I - 5 naval aviators

Reasons:

Gives the essential information. Dive angle can be checked on the VDI.

Gives the right amount of information.

No comments. (3)

Normal - 3 Naval aviators

Reasons:

A/G weapons delivery requires the dive angle, airspeed and altitude to be exact.

Easier to scan all parameters. Heading is important on run in.

I like the information presented.

Declutter II - 1 naval aviator

Reason:

Less clutter on HUD.

2. Which HUD format did you least prefer for A/G target tracking and acquisition? Why?

Declutter II - 5 naval aviators

Reasons:

Too little information for attacking the ground (2).

Insufficient information for dive parameters.

None of the information that is mandatory for A/G weapons delivery is presented. I don't want to hit the ground either.

No comment.

Normal - 4 naval aviators

Reasons:

Too much information. I don't like the pitch ladder or heading scale.

Blocks field of view of the target.

Too much information.

No comment.

3. Using the following rating scales, please rate the ease with which you could obtain the following information using the HUD A/G Gun track format.

TRACKING SYMBOLOGY

Pullup cue	--	Easy	1	2	3	4	5	Difficult
			3	2	1	1	1	Average = 2.4
Target reticle	--	Easy	1	2	3	4	5	Difficult
			2	5	0	1	1	Average = 2.3
Selected weapon type	--	Easy	1	2	3	4	5	Difficult
			3	5	1	0	0	Average = 1.8

4. Please indicate the display format you preferred (Normal, Declutter I or Declutter II) for the following conditions. If you thought there was no difference between the 3 formats then please indicate "N.D." in the space provided.

	DCL I	DCL II	Normal	No Difference
a) Ease in viewing the outside scene through the HUD.	1	7	0	1
b) Ease in target tracking	3	2	2	2
c) Ease in deciding when to fire weapon	4	0	3	2
d) Ease in maintaining airpseed	3	0	5	1
e) Ease in maintaining altitude	1	0	6	2

	DCL I	DCL II	Normal	No Difference
f) Ease in maintaining attitude	2	0	6	1
g) Ease in maintaining heading	0	0	6	1
h) Least amount of eyestrain or visual fatigue	4	5	0	0

5. Do you have any suggested changes to A/G Gun Track HUD format?

Need pitch lines in other declutter modes besides Normal to set dive angle. (2)

Do not need AOA or Max G on the HUD (2)

Need bomb fall line for predictive tracking similar to F-14A A/G gunsight. (2)

Need range information prominently displayed (2)

Have altitude readout stay in 100 ft. increments not 50 ft. increments below 5,000 ft. when using analog altitude display format (2).

Always have altitude and airspeed boxes no matter what mode.

SPIN SEGMENT QUESTIONNAIRE

I SPINS:

Maximum -Gx experienced

-3	-4	-5	-6	
1	2	2	6	Average = 5.2 (-Gx)

A. What effect did the following recovery aids have on your recovery?

F-14A Spin Arrow

Very Helpful	1	2	3	4	5	Useless
	5	2	1	2	1	Average = 2.3

F-14D Spin Arrow

Very Helpful	1	2	3	4	5	Useless
	11	0	0	0	0	Average = 1.0

* Voice Commanded Recovery

Very Helpful	1	2	3	4	5	Useless
	3	1	1	0	0	Average = 1.6

B. What effect did the following items have on your recovery

Harness lock (> -3 Gx)

Very Helpful	1	2	3	4	5	Useless
	10	0	0	0	0	Average = 1.0

-Gx on Recovery Control Input

Lessened difficulty	1	2	3	4	5	Increased difficulty
	0	1	2	1	6	Average = 4.2

Note: * indicates missing data

II. GENERAL:

A. Roll SAS switch position and size.

Excellent	1	2	3	4	5	Poor
	0	0	2	4	5	Average = 4.3

B. Would you recommend that others receive this exposure ?

Yes	No
11	0

If yes, then how often?

0	1	once every 4 months
1	2	once a year
7	3	once a tour
3	4	once
	5	other

Who should participate?

1	1	Student pilots
0	2	Instructors
1	3	Test pilots
3	4	Fleet pilots (F-14 only)
3	5	All fleet pilots
2	6	other: engineers, all of the above
1		No response

APPENDIX F: VOICE COMMANDED RECOVERY SYSTEM (VCRS) QUESTIONNAIRE

VOICE COMMANDED RECOVERY SYSTEM QUESTIONNAIRE

The Voice Commanded Recovery System (VCRS) you have just flown is still in the development stage. It was developed using one point in the flight envelope and has not been optimized even for that point, and there is little experience to guide the development of voice advisors. We need guidance from experienced pilot, and so we ask you to complete the following questionnaire. It is meant to provide feedback for Grumman's development work, so the questions are only meant to be guides; we appreciate all of your comments.

1. Any reactions or general comments?

First time I heard it, it was a distractor

I liked it, I believe I would get out of an unintentional spin, if I were disoriented, using this system.

Good instructions.

I thought it worked well, the voice needs to be such that you can tell it's the VCRS and not your RIO, wingman, etc.

Nice, if it doesn't cost an arm and a leg.

2. Do you feel the VCRS aided your recovery from a spin? If so, how so?

Yes, I didn't have to think, just react.

Yes, confirmed correct inputs. (2)

Yes and no, since I already knew how to get out of a spin, I simply put in the correct control inputs. If I was in an unintentional, very disorienting spin, the voice cues would be very helpful.

During -Gx, the oxygen mask slid over my eyes and I could not see the spin arrow. It would be very helpful in this case.

a. Do you think vocal cuing of departures would aid the prevention of full-blown flat spins?

No

Yes, very much. (2)

Possibly

Most spins occur so rapidly that they weren't apparent to the pilot until it was too late. Will the system speak fast enough to a pilot during a coupled departure.

3. The VCRS provides direction, not diagnosis of a situation. For spins, Grumman feels this is appropriate. Do you agree?

Yes (5)

4. Are there other flying situations where immediate direction would be helpful? (Check lists or system status reports, for instance).

That's what they pay me for.

No comment (3)

Low altitude warning

5. Is the information provided by the VCRS useful?

a. Did the messages appear to be presented at the appropriate time?

Yes (3)

Yes, but needs to be a more attention getting initial warning

Yes, might have to come faster with a coupled departure.

b. Was the order of messages useful or can you suggest any changes?

Yes (3)

Yes, but voice was not attention getting. (2)

c. Which wording do you prefer - subject-then-verb, such as "stick center" or verb-then-subject as "center stick" ?

Doesn't matter.

Subject-verb (3)

Verb-subject (1)

d. Are there enough directives, that is, was it clear that you were recovering from the spin and that your inputs were correct?

Yes (3)

No initial warning

No comment

e. Related to (d) should a messate be repeated after you have responded to indicate that the input is still correct or should the system remain silent until a new message is appropriate.

Keep repeating (2)

Add the word "hold" for correct inputs until next input.

don't know

No comment

f. Should there be additional directives - for altitude changes (loss), for instance, or NATOPS bailout altitude?

Yes (2)

Yes, 10 K eject call would be good

Yes, altitude loss (2)

g. Were the directives spoken too fast or slow?

Perfect

Too slow (2)

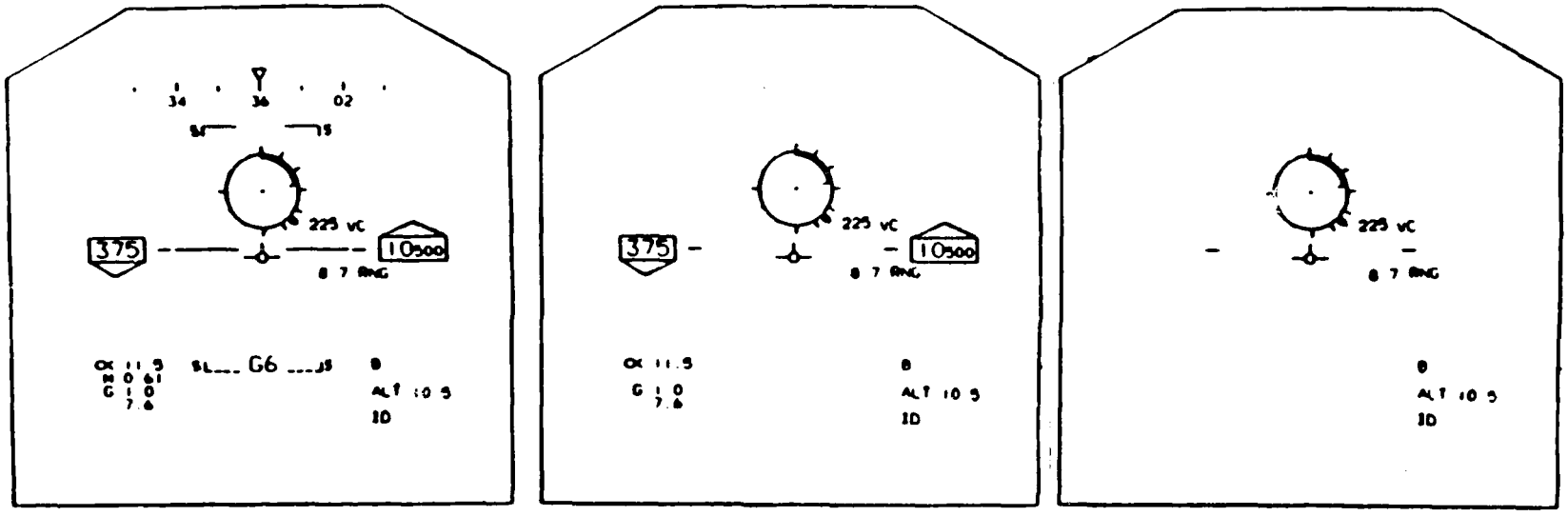
About right (2)

h. If voice cues are added to cockpits, various classes of messages should be identifiable. What sort of vocal characteristics would be appropriate? Female voice? Do it now voice?

Female voice (4)

Anything that can be differentiated from you RIO or other airborne voices

APPENDIX G: MODIFIED DECLUTTER MODES FOR A/A HUD FORMATS



a. GUN SELECTION
MANUAL MODE
DIGITAL SELECTED
NO DECLUTTER

b. GUN SELECTION
MANUAL MODE
DIGITAL SELECTED
DECLUTTER 1

c. GUN SELECTION
MANUAL MODE
DIGITAL SELECTED
DECLUTTER 2

RECOMMENDED F-14D HUD FORMAT
MODIFICATION FOR THE
AIR-TO-AIR (A/A) MODE

NADC-87178-60

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