LEVEL II

(12)

ASD-TR-81-5016

AD A104684

INVESTIGATION OF SPATIAL DISORIENTATION OF F-15 EAGLE PILOTS

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August 1981

TECHNICAL REPORT ASD-TR-81-5016
Final Report 15 January 1980 - August 1980

Approved for public release; distribution unlimited

DIRECTORATE OF EQUIPMENT ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

This technical report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ASD-TR-81-5016	2. GOVT ACCESSION NO.: AD-A104 684
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): INVESTIGATION OF SPATIAL DISORIENTATION OF F-15 EAGLE PILOTS	5. TYPE OF REPORT & PERIOD COVERED: Final Report 15 Jan 80 — Aug 80
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Dennis W. Jarvi, Lt Col, USAF	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Directorate of Equipment Engineering, Aeronautical Systems Division, Wright-Patterson AFB OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Crew Equipment and Human Factors Division, ASD/ENEC, Wright-Patterson AFB OH 45433	12. REPORT DATE: August 1981
	13. NUMBER OF PAGES: 78
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Spatial Disorientation, Lighting, Interior Lighting, Exterior Lighting, Head-up-Displays, HUD.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The F-15 Spatial Disorientation Investigation Team was comprised of multi-disciplinary members from five of ASD's product SPOs, the Aerospace Medical Research Laboratory, The Human Resources Laboratory, and the Directorate of Equipment Engineering. An extensive investigation, including F-15 pilot interviews at Eglin AFB FL, and Langley AFB VA, into the characteristics and operation of the F-15 Eagle was conducted over a seven month period. In addition, F-16 pilots at Hill AFB UT, were interviewed. The following

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) cont'd

conclusions were drawn from the information acquired: The F-15 does not possess any unusual flight handling characteristics that could lead to pilot spatial disorientation. The large bubble canopy and the pilot's sitting height in the cockpit generally do not appear to significantly contribute to spatial disorientation. The asymmetrical exterior lighting strips on the F-15 can cause confusion on the part of the wing man regarding his formation position relative to the lead aircraft or the bank angle of the lead aircraft. Night formation join-ups, particularly from the stern, are rather difficult for the F-15 pilot due to the absence of adequate exterior lighting to provide the necessary depth perception cues for ascertaining the range and attitude of the lead aircraft. The layout of the F-15 cockpit generally manifests adherence to good human factors design principles. The F-15 Spatial Disorientation Team also uncovered some areas of potential pilot distraction. These areas, uncovered during pilot interviews, do not necessarily affect the incidence of spatial disorientation, but may add to the F-15 pilot's workload. The report includes these areas, and also makes a number of recommendations based on the results of the study.

FOREWORD

This evaluation of spatial disorientation of F-15 Eagle pilots was conducted under the authority of Air Force Systems Command (AFSC) in response to Headquarters Tactical Air Command (TAC) request for a study to evaluate possible causes of spatial disorientation. This program was conducted during the period of January to August 1980.

The following personnel were responsible for the conduct of this program:

Chairman	Dennis W. Jarvi, Lt Col, USAF ASD/ENEC
Project Scientists and Engineers	
	Dr. Kenneth R. Boff AFAMRL/HEA
	Mr. Nathan W. Davis ASD/ENECH
	Lt. Cmdr. (Dr.) Harry P. Hoffman ASD/AESA
	Mr. Robert C. Pangburn ASD/TAFEC
	Mr. Ronald W. Schwartz ASD/ENECC
	Mr. William L. Welde AFAMRL/TSZ
	Mr. John H. Wilson ASD/YWE

The assistance of personnel from AFAMRL/HEA, Wright-Patterson AFB OH, 58 TTW, Luke AFB AZ, 1 TFW, Langley AFB VA, 33 TFW, Eglin AFB FL, 388 TFW, Hill AFB UT, and USAF/AFSIC, Norton AFB CA during the conduct of this study was greatly appreciated.

This report was submitted by the author in August 1980.

ACKNOWLEDGEMENT

The team wishes to express their appreciation to Mrs. Evelyn Davidson, ASD/ENECE, for her secretarial support. Her patience and many long hours of typing and editing was an inspiration to the team.

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The following conclusions were drawn from the information acquired:

The F-15 does not possess any unusual flight handling characteristics that could lead to pilot spatial disorientation. (See p. 16, 35.)

The large bubble canopy and the pilot's sitting height in the cockpit generally do not appear to significantly contribute to spatial disorientation. (See p. 17.)

The asymmetrical exterior lighting strips on the F-15 can cause confusion on the part of the wing man regarding his formation position relative to the lead aircraft or the bank angle of the lead aircraft. (See p. 31, 32, 38.)

Night formation join-ups, particularly from the stern, are rather difficult for the F-15 pilot due to the absence of adequate exterior lighting to provide the necessary depth perception cues for ascertaining the range and attitude of the lead aircraft. (See p. 33, 38.)

The layout of the F-15 cockpit generally manifests adherence to good human factors design principles. (See p. 18, 19.)

The F-15 Spatial Disorientation Team also uncovered some areas of potential pilot distraction. These areas, uncovered during pilot interviews, do not necessarily affect the incidence of spatial disorientation but may add to the F-15 pilot's workload.

These areas include:

Canopy reflections of interior cockpit lights during night flying. Interior lights produce some canopy reflections when sufficiently increased to easily discern the data on the instrument panel. (See p. 20, 21, 37.)

The level of HUD symbology brightness is difficult to optimize during night flying. (See p. 22, 38.)

The pilot is unable to adjust the lighting on the primary flight instruments individually during flight. (See p. 20, 38.)

The following recommendations are made from the conclusions drawn:

Recommend the addition of some method of lighting the vertical tails of the aircraft. Two options were cited, electroluminescent (EL) strip lights or flood lights mounted in the fuselage to illuminate the vertical tails of the aircraft. Other solutions may be equally suitable. (See p. 32, 38.)

Recommend mounting two additional white lights on the fuselage, one on the top of the fuselage just aft of the canopy and the other in a similar location on the bottom of the fuselage. (See p. 38, 39.)

Recommend the F-15 pilots be trained to avoid using the HUD as an instrument reference when transitioning from formation flying at night or in instrument conditions, especially in lost wing man situations. Rather, they should be trained to refer to the ADI and primary flight instruments. (See p. 36, 37.)

Recommend the F-15 pilots practice HUD-out instrument approaches to decrease dependence on the HUD and to permit the pilot to become more familiar with and comfortable at flying instruments without the HUD. (See p. 36, 37.)

With respect to those items considered to be potential pilot workload areas the following recommendations are suggested:

Recommend further advances in reducing canopy reflections be studied for possible F-15 application. (See p. 20, 21, 37.)

Recommend the HUD symbology brightness control be reviewed for improvement under night flying conditions. A scheme similar to the yellow filter on the A-7 aircraft HUD is suggested for review. (See p. 22, 38.)

Recommend the F-15 interior lighting control system be reviewed for possible improvements in individual flight instrument brightness control by the pilot. (See p. 20, 38.)

PART I

BACKGROUND INFORMATION

A. GENESIS OF THE INVESTIGATION

1. As a result of two F-15 aircraft accidents in 1979 in which there was some indication that pilot disorientation may have been a factor contributing to these accidents, Tactical Air Command, in a TAC/DO/DR message, 220030Z Nov 79, expressed concern to the F-15 SPO that exterior lighting on the F-15 may have precipitated pilot disorientation. In response to TAC, the F-15 SPO requested the Director of Engineering, Aeronautical Systems Division (ASD/EN), to form a technical investigation team in a letter dated 7 December 1979.

2. Mr. Gino Santi, of the Directorate of Equipment Engineering (ASD/ENE) was initially appointed chairman of that investigation team. Subsequent to Mr. Santi's retirement, Lt Col Dennis W. Jarvi assumed the position of chairman. The F-15 Disorientation Team, as it became known, was charged with the responsibility of reviewing the phenomenon of spatial disorientation and/or vertigo and providing recommendations for reducing the potential for pilot disorientation in the F-15 aircraft. At the direction of the Chief Engineer of the F-15 SPO on 18 January 1980, the scope of the F-15 disorientation investigation was expanded to include a review of the F-15 external visibility characteristics associated with a formation join-up after take-off and maintaining sight of the lead aircraft while flying formation in and out of adverse weather conditions.

B. TEAM FORMATION

1. The F-15 Disorientation Team was comprised of multi-disciplinary members from ASD's A-10, F-15, F-16, Life Support, and Simulator SPOs, the Aerospace Medical Research Lab, the Human Resources Lab, as well as from the Crew Station and Human Factors Division of the Equipment Engineering.

2. The initial meeting of the team was on 15 January 1980 and consisted of the following members:

a. Mr. Gino P. Santi - Chairman, ASD/ENE. An engineer and the acting Technical Director for the Directorate of Equipment Engineering. An employee of Aeronautical Systems Division for over forty years, he was well known in cockpit design, parachute, and escape areas.

b. Lt Col Dennis W. Jarvi - Mechanical Engineer with an MBA assigned to Aeronautical Systems Division, Directorate of Equipment Engineering.

Professional Background - Chief of the Crew Equipment and Human Factors Division, Directorate of Equipment Engineering.

Military Background - Command pilot with over 3200 hours. Graduate of USAF/GAF Fighter Weapon School. He has flown the F-101B, F-102, F-104G/S and the F-105D/F/T-Stick II. He flew a combat tour over North Vietnam in the F-105D. He has flown the F-104 with five NATO nations in Europe.

c. Dr. Kenneth R. Boff - Engineering Research Psychologist with a PhD (Sensory Psychology), from Columbia University. Assigned to Air Force Medical Research Laboratory. Recently departed the Human Resources Laboratory.

Professional Background - Over the past few years, Dr. Boff has been actively involved with the technical transfer of basic sensory and perceptual data, principles and models to the design and specification of aircrew training simulators.

d. Mr. Nathan W. Davis - Engineering Psychologist with a BA in Psychology

Assigned to the Equipment Engineering Directorate, Human Factors Branch.

Professional Background - Involved in application of human factors principles to equipment/system design at Wright-Patterson AFB for nine years. His areas of expertise include advanced display technology and video technology. He is presently serving as a human factors engineer for the F-16 Systems Program Office. He has served as a human factors engineer for other systems including the Air Launched Cruise Missile and Remotely Piloted Vehicles.

e. Lt Cmdr Harry P. Hoffman - Aeromedical Advisor (pilot/physician) to Life Support SPO, ASD/AESA, Wright-Patterson AFB.

Professional Background - USN Attack Weapons pilot as Naval aviator with 200 combat missions in Southeast Asia. Received MD from Hahnemann Medical College, Philadelphia PA. Designated Naval Flight surgeon, board eligible in aerospace medicine. Flew RDT&E tour at VX-5, NAS Pt Mugu, CA. MPH in Epidemiology, U.C. Berkeley. One combat loss and ejection experience (ESCAPAC/A-7/A). Currently on USN/USAF exchange tour.

f. Mr. Ronald W. Schwartz - Aerospace Engineer with a BS in Mechanical Engineering and an MS in Systems Engineering Management.

Assigned to the Directorate of Equipment Engineering, Crew Station and Escape Branch.

Professional Background - Has participated in crew station, control-display, and life support system design and research at Wright-Patterson Air Force Base for 18 years. Experience includes having had overall design responsibilities for both the F-15 and A-10 crew stations and life support subsystems. Responsibilities have also included several other tactical, cargo, and rotary wing aircraft, as well as review and updating of crew station design criteria.

g. Mr. William L. Welde - Engineering Research Psychologist with an MA in Experimental Psychology

Assigned to Air Force Aerospace Medical Research Laboratory, Plans and Program Branch.

Professional Background - Has been involved in human factors research at Wright-Patterson AFB on Air Force weapon systems for 19 years. Areas of expertise are aircraft control/display concepts, simulation, pilot workload, vision, and pilot training aspects. Research responsibilities have included bench level scientist through major program manager in more recent years. Presently serving on Laboratory Commander's senior technical staff.

Military Background - Command pilot with over 4100 hours including five years service in the Air Force in SAC and 17 years as a tactical fighter pilot in the Ohio Air National Guard. Currently combat ready in the A-7D with the additional duty as Director of the Group Command Post.

h. Mr. John M. Wilson, Jr. - Aerospace Engineer with an MS in Aeronautical and Astronautical Engineering

Assigned to the Deputy for Simulators, Directorate of Engineering

Professional Background - Has been working as an engineer on flight simulators and flight simulator visual systems for 11 years. Senior Systems Engineer at Link Division of Singer Company for 4 years and an Aerospace Engineer for the USAF for 7 years. Areas of expertise include aerodynamic design, visual system integration, training analysis, motion cueing systems, design and conduct of system evaluations, visual cue analysis, and visual system engineering and evaluation. Currently Deputy Chief Engineer for the Tactical Combat Trainer engineering development program.

Military Background - Command Pilot with over 3500 hours, 3300 in Fighter aircraft including the F-102 and F-4C/D/E on active duty (8-1/2 years) and the F-100C/D, F-101B, and the A-7D in the Air National Guard (10 years). Combat tour as an F-4D aircraft commander in Southeast Asia. Currently combat ready in the A-7D.

i. Mr. Robert C. Pangburn - Engineering Psychologist with an MA in Experimental Psychology

Assigned to the F-15 SPO Division of Equipment Engineering

Professional Background - Has been involved in human factors research and participated in crew station, control-display and life support system design and research at Wright-Patterson Air Force Base for 18 years. Assigned to F-15 SPO for the last 10 years as human factors engineer with responsibilities including the F-15 crew station engineering manager.

C. THRUST OF STUDY

The team focused its investigation in two areas of concern. The first area investigated was the phenomenon of spatial disorientation in the F-15. Secondly, the team examined the exterior lighting of the F-15 in order to search for (a) any relationship to causal factors for spatial disorientation and (b) any deficiencies in lighting that might detract from the pilot's ability to attain and maintain formation position.

1. SPATIAL DISORIENTATION

Although, on the whole, team members were familiar with spatial disorientation and its effect on the pilot's ability to fly, further review of specific phenomenon was necessary.

a. Literature Search. A review of publications dealing with spatial disorientation were listed to provide an investigative guide.

b. Baseline Data. The team then decided the proper approach was to examine the flying incident/accident records at the USAF/AFSIC Flight Safety Center at Norton AFB CA to determine what incident rate due to spatial dirorientation could be applied to all aircraft accidents. These data were necessary to establish a baseline rate of accidents associated with spatial disorientation.

c. F-15 Data. A second search of the USAF Safety Center data file was accomplished in order to determine if any differences existed between F-15 data and the baseline data acquired related to the incidence of spatial disorientation. The team then began examining the F-15 aircraft to locate F-15 design features that may contribute to inducing spatial disorientation. The first area dealt with the F-15 flight handling characteristics, the second was the cockpit configuration, and the third area was the F-15 exterior lighting configuration. This last area was treated as a separate issue which considered additional factors outside of spatial disorientation.

d. F-15 Flight Handling Characteristics. This effort included interviews with operational F-15 pilots with a wide variety of previous experience and the analysis of G levels associated with a variety of stick forces. These data were compared with other aircraft. The underlying question was: "Does the F-15 handle in such a way that may tend to induce spatial disorientation?"

e. F-15 Cockpit Configuration. The F-15 cockpit was examined in great detail. Here the effect of the large bubble canopy was studied to determine the effect of sitting relatively high in the cockpit coupled with increased peripheral vision. Layout of the cockpit was studied as well as the effect of interior cockpit lighting. The HUD and its use was examined. Further, interviews of F-15 pilots at two different bases were accomplished. Interviews were also conducted with F-16 pilots for the purpose of comparing high performance aircraft. The underlying question during this phase was: "Are there design features in the F-15 cockpit configuration that may cause spatial disorientiation?"

f. Training. The team evaluated what training was being accomplished to combat spatial disorientation. F-15 "lost wing man procedures" were assessed as well as instruments specifically used for maintaining aircraft control in marginal VFR conditions.

2. EXTERIOR LIGHTING

The exterior lighting factor was investigated. This aspect of the investigation was treated separately from two major viewpoints. The first area was the relationship of the F-15 exterior lighting to the occurrence of spatial disorientation, and the second area of concern was the pilot's ability to attain and maintain proper formation position at night and/or in marginal weather conditions.

a. History of F-15 Exterior Lighting. In order to understand the rationale for the current F-15 exterior lighting array, a historical review of the F-15 lighting schemes as they evolved was necessary.

b. Current F-15 Exterior Lighting. Having studied the historical data, the current F-15 exterior lighting configuration was evaluated.

c. F-15 Lighting Compared to Other Aircraft. The F-15 exterior lighting was then compared with a large variety of other aircraft to note what configuration differences exist.

d. Pilot Interviews. Interviews with operational F-15 pilots were accomplished to determine what they perceived as deficiencies and their suggestions for improvements.

3. Nine meetings were held during the 7 month period. Team members travelled to Eglin AFB Florida, Hill AFB Utah, and Langley AFB Virginia to conduct pilot interviews. The study was conducted without simulator or flight tests. The operational period considered was 1972 to 1 July 1980. The final team meeting was held on 30 July 1980.

PART II

ANALYSIS

A. SPATIAL DISORIENTATION INVESTIGATION

1. LITERATURE SEARCH

a. Types of Spatial Disorientation. Spatial disorientation in this report refers to all circumstances in which a pilot is uncertain of the attitude or position of himself and his aircraft with respect to the surface of the earth or other reference object. (Benson, 1965.) Spatial disorientation primarily results from either: (a) normal reactions of the vestibular system to the stimulation of motion in three dimensional flight or (b) from visual illusions arising from erroneous interpretation of information from the visual field. Combined or interrelated effects of (a) and (b) often compound spatial disorientation.

(1) VESTIBULAR INDUCED SPATIAL DISORIENTATION

During flight, pilots are subjected to unusual G force environments which stimulate the vestibular mechanisms of the inner ear. Variations in the magnitude and/or direction of the G force are responsible for a number of postural and visual illusions. For terrestrial man, vestibular cues to spatial orientation normally correspond with direct visual stimulation. When the correspondence between these modalities is disrupted, spatial disorientation will result that is characterized by constant errors in judgment with respect to the apparent motion of visual objects and in the estimation of their true spatial locations. (Clark, 1963.) Confusion between these two sensory inputs must be resolved quickly in flight for safe maneuvering of the aircraft.

The following listing of spatial disorientation effects resulting from vestibular stimulation was adapted from Peters (1969) and serves as examples of vestibular inputs and their perception by the aircrew:

(a) Stimulation of the Transducer Mechanism for Linear Acceleration, the Otolith Organ. The otoliths are generally believed to be affected by any linear accelerative force, including gravity. (Clark, 1963.) The following postural and visual illusions result from stimulation of the otoliths:

1. Unperceived Bank. In a coordinated turn the G vector lies in the vertical plane of the aircraft, creating a sensation of sitting erect. (The pilot would not correct this turn until he has some reliable visual cue to do so, such as a horizon, lead aircraft, or instruments.)

2. Sensation of Climbing in a Turn. In a coordinated turn when the horizontal turn and bank are not perceived, the increased G force in the turn yields a sensation of climbing or a nose-high attitude. The resultant tendency is for the pilot to push the stick forward.

3. Sensation of Diving when Recovering from a Turn. When recovering from a dive or a nose-down attitude. (The rotational accelerative forces perceived by the otolith are giving perceptual cues to the pilot which simulate diving if all his other conscious senses are disregarded. Again, he must override this feeling using valid cues .... usually visual.)

4. Sensation of Opposite Tilt in a Skid. If the aircraft skids during a turn, the centripetal acceleration producing the skid also acts on the pilot. The resultant G vector is no longer perpendicular to the transverse or lateral axis of the aircraft. The sensation is created that the aircraft is banked in the direction opposite its true position.

5. Sensation of Nose-High Attitude During Takeoff. During the rapid acceleration of a high performance aircraft at takeoff, the resultant G force is at such an angle that the pilot may have a sensation of being tilted backward or that he is in a nose-high attitude. He may attempt to correct for this sensation by pushing the stick forward, which would increase the acceleration (and the sensation) and result in the aircraft impacting the ground. (This sensation occurs predominantly during night takeoff.)

6. Sensation of Nose-Down Attitude During Deceleration. In level flight during deceleration of the aircraft, (eg. as when the speed brakes are extended or power reduced), the resultant G force is at such an angle that the pilot may have a sensation of being tilted forward or being in a nose-down attitude. He may correct for this by pulling back on the stick, which could result in a stall.

7. Sensation of Nose-High Attitude or Inversion During Push-Over From a Climb to Level Flight. As a high-performance aircraft pushes over into level flight from a climb, it will accelerate along its flight path. The combination of the rotating gravity vector, the increasing tangential acceleration, and the centripetal acceleration resulting from the curved flight path yield a resultant G vector which rotates backward and upward relative to the pilot. The pilot has the sensation that he is tilting over backward until nearly inverted at the apex of the climb. He has a tendency to compensate for this illusion by pushing forward on the stick, which intensifies the illusion. Safe recovery may not be possible from the resultant nose-down, negative pitch angle.

8. Oculogravic Illusion. This illusory effect is associated with a change in magnitude and direction of the resultant force acting on the body and results in apparent motion and accompanying displacement of visual targets in darkness. This effect is clearly minimal. In some instances the oculogravic illusion may be suppressed by a good outside visual reference.

9. Elevator Illusion. The elevator illusion involves the motion and displacement of objects in the visual field in accordance with changes in the magnitude of the gravitoinertial vector. The elevator illusion is thus distinguished from the oculogravic illusion, which is caused by changes in the direction of the gravitoinertial vector.

(b) Stimulation of the Transducer Mechanism for Angular Acceleration; The Semi-circular Canals.

1. The Leans. The leans is probably the most commonly experienced form of spatial disorientation and is caused by the aircraft rolling in one direction at an acceleration level below the threshold of perception and rolling in the opposite direction with an acceleration level above threshold. The pilot perceives only the suprathreshold roll displacement and, thinking he has been displaced from the upright, leans his body in the opposite direction to compensate. The sensation may persist even though cockpit instruments inform the pilot that he's flying straight and level.

2. Estimating the Degree of Bank. A rolling acceleration on entering a turn may be below the threshold of perception, in which case the bank angle attained is underestimated. This causes the pilot to bank too much going into a turn and to overcorrect when recovering from the turn, thus causing a bank in the opposite direction.

3. Illusion of Turning. This illusion can occur when an aircraft enters a gradual unperceived turn. When the pilot becomes aware of the turn he may correct for it by applying sharp opposite rudder. After recovering from the turn he then has a strong sensation of turning in the opposite direction. The illusion is caused by a combination of threshold and dynamics phenomena.

4. Graveyard Spin. When an aircraft enters a spin the initial angular accelerations in roll and yaw are perceived by the pilot, giving him a sensation of the angular motion of the spin. As the spin continues, the sensation of angular motion gradually subsides as the cupulae of the affected semicircular canals return to their neutral positions. As the pilot effects a recovery from the spin, he experiences angular acccelerations in roll and yaw in the direction opposite the spin which deflect the cupulae in the direction opposite their initial deflection, giving rise to a sensation of spin in the direction opposite the initial spin. The pilot may then correct for this sensation by reentering the original spin.

5. Graveyard Spiral. This illusion is similar to that experienced in the graveyard spin; the semicircular canals equilibrate to the constant angular velocity in the spiral and the motion sensation subsides to zero. The aircraft motion in the spiral is that of a descending, coordinated turn. The novice pilot, noting the decrease in altitude, may attempt to correct for it by pulling back on

the stick and adding power. This worsens the situation by tightening the spiral. If the pilot takes the appropriate action of correcting his bank angle first, followed by his turn rate and descent, he may experience an illusion of turning in the opposite direction, correct for this illusion, and reenter the original spiral.

6. Coriolis Illusion. If the aircraft is negotiating a constant rate turn, ω, to which the pilot's semicircular canals have equilibrated, and the pilot then moves his head about a second axis not aligned with the ω axis, he may experience a sensation of rotation and tilt about a third axis, which is approximately orthogonal to the axis and the head tilt axis. The experience, known as the Coriolis effect, can be extremely strong creating postural disorientation, strong visual effects, and nausea.

7. Oculogyral Illusion. The oculogyral illusion involves the apparent motion of objects in the visual field (see autokinesis) in response to prolonged passive rotation. The oculogyral illusion can be demonstrated if a subject is rotated in darkness while he observes a visual object, which rotates with him, so that physically it is always directly in front of him. Under these conditions at a constant velocity, he will report that the target appears to move rapidly to his right, but there will be little apparent displacement of the object. In other words, the target appears to move but does not change its position. This will continue for a few seconds, then the motion will begin to slow down, and after 20 to 30 seconds the apparent motion will stop. This is known as the first effect of the oculogyral illusion. If the subject continues to observe the visual target, he may observe apparent motion of the target to the left for what has been called the second effect.

(2) VISUALLY INDUCED SPATIAL DISORIENTATION

Orientation from the external scene during flight depends upon perception of complex and continually changing patterns of visual stimuli. The validity and accuracy of both the perception and the interpretation of these cues is a function of the aviator's experience and training. Attitude is judged by reference to the horizon or when nearer the ground, by the verticals of buildings, masts and trees. Distance and depth are determined principally by monocular cues such as parallactic displacement, aerial perspective, apparent size and by changes in both detail and color with distance. (Benson, 1965.)

Unfortunately, outside visual references are often reduced by smoke, haze, fog, inclement weather, or darkness. In such situations the pilot's interpretation of visual cues becomes more difficult, illusory visual information may occur, and visual phenomena themselves may contribute to disorientation. Examples of these types of spatial disorientation (adapted from Peters, 1968) are listed below:

(a) Autokinesis. This illusion consists of an apparent motion of isolated lights viewed in a meager visual framework. If an isolated light is viewed continually in the dark, it will appear to wander about at random over a small area. The apparent motion may extend as much as 15 degrees and is indistinguishable from real motion. Pilots have reported attempts to join up with a formation of stars, buoys, lights on bridges, and street lights which appeared to be moving and were interpreted as other aircraft.

(b) Fascination. This is a condition in which the pilot fails to respond adequately to a clearly defined stimulus situation in spite of the fact that all of the necessary cues are present for a proper response, and the correct procedure is well known to him.

(c) Target Hypnosis. Target hypnosis is a form of fascination and is characterized by a pilot becoming so intent on destroying the target during an attack that he fails to pull up in time to avoid striking the ground, usually with fatal consequences.

(d) Illusory Effects Due to Inadequate Stimuli. Restriction of the visual field by smoke, dust, haze, fog, rain, or darkness can produce gross discrepancies between physical entities and their appearance as perceived by the pilot. The pilot's attempt to restructure the physical entity from his meager perception of it may result in a false identification and consequent disorientation.

(e) Improper Grouping of Lights at Night. The tendency to group items in the perceptual field can contribute to illusory effects. A small cluster of isolated lights on the ground on a dark night with a high overcast may be interpreted as the lights of a formation flight.

(f) Illusions of Relative Motion. Experience of illusions of relative motion are numerous. To an observer in a fast aircraft crossing the path of a much slower aircraft at a different altitude, the slower aircraft appears to be flying sideways and backwards. Illusions of relative motion can be especially provocative and potentially hazardous during formation flights at high altitude or at night when cues to forward speed are absent.

(g) Illusory Horizons. The primary cue to the vertical is the visible horizon; using this cue the pilot can orient his aircraft properly and with great precision. Under conditions of restricted visibility the horizon may become obscure or occulted. Under these conditions the pilot may rely on some other indicator which he believes to represent the horizontal. Under certain other conditions and in perfectly clear weather the pilot may orient his aircraft improperly despite using the visible horizon as a reference. Various types of disorientation may be produced by reliance on fictitious horizons. (e.g. Tilted cloud banks; depressed horizons due to high altitude flight; confusion between city lights and stars.)

(3) CLASSICAL FACTORS CONTRIBUTING TO DISORIENTATION IN FLIGHT

Accident reports, questionnaires, and pilot reports of disorientation incidents have revealed a number of factors which predispose the pilot to experience disorientation. (The following listing was excerpted from Peters, 1969.)

(a) Factors related to a given flight condition:

1. Flight during conditions of reduced visibility
2. Formation flying in weather
3. Formation flying at night
4. In-flight refueling in weather
5. Flying alone
6. Transitioning from an outside visual reference to an instrument reference
7. Night takeoffs

(b) Factors related to a given procedure by the Pilot:

1. Head movements, during a turning maneuver, (e.g. as a result of trying to maintain position in a formation, or by trying to view or adjust an improperly located instrument)

2. Shifting control of stick from one hand to the other to change a radio channel during a maneuver under instrument conditions.

(c) Factors Related to inability to establish an orientation reference:

1. Failure to pilot to monitor attitude and motion
2. Attempting semi-contact flight; attempting to mix the outside visual reference and the instrument reference
3. Trying to fly visually in marginal weather
4. Waiting until the last moment to make the transition from a visual to an instrument reference
5. Conflict between instrument reference and sensations of motion and orientation.

(d) Factors related to a particular maneuver or sequence of maneuvers:

1. Prolonged constant speed turns with rapid recovery
2. Unusual maneuvers at night
3. Slow unperceived turn entries
4. Sudden acceleration or deceleration
5. Flight during and immediately following aerobatics, prolonged spinning, or rolling maneuvers
6. Flight following large pressure changes produced by ascent or descent.

(e) Factors related to the level or recency of training of the pilot:

1. Inexperience with instrument flight
2. Lack of recent instrument experience
3. Flight following a period of flying inactivity.

(f) Factors related to misinterpretation of visual phenomena:

1. Prolonged fixation on isolated lights at night
2. Flight over sparsely lighted terrain
3. Flight at high altitude (causing fictitious horizon due to curvature of the earth).

(g) Factors related to the physical and mental condition of the pilot:

1. Deteriorated physical and mental state of pilot caused by hypoxia, hyperventilation, toxic agents, fatigue, illness, alcohol, drugs, anxiety, etc.

2. BASELINE INCIDENT RATE

a. The primary data reviewed were two reports prepared by AFISC analyzing the incidence of spatial disorientation in aircraft accidents. The method of analysis used was to survey accident reports for cases in which spatial disorientation was mentioend as a primary, contributing, or possible cause. Throughout the overall period surveyed for this study, (1 Jan 1958 through 31 Dec 1971), the incidence of accidents in which spatial disorientation was identified as a causative factor was six percent of the major aircraft accidents. During the first study period (1958 through 1968) the fatality rate in accidents having spatial disorientation as a causative factor was 75 percent. This rate dropped to 62 percent during the second study period (1968 through 1971). The overall fatality rate for the period was 73.4 percent.

b. The data of primary concern, however, is the overall rate of six percent of the accidents in which spatial disorientation is considered to be a causative factor. This rate has remained constant for many years, throughout the period of the referenced surveys. A recent cursory examination of data obtained on current tactical aircraft indicates the overall incident rate has not changed. This examination revealed that 18 percent of the accidents have spatial disorientation mentioned in the report.

3. F-15 INCIDENT RATE

a. To determine the F-15 incident rate, AFISC was contacted and a computer printout was obtained of all F-15 major accidents to date. This study includes two further accidents which occurred recently. The computer printout showed 20 accidents which, with the two additional accidents referenced above, provided a total of 22 data points. Of the 22 accidents surveyed, four of them listed disorientation as a causal factor and one listed it as a potential causal factor. A look at the simple percentages indicate that considering only four accidents having disorientation as a factor provides a rate of 18.2% (4/22). If all five incidents are considered the rate increases to 22.7% (5/22). On the surface this appears to be a significant increase in the rate of occurrence of disorientation incidents in the overall population of six percent. For this reason, statistical analysis was performed on the data to determine if this inference can be drawn. The test performed was a chi square analysis. When tested at the 95% confidence level, we cannot statistically disprove the hypothesis that the F-15 data has come from a population having a disorientation incident rate of 6% when considering either four or five incidents in a sample of 22. Consequently, because of the low number of data points, ($N \ll 30$) the obviously higher incident rate among F-15s (18.2 - 22.7%) cannot yet be validly shown to have occurred other than by chance.

b. Common Factors in F-15 Disorientation Accidents. Five F-15 accidents were analyzed subjectively in which spatial disorientation was listed as a primary, contributing, or possible cause. The purpose of this survey was to look for common factors in the accidents that might lead to conclusions regarding correctable aircraft configuration faults. The results of the survey, however, point more towards pilot and training factors than aircraft configuration factors. In three accidents weather and the failure to properly execute the lost wingman maneuver surfaced as factors. Three additional factors surfaced in three of the accidents and included limited actual instrument flying experience, use of medication and potentially channelized pilot attention. The only findings that specifically pointed towards aircraft configuration were: a case where the pilot looking down to check his in flight refuel (IFR) switches may have been a factor and one where the pilot perhaps was confused by the formation lights on the lead aircraft. (He also failed to execute the lost wing man procedure properly.) A second pilot also failed to properly perform the lost wingman procedure and crashed. The other lost wingman incident occurred at night in clear weather beneath an overcast. These combinations of incidents lead to a conclusion that there are deficiencies in the external lighting system, particularly the combination of lights used to fly formation. There are two possible conclusions that may be drawn from this data. The configuration of the formation lights may cause confusion and, in themselves, be disorienting or, the lighting is inadequate in weather conditions making it easy to lose contact with the lead aircraft (or both).

TABLE 1

F-15 ACCIDENT FACTORS
(1977 - 1980)
ACCIDENT

Factors Identified	No. 1	No. 2	No. 3	No. 4	No. 5
Weather	X	X	X		X
Failure to go lost wingman	X	X	X		
Use of Medication	X				
Channelized Pilot Attention	X			X	X
Limited Flight in Weather		X	X		X

4. F-15 FLIGHT HANDLING CHARACTERISTICS

a. Interview Data. During interviews the F-5 pilots universally commented that the aircraft is extremely light and smooth in terms of the amount of control stick input required for maneuvering. Although the pilots were all very positive in their statements of the smoothness of the flight control response, there were also some thoughts expressed that this characteristic could perhaps contribute to a minor degree to disorientation problems. This would be particularly valid when flying on the wing in a homogenous external visual environment such as that encountered in a stratus or cirrus cloud deck or on a clear night.

b. F-15 Flight Handling Characteristics (Engineering Data). The F-15 longitudinal control system breakout force (force required for initial airframe response) is approximately 1 pound. The stick can be displaced approximately 1 inch in the longitudinal axis with a 1 pound force; beyond that a schedule of 3.75 pounds per G is maintained throughout its flight envelope. The schedule does not provide a linear relationship between 1 inch of stick travel and stick force but varies between 5 and 8 pounds of force per inch.

The F-15 lateral control system breakout force is approximately one pound. Approximately 5 pounds of force is required to displace the stick 1 inch laterally, 8 pounds for 2 inches of movement and approximately 15 pounds of force for 4 inches of lateral displacement.

c. Comparison With Other Aircraft. The F-16 longitudinal control stick break out force is 1.75 pounds of force. The stick is nearly rigid and moves only .178 inch aft with a force of 31 pounds applied on the stick. The F-16 lateral control stick break out force is 1 pound. At 17 pounds of lateral force, the stick deflects .116 inch and commands a 308°/sec roll rate. The F-16 aircraft has a constant stick force per G with auto trim throughout the flight envelope (gear retracted) and has a very smooth response to control input. Pilots rated this response as excellent for maneuvering but stated it does permit unintentional small control inputs especially during wing weather formation. This may contribute to disorientation. F-16 pilots do not consider disorientation to be a significant problem in the F-16. The smoothness of control on the F-15 received similar comment. The F-15 and F-16 both use a newly developed feature concerning stick forces (vs) aircraft G which is independent of airspeed. The rate for the F-16 is 2-1/2 pounds of force for each G up to a maximum of 34 pounds where it is limited by computer. Further, the F-16 employs an automatic trim feature not found on the F-15. In both aircraft, the handling features were not felt by pilots to significantly contribute to spatial disorientation.

(1) The A-10 aircraft longitudinal control stick breakout force is 4 pounds forward and 3 pounds aft. Its lateral control stick breakout force is 3 pounds.

(2) The F-4E aircraft control stick breakout force is 3 pounds in the longitudinal axis and 2 pounds in the lateral axis while the aircraft is on the ground. In flight tests 1 to 2 pounds of force was recorded as the longitudinal axis breakout force. The control system is designed to require approximately 5 pounds of force per G.

(3) The F-5A and T-38 aircraft control stick breakout force is 3 pounds in the longitudinal axis and 2 pounds in the lateral axis.

(4) The F-15 control stick forces are relatively light. An experienced F-4 pilot transitioning into the F-15 may initially note the light control stick forces required to generate an aircraft response. A new pilot arriving from a UPT program with the T-38 as his most recent aircraft would likely find the F-15 quite sensitive.

TABLE 2

CONTROL STICK BREAKOUT FORCES

	Longitudinal Axis (pounds)	Lateral Axis (pounds)
F-15	1	1
F-16	1.75	1
A-10	4 fwd/3 aft	3
F-4E	1-2 (air)	2
F-5/T-38	3	2

5. F-15 COCKPIT CONFIGURATION

a. Bubble Canopy

(1) The F-15 is equipped with a large bubble canopy which provides the pilot with excellent visibility. From the pilots design eye position he is able to see 15° down over the nose of the aircraft and 40° down over the side frame at the 90° relative bearing.

(2) Other aircraft provide the pilot a view outside the aircraft very similar to the F-15 as shown in Table 3.

(3) Use of lateral head movements and the raising the seat higher than the design eye position will increase the pilot's visibility. The increase in visibility is dependent upon the amount of head movement. In the F-4 the pilot can see 50° down over the side frame at 90° relative bearing by placing his helmet against the inside of the canopy.

TABLE 3
EXTERNAL VISION FROM DESIGN EYE POSITION
DEGREES OF ANGULAR DEPRESSION

	Over the Nose	Over the Side Frame (Without Shoulder Movement)		
	0^o	30^o	60^o	90^o relative bearings
F-15A	15^o	27^o	38^o	40^o
F-16	15^o	28^o	38^o	40^o
A-10	20^o	30^o	40^o	40^o
A-7	17^o	37^o	42^o	45^o
A-37	12^o	22^o	38^o	41^o
F-5	11^o	17^o	24^o	26^o
F-4	13^o	25^o	32^o	30^o
F-100	11^o	23^o	31^o	32^o
F-105D	13^o	22^o	41^o	44^o

b. Pilot Sitting Height. The pilot's design eye position in the F-15 requires a sight angle depression of 36^o to view the ADI. This is 5^o more than pilots flying the F-16 and F-4, 4^o more than A-10 pilots, 22^o more than F-5 pilots and 23^o more than T-38 pilots. This amount of depression angle did not surface as a problem to F-15 pilots. No known studies confirmed a human factors problem with the relationship between the F-15 design eye position and the location of the F-15 ADI and related flight instruments. But this area may warrant further investigation.

c. Cockpit Design.

(1) There has been speculation that there may be factors in the layout of the F-15 instrument panel that contribute to pilot disorientation. The first and foremost conclusion that can be drawn regarding that possibility is that every aircraft will have a certain degree of built-in disorientation producing factors out of the simple necessity to accommodate all the controls and displays required to operate the system. One of the primary sources of pilot disorientation is looking down into the cockpit to either the right or left, particularly during maneuvers. The further down and aft that the pilot must look into the cockpit, and the more head motion involved, the more pronounced the disorienting effects will be. The objective of good crew station design is to minimize the potential for disorientation by limiting the aft portion of the consoles to seldom used controls and placing those used often high and forward (within the limits of practicality and accessibility). Early in the design of the F-15 a very strong effort was mounted to do just that. This effort resulted in the UHF Comm controls and the IFF Mode 3 controls being located high under the HUD display unit. This permits control inputs to be made to these panels with little diversion of the eyes from outside the cockpit scanning requirement. One fact brought out by pilots, however, was that the digital knobs required to make a frequency change work much the same as an odometer (i.e., tenths must be manually cranked through completely to make a whole digit change). This requires a longer break in the pilot's attention span despite its ideal location.

(2) The remaining communications and IFF functions and the radar control panel are clustered outboard and aft of the throttle. This location is superior to a location further forward on the console since the panels are more accessible, both visually and manually in this location due to the throttle location. However, it must also be stated that they are located sufficiently far aft in the cockpit to have the potential for inducing disorientation. This is particularly true if the pilot attempts to operate these controls during maneuvers.

(3) The basic flight instrument group is somewhat deeper in the cockpit than is considered desirable. This was necessitated by the size of the head-up-display (HUD) unit. There has not tended to be any adverse pilot comments about this situation so there may not be a contribution to the spatial disorientation problem. The flight instruments are located on aircraft centerline which provides minimal false vestibular cues, particularly when maneuvering head down. It should be noted, however, that newer pilots may depend on the HUD as a primary flight instrument (unlike pilots trained before HUDs) and actual use of the instrument group in weather may be new to them.

(4) There are four potentially high use panels on the right console. It is doubtful, however, that any of these played a part in any of the incidents under evaluation. Two of the four panels in question are the TEWS and ECM panels, which may require quick action. The other two are the nagivation control panel and the interior lighting panel. Both of these panels may be operated at the pilot's leisure and when flying wing or in a lost wingman situation the pilot should not involve himself with the navigation panel until a successful recovery has been completed. It has been suggested by 33rd TFW pilots, however, that the "steer to" window is poorly positioned and illuminated at present. Moving it to above the radio call plaque was suggested, since it is a "primary use" instrument on INS.

(5) The overall review of the F-15 cockpit design, as in all other aircraft reveals that the potential exists for inducement of spatial disorientation when the pilot looks down while in maneuvering flight. A caution note in the TAC Regulation 55 series outlining aircraft operation procedures might be considered. This would remind aircrews that looking at these panels during maneuvering flight or when any symptoms of disorientation are present may compound the problem.

d. Interior Lighting

(1) The interior lighting system on the F-15 is a sophisticated and easily controlled cockpit lighting system. It was noted that numerous improvements over previous aircraft had been made.

(2) The chromaticity requirements for the light output for both instruments and panels levied on the contractor were those of MIL-L-27160, which is the instrument lighting specification. Since that time, MIL-P-83335 has been developed to apply these same chromaticity requirements to panel lighting. The contractor, however, levied even more stringent chromaticity requirements on his vendors. These requirements were supported by a comprehensive quality assurance program which included visual inspection of every lighting unit against a calibrated source that is recalibrated quarterly. Surprisingly, even with the stringent chromaticity requirements placed on the vendors by McAir a visual comparison inspection of the lighted panels will easily detect panels that approach the outer limits of tolerance in both chromaticity and brightness.

(3) The F-15 has more control capability in the lighting circuits than has been common in the past. The main lighting has five rheostat type controls on the main panel. These include separate controls for the left and right consoles, the flight instruments, engine instruments, and auxiliary instruments which includes all lighting units in the forward quadrant that are not part of the primary flight and engine instruments with the exception of the armament control panel. The armament control panel has its own light intensity control located on its face. The standby indicators are controlled by the auxiliary light circuit but may be extinguished independently by a toggle switch on the lighting panel. The warning and caution lights have a variable dimming circuit. In this case, full bright for warning and caution lights is 28 VAC. Actuation of the dimming circuit provides continuous dimming from 6 to 14 VAC. This provides a degree of dimming to reduce the distraction in dark adapted cockpits but not the capability to totally extinguish them. The flood light control provides continuous control from off to full bright which also provides thunderstorm lighting. All of the dimming controls provide a broad range of adjustment at lower levels of illumination to allow the pilot to fine tune his adjustments as his dark adaptation increases. The system was mechanized in this manner as a reaction to pilot comments resulting from night operations in Vietnam. Comments that appeared in previous pilot interviews indicating the F-15 lacked independent control of instrument lighting and that the layout of the lighting controls was confusing. The F-15 has an individual trimming potentiometer for each lighting unit in the crew station. Unfortunately, these fine adjustments can be made only by technicians between flights and not by pilots in the air. Thus a pilot will not get the benefit of his personal preference unless he has two or more back to back flights or specifies his desires before the flight. One pilot stated he was sometimes confused by the layout of the lighting control panel because the location of the console, instrument, and engine control rheostat knobs do not correspond to their fore and aft position in the aircraft.

(4) The F-15 had a lighting mock-up in which many of the lighting problems were worked out early in the program. The mock-up had a complete canopy which was beneficial in the suppression of reflections. A number of major reflection problems were discovered and the reflections

suppressed by an extension to the glare shield. There is still the obvious problem with overall reflections of individual lighted legends across the canopy, particularly from the side consoles. These reflections are nearly impossible to suppress and may be detracting to the pilot. There is an additional problem common to all aircraft with white lighting in that the reflections from white lighting tend to be more opaque than those from the other colors of lighting that have been in common use. The lower the level of illumination, the less bothersome this becomes because the brightness of the reflection is reduced. At lower levels of illumination the white incandescent lighting moves toward the yellow end of the spectrum. Reflections tend to distract and cause refocusing of the eye at the level of the reflections.

e. Heads-up Display (HUD).

(1) F-15 Heads-up Display (HUD). A fundamental concern was expressed by some of the F-15 pilots that there exists an over dependence on the HUD in flying the aircraft. This is particularly true when a pilot finds himself either in an unusual attitude or recognizing the symptoms of vertigo. There is a tendency for the pilot to initially look at the HUD to become reoriented and effect recovery. However, the recommended procedure in this situation is to completely ignore the HUD and immediately transition heads down to the cockpit panel instruments. This natural tendency for the F-15 pilots to employ the HUD as the primary instrument display has reportedly at times caused a loss of reference by pilots, which probably can best be described as the experiencing short-term disorientation phenomenon. This effect may occur from either (a) the "rush" of the flight parameters in the HUD, such as the scale displays of altitude, airspeed, heading and pitch attitude, during aircraft maneuvering, or (b) the visual transition from the HUD to the external world scene at night, which is a function of the accommodation and contrast effects on the human visual system during reduced ambient illumination levels. Although the HUD is collimated at infinity, the display tends to cause the pilot's eyes to focus at the near point of the combining glass rather than seeing the symbology superimposed on the external scene. Furthermore, the HUD symbology brightness level cannot be adequately adjusted at night. In order to readily discern the numbers which are displayed in green, the display brightness must be increased to a level where the pilots feel they cannot see out of the cockpit. Thus, when there is a requirement to scan outside the aircraft, the display brightness must be reduced, which only adds to the pilot's workload problems.

(2) Most of the pilots interviewed reported that they flew instruments primarily with the inside panel and utilized the HUD for cross-check purposes and during stabilized flight. Although the pilots indicated that the HUD information provided fairly accurate information, instrument flying with the HUD in actual weather conditions tended to increase the probability of disorientation. Interestingly, the HUD was designed by McDonnell Douglas as a primary flight reference, but the

Dash One cautions against using the HUD for this purpose due to inadequate failure warnings. It was suggested that a minimum number of HUD-out instrument approaches should be required in the simulator and in the aircraft in order to reduce the dependence on the HUD. Although this training requirement would be difficult to enforce, it nevertheless would emphasize the need for pilots to become more familiar and comfortable with HUD-out instrument flying. Newer pilots have not used the instrument group over the HUD to the point where they feel confident, such as older pilots who once had only instrument experience and feel comfortable relying on them. In summary, the pilots find the HUD a very compelling display, presumably because of its information content, prominent location in the pilot's visual field, novel display mode, and the overall integrated relationship of the HUD to flying the aircraft and accomplishing the mission.

(3) F-16 Heads-up Display (HUD). The F-16 HUD is considered a primary reference except for instrument flight. All pilots stated they would go directly to head down instruments when in instrument conditions or disoriented without trying to use the HUD. One pilot commented that the HUD is the worst place to look if disoriented. The only other HUD comment that was expressed concerned the small field of view that requires taller pilots to lean forward or slouch down to view the level flight reference below 300 knots.

f. Interview Data.

(1) F-15 Pilot Sitting Height. When queried, the F-15 pilots did not generally feel that the slightly higher sitting height in this aircraft contributed in any significant way to disorientation, nor did the larger bubble canopy. A small number of pilots, however, agreed with perceptions of F-16 pilots discussed in the next paragraph.

(2) F-16 Pilot Height. Pilots commented that the high seating height and low canopy rails make them feel as if they are on top of the aircraft in the weather. A flight that intermittently penetrates clouds was said to be more distracting than in previous aircraft. The change in line of sight from the HUD to the cockpit instruments is much greater than in other aircraft and pilots commented that a more conscious effort must be made to transition from one to the other. These distractions, even though relatively minor, may help contribute to the overall cumulative distraction level facing any aircrew in a tactical scenario.

(3) F-15 Interior Lighting. Considerable interview comments were generated on the white interior cockpit lighting causing reflections in the canopy at night when adjusting the lights to the higher illumination level which is required to adequately read the instruments. The pilots find that they are continually adjusting the cockpit lights at night; that is, turning the lights up to read the instruments and then reducing the brightness level in order to minimize the glare, canopy reflections, and enhance visual scanning outside the cockpit. This requirement, of course, unnecessarily increases pilot workload in the F-15.

(4) F-16 Interior Lighting. No significant comments were made regarding interior lighting possibly due to the relatively limited night experience in the F-16.

(5) F-15 Day Formation References. With the F-15 being a large tactical aircraft, the wingman flys out quite a distance from the fuselage and canopy of the lead aircraft. Pilots commented that when lead rolls his aircraft, the wingman perceives he is on a very long moment arm that requires large control movements in order to maintain proper wing formation position. Furthermore, the pilot's head must be turned considerably to the side in order to fly good formation, which results in a large angular difference between the outside formation references and the line of sight to his HUD or ADI (possibly as much as 60°). This, of course, necessitates significant head movements by the wingman whenever he wishes to cross-check the cockpit instruments. Both pilots and physiologists know that large head movements in the cockpit can produce vertigo. In order to minimize these head movements, the wingmen prefer to slide down and back from the normal formation position. However, if the wingman drops too far down and in toward lead during intense weather formation flight, the wingman's aircraft wing overlaps the horizontal stabilizer of the lead aircraft in the vertical plane. This is to be avoided since it is somewhat dangerous and can interfere with the normal flight dynamics of the lead aircraft to the extent that lead can "feel" when the wingman is in too tight. Pilots also reported that they lose the F-15 when flying formation during day weather conditions more than any other tactical fighter they have flown. This may be attributable to the gray paint scheme of the F-15 being of minimal color contrast with the weather, gray paint scheme of the F-15 being of minimal color contrast with the weather, which results in the aircraft easily blending into the weather, but no data exists to verify this.

(6) F-16 Day Formation References. Day formation and day formation references are considered to be typical of other fighter aircraft. Pilots did comment on the unintentional small control inputs mentioned under handling characteristics. In addition canopy reflections from clip boards, helmets, and other cockpit items occur about 30 degrees forward of the pilot's ear line and prove distracting. Pilot's helmets were painted gray to decrease such reflections.

6. TRAINING

a. Formal Training and Guidance.

(1) Spatial disorientation is a mandatory topic to be covered during the annual instrument refresher course each pilot attends. Further, this topic is discussed every three years during the Aircrew Physiological Training at an altitude chamber. The topic is listed in preflight briefing checklists for all tactical fighter aircraft and has appeared in publications made available to aircrew members.

(2) In the formal F-15 Combat Crew Training Course at Luke AFB AZ, spatial disorientation training is listed in the syllabus. Completion of this training is mandatory for graduation from the program.

(3) These programs all identify the aspects of spatial disorientation and reflect what action must be taken to counter the effects of the disorientation.

(4) Pilots at the 33rd TFW indicated that present tactical requirements do not show any need for purely instrument flights. Tactical Air Command has taken steps to ensure an instrument manual change to require two instrument sorties in every 6 month period. The current syllabus requirements presently do not include unusual attitude practice because two aircraft are required (one to "chase") in single-seat aircraft. Present aircraft assets made this difficult to achieve.

b. Lost Wingman Procedures. The lost wingman procedures for the F-15 are well defined in TACM 55-115 and are standard with all tactical fighter aircraft. These procedures are taught to all pilots and these pilots are quizzed to ensure they understand the procedures.

B. EXTERIOR LIGHTING

1. HISTORY OF F-15 EXTERIOR LIGHTING

a. Although there were some concerns voiced by McDonnell Douglas Aircraft human factor and lighting engineering personnel in 1970, the F-15 as presently designed was considered by the contractor and the Air Force to meet the Mil Spec on lighting (MIL-L-6503).

b. The exterior lighting system was designed essentially as presently configured and was first flown at Edwards AFB CA in 1972. The first night flight was flown one year later in Jul 73. Pilots reported that it was difficult to maintain position and make join-ups during night formation flight because the formation lights, due to their positions relative to each other on a straight "water line" did not provide adequate roll cues to the wingman. Bank angles of 20 to 30 degrees were attainable before roll was detected, and even then the direction of the roll could not be determined. This was documented in Deficiency Report No. 191-175 (Appendix A).

c. A study was performed by the Joint Test Force at Edwards AFB, to determine an optimal exterior lighting configuration. Using a scale model of the F-15, several modifications to the lighting were made and these were displayed, under simulated conditions, to the pilots for comments. An optimized configuration was arrived at, by pilot consensus, which was recommended for implementation to the SPO for flight test evaluations.

d. McDonnell Douglas modified one aircraft for evaluation as depicted in Figure 1. In addition, a 26 watt bulb (versus 40 watt) was installed in the right wingtip position light. This aircraft was flown in night flights (clear air) to verify findings of the previously performed laboratory study.

e. Summarizing the results, the pilots were unanimous in their preference for the modified formation lights. The modified formation lights provided adequate cues for night join-ups and formation flying under all ambient light conditions tested. Two pilots reported that the addition of the flood light greatly enhanced formation cues, but it was not considered essential for production aircraft. The formation lights were estimated to be visible for 3,500-4,000 feet when set on bright. The crossover cues were adequate. The colors of the position and anti-collision lights were readily discernible by the pilots. The intensity of the formation and position lights were satisfactory for the join-ups and close formation flying except for the white position light on the left vertical fin which was judged to be too bright and the luminescent strips on the wingtips which appeared noticeably dimmer than the other strips.

f. Thus, a modified formation light configuration consisting of the original luminescent strips plus luminescent strips on the inside and outside of the vertical tails and two strips in the shape of an open V on the dorsal surface of the aircraft behind the speed brake, all adjusted to appear at the same intensity, would be satisfactory for operational use. This modified formation light configuration was recommended for production aircraft by the Joint Test Force.

g. As a result of AFFTC Category II test program Deficiency Report 191-175, three main endeavors were pursued as follows:

(1) The exterior lights control panel was redesigned to provide continuous dimming capability and to provide the pilot with tactile feedback controls. Those controls resulted in a five detent rotary switch for both the position and formation lights.

(2) The green wingtip light/lens assembly was reviewed by McAir and by the light vendor (Grimes) and it was determined that it met Air Force requirements. The white appearance at full bright setting at certain visual angles was not verified. No further action was pursued.

(3) A request for an ECP was sent to McAir to improve the exterior formation lights by adding the strip lights as tested by the Joint Test Force. Based on the above action, the Deficiency Report 191-175 was officially closed in Mar 74.

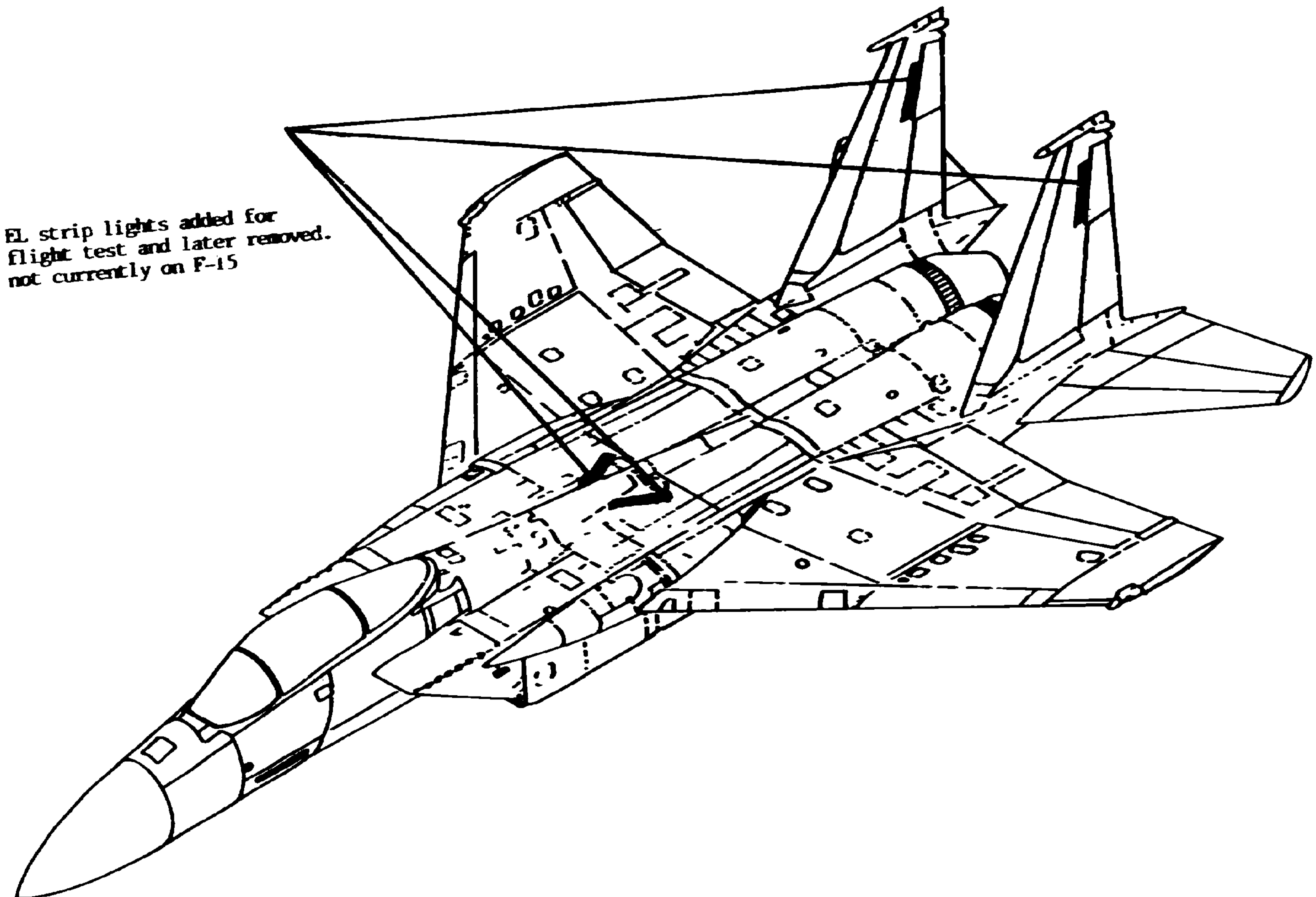

EL strip lights added for
flight test and later removed.
not currently on F-15

Figure 1

h. As a result of the request for exterior lights improvement change, ECP 0292 to add additional formation strip lights to the F-15 was submitted to the SPO and disapproved by all members of the Configuration Control Board (CCB) on 5 Sep 75. Disapproval was based on HQ TAC nonconcurrence and AFSC direction to ASD to study Air Force aircraft visibility in general and the application of strobe lights. The thrust of this study was collision avoidance. Results of this AFSC directed study was the establishment of the USAF Mid-Air Prevention Systems (MAPS) program. The MAPS program was an outgrowth of the ASD-TR-77-33 ASD strobe light evaluation and the ASD-TR-77-76 investigation to support Phase I of USAF MAPS program, Dec 77 which defined a USAF program to reduce midair collision potential. It is our understanding that a program management plan was written and presented to USAF for implementation in early CY 78. To date, no Program Management Directive (PMD) has been issued for this MAPS program.

i. In 1978, a review team of high level personnel from the F-15 SPO visited USAFE Headquarters and made a stop at Bitburg AB GE (36 TFW). It was learned that pilots operating from Bitburg flying in European weather were complaining of difficulty when performing join-up and formation flight. As a result, the F-15 SPO investigated improvements of the exterior lighting for aiding join-up and formation flight during inclement weather (Figure 2). This effort resulted in a modification package which improved the intensities and angular coverages of the wingtip and tail navigation lights. The lights package was delivered to Bitburg AB in Oct 79 for a flight evaluation.

j. The lighting improvement included the addition to the wingtip position lights of a reflector for greater angular coverage and the combined addition of brighter bulbs. Also, brighter bulbs increased the angular coverage of the tail position light (See Figures 2 and 3).

k. The results of the lighting modification flight test at Bitburg AB was that the lights were of little or no value to the pilots during join-up or formation flying. The final report from Bitburg AB stated that night rejoins are accomplished in visual meterological conditions, and as long as the position lights and anti-collision lights were operating normally, there was no problem in acquiring the lead aircraft early in the rejoin phase. During formation flight in either night or day weather, the modified position lights were of little value. The pilots, however, indicated a need for additional formation lights (electroluminsescent strip lights) or flood lights on the vertical stabilizer.

Two sets of each modification were used in the tests. Four aircraft were modified as shown in Table 4.

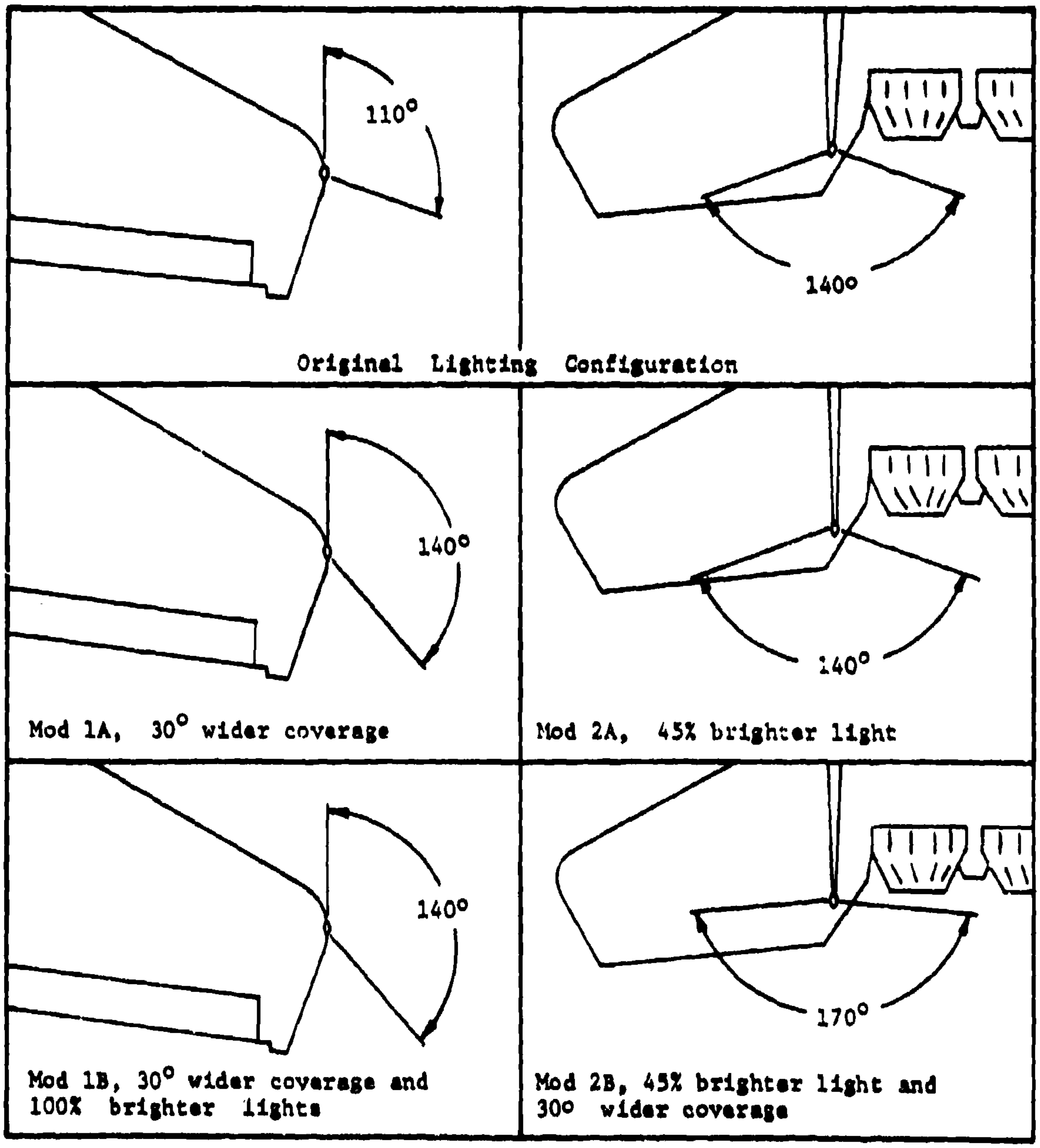


Figure 2

Modification of F-15 Exterior Lights

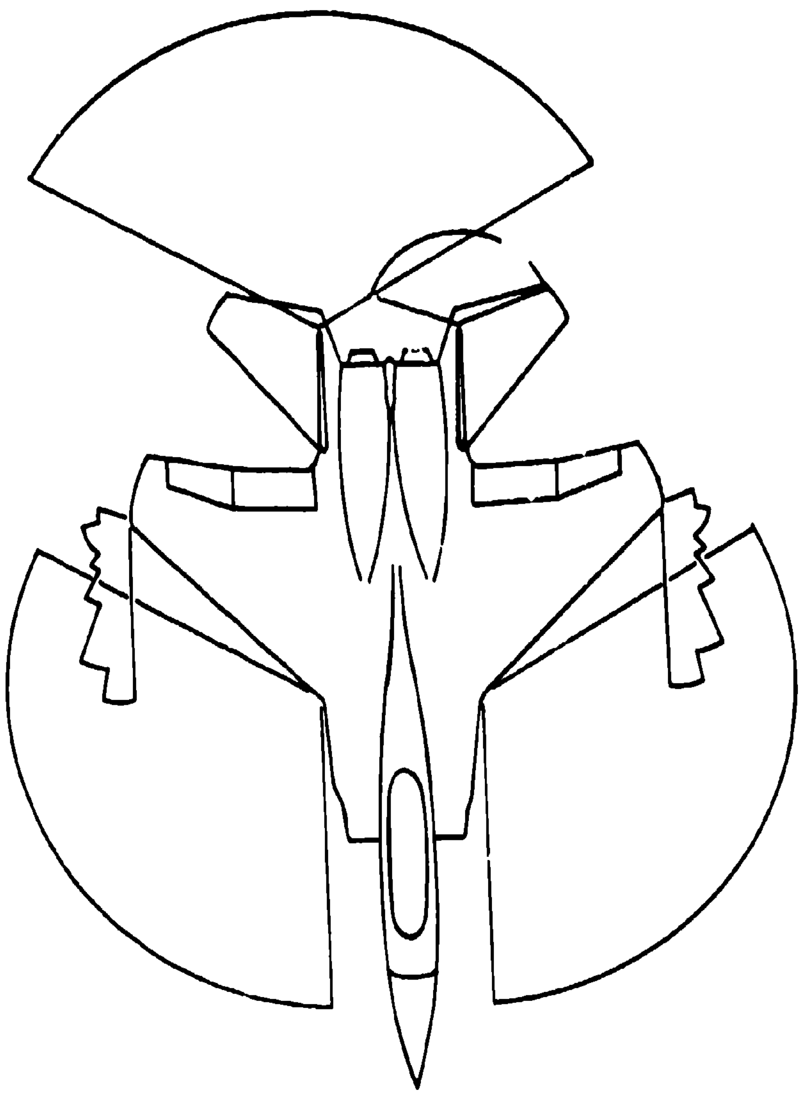


Figure 3

TABLE 4

F-15 EXTERIOR LIGHTING MODIFICATION TEST			
	AIRCRAFT AND TAIL NUMBER	WINGTIP LIGHTS	TAIL LIGHTS
1	F-15A 6051	Mod 1A 30° Wider	Mod 2A 45% Brighter
2	F-15A 6036	Mod 1A 30° Wider	Mod 2B 30° Wider 45% Brighter
3	F-15B 6126	Mod 1B 30° Wider 100% Brighter	Mod 2A 45% Brighter
4	F-15A 6011	Mod 1B 30° Wider 100% Brighter	Mod 2B 30° Wider 45% Brighter

2. CURRENT F-15 EXTERIOR LIGHTING

a. The F-15 exterior lighting is comprised of position lights, anti-collision lights and formation lights. The aircraft also has landing and taxi lights which are not normally used except during takeoff and landings.

b. Position Lights. The position lights include a green light on the forward edge of the right wing tip, a red light on the forward edge of the left wing tip, and a white light just below the tip of the left vertical tail fin. The position lights are controlled from the exterior lights control panel located on the left console. With the anti-collision lights on, the position lights automatically go to steady full brilliance, regardless of the mode selected on the position lights knob except off. The various options for the position lights are:

(1)	OFF	Lights are off.
(2)	1 - 5	Guide numbers for varying brightness from off to full bright.
(3)	BRT	Lights are at full brightness.
(4)	FLASH	The lights will flash at full brightness.

c. Anti-Collision Lights. There are three red anti-collision lights; one on the leading edge of each wing just outboard of the air intake and another just below the tip of the right vertical tail fin. The anti-collision lights are controlled by a single toggle switch on the exterior lights control panel. The switch positions are OFF and ON.

d. Formation Lights. Six green electroluminescent formation lights are provided. Two lights are on the wingtips behind the position lights, two lights are on the side of the forward fuselage just forward of the cockpit, and two lights are on the aft fuselage just aft of wing trailing edge. The formation lights are controlled by a single knob on the exterior lights control panel with the following options that may be selected.

(1)	OFF	Lights are off.
(2)	1 - 5	Guide numbers for varying brightness from off to full bright.
(3)	BRT	The lights are at full brightness.

3. F-15 EXTERIOR LIGHTING COMPARED TO OTHER AIRCRAFT

a. In an attempt to determine if there were factors in the F-15 exterior lighting system that may contribute to the disorientation problem or to the number of lost wingman situations being encountered, a comparative survey of the external lighting of a number of contemporary aircraft was accomplished. The primary purpose of this survey was to look for significant elements of the lighting systems that were different on the F-15 that might contribute to this problem.

b. The aircraft surveyed, other than the F-15, included the following: F-111, F-105, F-4, T-38, F-5, A-10, A-7, and F-16. The review of the various lighting systems indicated that there was little consistency from aircraft to aircraft with the exception of the position light system which by the nature of international (ICAO) standards must be similar. The F-15 and F-4 were the only aircraft of those surveyed that used electroluminescent (EL) formation lights. There is considerable difference in the formation lighting between these two aircraft. The F-15 has three EL strips on each side, one on the forward fuselage, wingtip, and trailing edge wing root. The F-4 has four strips on each side, one on the forward fuselage, wingtips, mid-fuselage above the wing root, and on the vertical tail. The F-4 has, in addition, join up lights on the wingtip trailing edges and three semi-flush fuselage lights. The A-10 and A-7 use combinations of flood lights; the common denominator being use of flood lights on the vertical tail. There is little other commonality among the other systems reviewed except that most have upper and/or lower fuselage lights.

c. The F-15 appears to have certain shortcomings in the current formation lighting when compared with other aircraft. There is an apparent lack of roll reference which upper and lower fuselage lights and/or lighting on vertical tail provides. In fact, pilot comments indicated the current strip lighting configuration may contribute to a false roll cue. The F-15 has no join-up lights. Join-up lights would be beneficial in rejoining when lead is temporarily lost in weather. F-15s suffer from a high incidence of failures of the position and anti-collision lights on the vertical tail which serve as one of the prime join up/rejoin references.

4. INTERVIEW DATA

a. Pilots comments related to their ability for maintaining good formation position when flying on the wing at night were somewhat dichotomized. The young pilots who fly strictly wing formation position indicated no problem with the available references at night. However, the more experienced pilots who normally fly lead and number 3 position commented that problems do exist with the lack of adequate night formation references. Their comments ranged from "difficult" to "terrible" to "delta sierra." Conceivably, the previous experience of the second group in flying other tactical fighter aircraft provide a different perspective on what are good night formation references.

The F-4 was often referred to as a good example because of the strip lights that have been retrofitted to that aircraft.

b. Wing formation position in the F-15 is principally flown with reference to three strip lights that are oriented with the longitudinal axis of the aircraft as depicted below for the normal wing position.

EXTERIOR LIGHTING ARRANGEMENT

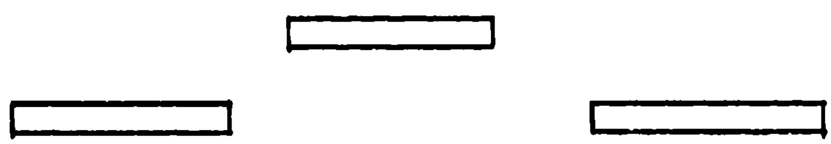


FIGURE 4

The forward strip light is located on the side of the fuselage forward of the engine inlet, the middle light at the edge of the wing tip, and the aft light is located on the fuselage just aft of the leading edge of the vertical stabilizer. As can be seen from the above drawing, the pilot must maintain his formation position at night by using an asymmetrical sight picture, which to a minor degree is an unnatural reference. Whenever the pilot sees the strip lights in a symmetical fashion, he is either flying dangerously high on lead's wing or, worse yet, he discovers that lead has rolled into him. Pilots reported a tendency to fly further out from lead in order to provide a safety margin since the strip lights were somewhat inadequate with respect to providing a readily discernible reference to the wingman when lead rolls his aircraft. It was suggested by several pilots that a vertical strip light on the leading edges of the two tails would assist considerably in detecting lead's attitude and relative closure rates. Another idea proposed was to install a shielded light in the wings that would illuminate the aircraft fuselage.

c. Another prevalent concern of the F-15 pilots was the frequency with which the aircraft tail position lights were inoperative. This problem arises apparently because of tail vibration and, of course, significant dynamic loading during Aircraft Combat Maneuvering (ACM). The effect is to create at least a difficult situation and, at times, even a dangerous overrun situation whenever a stern formation rejoin is attempted with the tail position lights inoperative. There is insufficient illumination on the F-15 with the lights out such that closure rates cannot be accurately determined during a stern rejoin. TAC is well aware of the tail light problem and corrective action has been initiated.

d. Pilots at the 33rd TFW stated that the flashing effect of the anticollision lights is very distracting in weather, where the strobe effect illuminates the cloud layer the aircraft is flying through. This is true even with the lead aircraft's anti-collision light off. The wingman can, in fact, see his own strobe reflection more than the lead aircraft can. It is possible that being able to select the light on the vertical fin only (for weather and night flying) may minimize this effect.

e. F-16 Exterior Lighting. F-16 exterior lighting is felt to be representative of other fighter aircraft with no adverse comments. The F-16 has position lights just inboard of the wing tips on both top and bottom of the wing, a position light on the tail, formation lights on the sides of the intake, a formation light behind the canopy, and a flashing beacon on the tail. The normal day formation position correlates closely with that defined by the wing tip position lights and the formation lights. The pilots that were queried considered that both the F-4 with the strip lighting and the A-7 have good lighting for night formation.

PART III

CONCLUSION AND RECOMMENDATIONS

A. SPATIAL DISORIENTATION

The accidents reports that precipitated the establishment of the F-15 spatial disorientation team stated the pilots may have encountered spatial disorientation. These accidents and others that both preceeded and followed them have all had some of the following classical factors that contribute to spatial disorientation. The first of these relates to a given flight condition: flights during reduced visibility and formation flying in weather. The second factor noted relates to a pilot procedures: waiting until the last moment to make the transition from a visual to an instrument reference and making head movements during turning maneuvers. The third factor noted included the level of or recency of training of the pilot: inexperience with instrument flight and a lack of recent instrument flying experience. The final factor identified was related to a pilots physical and mental condition. At least one of the pilots was thought to have been using medication without the knowledge and concurrence of flight surgeon. This may have impaired his physical and mental state.

1. INCIDENT RATE

The F-15 accident rate with spatial disorientation listed as a possible cause is 18%. A statistical test known as CHI Square based on the probabilty of occurrence of events, was applied to the accident data where spatial disorientation was considered a possible cause. The hypothesis that the F-15 spatial disorientation accident rate did not differ significantly from the overall USAF spatial disorientation rate was accepted at the 95% confidence level. The apparent disparity in the accident rates is attributed to the small statistical sample (total number) for the F-15.

2. AIRCRAFT HANDLING

a. The aircraft handling characteristics were studied. No flight control characteristics were found that would significantly contribute to spatial disorientation. Some of the F-15 pilots interviewed stated the smooth control could perhaps contribute to a minor degree to disorientation problems, but they immediately added that they did not wish the flight control response characteristics modified. The F-15 apparently does not handle in such a way that induces spatial disorientation from a pilot's point of view.

b. Recommendations: None.

3. COCKPIT CONFIGURATION

a. Two features in the cockpit were investigated by the disorientation team that potentially could lead to spatial disorientation incidents. These are the locations of the IFF panel and the radar panel on the left console. The radar panel was identified because there appears to be tendency in a lost wing man situation, to use the radar to locate the leader for join up purposes. If the automatic acquisition modes are not used, the pilot may have to use the radar panel causing him to look down at it with the potential of inducing spatial disorientation. A similar argument is used for the IFF panel. In spite of these two potential problem areas, it is not recommended that corrective action be taken to change the panel locations because these panels are currently in their optimum location from a pilot utilization standpoint. Proper use of these panels is a training issue. If the pilot is well trained, and possesses the required knowledge and skill, his probability of encountering spatial disorientation is reduced.

b. Recommend that the 55 series manual should emphasize that the pilot must select the appropriate time to operate panel mounted equipment that may require him to move his head, especially during maneuvering flight.

c. The location of other instruments, the large bubble canopy, and the design eye location being relatively high in the cockpit have not surfaced to be significant factors that contribute to spatial disorientation in the F-15 during discussions with a limited number (approximately 30) of F-15 pilots at two operating bases.

4. TRAINING

a. Spatial disorientation is a topic that has not been pushed onto the back burner. Commands operating the F-15 have incorporated both ground and flying training to train aircrews to recognize spatial disorientation and have developed procedures to overcome it. Lost wing man procedures are well defined and are standard with all other fighter aircraft. Both TAC Attack and Aerospace Safety Magazines have recently written articles discussing spatial disorientation and lost wingman procedures.

b. Interviews held with F-15 pilots identified one area that could be strengthened in the using commands program to combat spatial disorientation. Pilots should be cautioned against use of the HUD during instrument flight and during the period of transition from formation flying to solo flying during night and/or instrument conditions. Many pilots, particularly those who had not flown older operational fighter aircraft, seem to be overdependent on the HUD when flying the aircraft. The HUD is a compelling display which draws the pilot's attention and, in a situation where the pilot requires rapid recognition of his attitude, altitude, airspeed and the rates of change of each, the information is not always easy to find on the HUD. Pilots who reported less dependence on the HUD expressed a lesser problem with spatial disorientation.

c. Recommend that pilots who find themselves in a "lost wing man" situation transition to the ADI and begin a basic crosscheck. The position of the ADI, along with the other instruments have been specifically located to provide the pilot with the information needed to retain aircraft control. Further the instrument background is not modulated in terms of brightness and contrast. The background through the HUD varies with the flight condition (in and out of clouds) and may impede the pilots ability to find the information needed.

d. Recommend that TO 1F-15A-1, TACM 55-115 and the Luke AFB F-15 Phase Manuals more strongly emphasize that pilots should rely on the ADI and basic aircraft instruments as primary references to fly the aircraft while in instrument conditions.

e. Recommend that pilots practice HUD out instrument approaches to decrease pilot dependence upon the HUD and permit the pilots to become more familiar with and comfortable at flying instruments without using the HUD.

B. LIGHTING

1. INTERIOR LIGHTING

Considerable comments were received during pilot interviews concerning various areas of the interior lighting system on the F-15. These areas do not necessarily affect the incidence of spatial disorientation but may add to the F-15 pilot's workload and may exhibit a potential for distracting the pilot's attention.

a. Canopy reflections - comments were noted during interviews concerning reflections on the canopy stemming from the white interior cockpit lights. These reflections can be distracting and can add to pilot workload by requiring adjustment of the light rheostats; up to read the instruments and back down to remove the reflection.

Recommend further advances toward reducing canopy reflections be studied for possible F-15 application. Such efforts are underway for the A-10.

b. Flight Instruments - comments were noted concerning the desire to the adjust the brightness level of the lighting of the ADI, HSI, altimeter, AOA, VVI, and Airspeed/Mach indicators by the use of individual rheostats operable by the pilot in flight. Although this capability exists in the F-15 it must be done before flight and with the aid of the crew chief.

Recommend the F-15 interior lighting control system be reviewed for possible improvements in individual flight instrument brightness control by the pilot.

c. HUD symbology brightness comments were received to the effect that in order to readily discern the alpha numerics which are displayed in green, the brightness must be increased to such a level that the pilots feel they cannot easily see real objects through the HUD without some distraction. A brightness filter scheme similar to the A-7 was familiar to some pilots and considered to be a better technique for the night brightness adjustment problem. This system uses green for daylight symbology and yellow for night-time use.

Recommend the HUD symbology brightness control be reviewed for improvement under night flying conditions. A scheme similar to the yellow filter on the A-7 aircraft HUD is suggested for review.

2. EXTERIOR LIGHTING

a. Several pilots reflected dissatisfaction with the exterior lighting on the F-15. The most prevalent concern was the lack of lighting references when maintaining wing position. The normal wing position places the wing tip strip light higher than the two fuselage strip lights. A natural inclination in humans is to align strips rather than maintain these strips in a broken line. When these lights are aligned in a straight line, the wing man is stacked too high, a poor place to fly formation, or worse, the lead aircraft has turned into the wing man. This asymmetrical formation reference can possibly cause the wingman to momentarily be confused regarding lead's aircraft attitude, but does not result in classical spatial disorientation per se. However, the lack of a reference point to indicate a roll of the lead aircraft has been cited as the major problem. A survey of all of the current Air Force aircraft indicates the F-15 is among very few aircraft that do not have a light on the top of the fuselage just aft of the canopy and a similar light on the bottom of the fuselage. White lights in these locations would provide additional reference points for maintaining the wing position and for formation join up from the stern position.

These lights would be useful for maintaining the wing position because they would increase the pilot's capability to maintain a spatial relationship between the light on the top of the fuselage, the wing tip light and the light on the bottom of the fuselage. Maintaining this spatial relationship is an important requirement in formation flying. If the pilot noted a spatial relationship different from that prescribed the pilot would react by maneuvering the aircraft until the prescribed spatial relationship is achieved. Further, lights located on the top and bottom of the fuselage would provide the pilot with several point source lights (along with the wing tip light and tail lights) from which he can receive visual cues. Point source lights are generally visible for greater distances in weather than are EL strip lights. A pilot flying formation on an aircraft equipped with point source lights may have a lesser tendency to lose his leader while flying in weather.

The lights would be equally useful for a pilot attempting to join up on the lead aircraft. Once again, since the pilot depends upon maintaining a learned spatial relationship between lights, these fuselage mounted lights along with the wing tip light would provide the pilot with additional line up references to more easily effect a join up.

b. Several alternatives were suggested to correct the exterior lighting problem on the F-15. The alternatives offered differed based upon the aircraft the pilot had previously flown. The two ideas most often brought forward were adding EL strip lights on the tail as on the F-4 and adding flood lights on the fuselage to bathe both of the vertical tails in light. Either alternative would provide an additional roll reference and increase the area of the aircraft useable for a visual cross check to maintain the proper formation position and determine changes in lead's attitude and roll rates.

c. Recommend that lights be added to the top of the fuselage just aft of the canopy and on the bottom of the fuselage approximately below the light on the top.

d. Recommend either EL strip lights or fuselage mounted flood lights be added to aid in formation flying.

C O P Y

APPENDIX A

F-15 AF DT&E DEFICIENCY REPORT (DR)
AIR FORCE FLIGHT TEST CENTER
EDWARDS AFB, CALIFORNIA

I. GENERAL:

DR No: 191-175	DATE: 26 July 1973	MDRS REPORT: None
ACFT No: S/N 71-0285	MAJ SUBSYSTEM: Exterior Lighting	WUC: 44A00

II. DEFICENCY: The exterior lighting scheme is not operationally suitable for night formation.

III. DEFICIENCY CIRCUMSTANCES/DESCRIPTION/CAUSE: The F-15 exterior lights scheme requires improvement in the following areas to be operationally suitable for night formation.

1. The position lights were too bright in the "dim" detent. The glare was from the rear white light with the wingman in a normal formation position, but could be from the red/green lights if the wingman moved forward. The position lights did not provide continuous dimming adjustment from the (steady) BRT to the OFF position. The DIM position detent was arbitrarily placed at approximately the mid position of control travel. This was confusing to the pilot and did not allow him to use the full dimming capability of the system.

2. If the wing pilot was flying directly in line with the right wing, the glare from the green light appeared bright white. It appeared that not enough of a green filament cover had been provided on the light so that it would always appear green at any viewing angle.

3. The formation lights, because of their relative position to each other in a straight "water" line did not provide adequate role cues to the wingman. Bank angles of 20 to 30 degrees could be developed before the roll was detected, and even then the direction of the roll could not be determined.

4. The formation light control also had the DIM detent at the mid position control travel. This detent was confusing in that the pilot did not use the full intensity control of the formation lights (that position below the mid position of travel).

IV. LOCAL CORRECTIVE ACTION: Formation night flying could not be performed due to inadequate cues presented to the pilot by the formation lights.

C O P Y

V. DEFICIENCY CLASSIFICATION:

A. MISSION IMPACT: Degrades system performance and flight crew effectiveness.

B. SAFETY HAZARD CLASSIFICATION (MIL-STD-882): III

C. CORRECTION CATEGORY: Mandatory

VI. RECOMMENDATION:

1. Position Lights:

a. Provide a detent at the VRT steady position.

b. Provide a detent (or series of detents) in more appropriate values than at the mid position of control travel which would provide tactile cues to describe the full range of brightness control to the pilot.

c. Provide sufficient green filament cover for the wing light so that it will appear green at all viewing angles.

d. Provide a surface illumination of the vertical stabilizers which would give the wing pilot better definition of aircraft position and movement.

2. Formation Lights:

a. Provide a better detent arrangement for the formation lights that would describe the full range of brightness control.

b. Provide a formation light outside the present plan preferably diagonally along the vertical stabilizers.

/S/
WENDALL H. SHAWLER, Colonel, USAF
Director, F-15 Joint Test Force

JTF Point of Contact: Maj MacFarlane

C O P Y

APPENDIX B

TRIP REPORT

LOCATION: 1st Tactical Fighter Wing
Langley AFB VA

DATES: 19-20 February 1980

TRAVELERS: William L. Welde, AFARMRL/TSZ
Jack Wilson, ASD/YWE

PURPOSE: To conduct interviews with F-15 pilots to obtain detailed operational information related to reported disorientation/vertigo problems encountered in the aircraft.

INDIVIDUALS CONTACTED:

Col Dick Hawley, 1st TAC FTR WG/DO
Lt Col Devorshak, 27th TAC FTR SWD/CC
Pilots from 27TFS and 71TFS

INTRODUCTION:

The primary purpose of this trip was to respond to the requirements of the F-15 Disorientation/Vertigo Investigation Team to acquire detailed operational flight experience data from F-15 pilots related to those factors that contribute to the reported disorientation problems in the aircraft. Accordingly, Jack and I flew to Langley AFB in A-7D's on 19 February to conduct interviews with 1st Tactial Fighter Wing pilots and participate in a F-15 flight during a night refueling mission. The orientation flight was not flown, however, since written justification was not provided to TAC in order to obtain the required approval.

Nevertheless, in-depth interviews were accomplished with a total of 17 combat ready F-15 Eagle fighter pilots. These pilots ranged in rank from 1Lt to Colonel. Ten of the pilots normally fly in the position of flight lead and the other seven pilots fly strictly on the wing. Their flying experience varied from 400 to 5000+ total hours, primarily in fighter and training type aircraft. The pilots previous flying background was primarily in F-4C/D/E (including serving as a GIB for several), A-7D, T-38A and T-37B aircraft. Other aircraft experience included T-33A, F-100, F-5, F-86 and F-84.

INTERVIEW METHODOLOGY:

The interviews were purposesly conducted in an informal and unstructured manner in order to maximize the voluntary flow of information from the F-15 pilots. Anonymity was guaranteed to the pilots so there was no concern

C O P Y

regarding embarrassment or criticism for peers or superiors resulting from any information provided. The interviews were conducted in the flight briefing rooms in the two fighter squadrons with two to six pilots at each interview session. Initially, we explained that we represented the research community at Wright-Patterson AFB (to eliminate the confusion by our being dressed in flight suits - adorned with TAC patches) and defined the charter of the ASD F-15 Disorientation/Vertigo Investigation Team. The fundamental question posed to the pilots to stimulate their thinking on the problem area was: "Is there anything different about the F-15 from previous aircraft that you have flown that could induce or contribute to the perception of disorientation or vertigo?" As the subsequent discussion ensued on a specific problem that the pilots surfaced, pertinent questions were interjected to elicit details and anecdotal information on the problem. However, no attempt was made at this time to lead the discussion toward areas of concern or previously reported problems. An open-ended approach or posture was established and maintained to facilitate the free flow of information until it became obvious that the discussions had tailed off to idle conversation. At this time, the interviewers asked pointed questions on topics that had been previously surfaced by other F-15 pilots or identified as fundamental issues by the F-15 Disorientation Team. A major factor that asisted us in obtaining detailed data of problems encountered by the F-15 pilots in accomplishing their mission with the aircraft was the face validity aspect that we presented as interviewers. We were recognized as members of a select team concerned with their success and safety, and furthermore, we possessed the operational background in fighter aircraft equipped with a HUD, sophisticated weapon delivery and avionic systems, and were intimately familiar with the TAC mission that we could readily relate to their perspectives and problems.

INTERVIEW DATA:

The operational field data obtained during pilot interviews is discssed within the following major categories:

1. Overdependence on HUD - A general concern was expressed by some pilots that there exists an overdependence on the HUD for flying the F-15. That is, when a pilot finds himself either in an unusual attitude or recognizing vertigo symptoms, there is a tendency for the pilot to initially look at the HUD to become reoriented and affect a recovery. However,the recommended procedure in this situation is to completely ignore the HUD and immediately transition heads down to the panel instruments. It was suggested that a minimum number of HUD-out instrument approaches should be required in the simulator and in the aircraft in order to reduce the complete dependence on the HUD. Although this training requirement would be difficult to enforce, it nevertheless would emphasize the need for pilots to become more familiar and comfortable with HUD-out instrument flying. However, the pilots find the HUD a very compelling display, presumably because of its information content, prominent location in the pilot's visual field, novel display mode, and the overall integrated relationship of the HUD to flying the aircraft and accomplishing the mission.

2. Loss of Reference - Utilizing the HUD as the primary instrument display at times can cause a loss of reference by pilots, which probably can best be described as the experiencing short-term disorientation phenomenon. This effect may occur from either (a) the "rush" of the flight parameters in the HUD, such as the scale displays of altitude, airspeed, heading and pitch attitude, during aircraft maneuvering, or (b) the visual transition from the HUD to the external world scene at night, which is a function of the accommodation and contrast effects on the human visual system during reduced ambient illumination levels. Although the HUD is collimated at infinity, the display tends to cause the pilot's eyes to focus at the near point of the combining glass rather than seeing the symbology superimposed on the external scene.

3. Display Brightness - The HUD symbology brightness level cannot be adequately adjusted at night. In order to readily discern the numbers which are diplayed in green, the display brightness must be increased to a level that the pilots feel they cannot see out of the cockpit. Thus, when there is a requirement to scan outside the aircraft, the display brightness must be reduced, which only adds to the pilot's workload problems.

4. Instrument Flying - Most of the pilots reported that they flew instruments primarily with the inside panel and utilized the HUD for cross-check purposes and during stabilized flight. Although the pilots indicated that the HUD information provided fairly accurate information, particularly in the pitch attitude and heading parameters, instrument flying with the HUD in actual weather conditions tended to increase the probability of disorientation. Interestly, the HUD was designed by McDonnell Douglas as a primary flight reference, but the Dash One cautions against using the HUD for this purpose due to inadequate failure warnings.

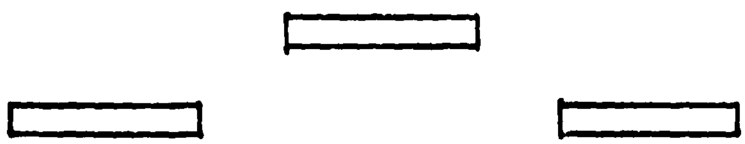
5. Declutter Options - One feature that pilots desired with the HUD was a capability to selectively reduce the amount of symbology displayed in the HUD according to their preferences and mission requirements. Such suggestions as installing mini-toggle switches on the HUD control panel or implementing the software in the computer to effect symbology declutter options were offered by the pilots. One feature designed into the HUD that pilots commented favorably upon was the capability to cage the pitch ladder in the center of the HUD field-of-view during crosswind landings, which made the information easier to use and reduced the visual cross-check requirement. Activated by a throttle switch, this function is not normally available in other aircraft HUDs.

EXTERIOR LIGHTING

1. Night Wing Position References - Pilots comments related to the ability to maintain good formation position when flying on the wing at night was somewhat dichotomized. The young pilots who fly strictly wing formation position indicated no problem with the available references at night. However, the more experienced pilots who normally fly lead and number 3 position commented that problems do

exist with the lack of adequate night formation references. Their comments ranged from "difficult" to "terrible" to "delta sierra". Conceivably, the previous experience of the second group in flying other tactical fighter aircraft provide a different perspective on what are good night formation references. The F-4 was often referred to as a good example because of the strip lights that have been retrofitted on the aircraft.

2. F-15 Strip Lights - Wing formation position in the F-15 is principally flown with reference to three strip lights that are oriented with the longitudinal axis of the aircraft as depicted below for the normal wing position:



The forward strip light is located on the side of the fuselage forward of the engine inlet, the middle light at the edge of the wing tip, and the aft light is located on the fuselage just aft of the leading edge of the vertical stabilizer. As can be seen from the above drawing, the pilot must maintain his formation position at night by using an asymmetrical sight picture, which to a minor degree is an unnatural reference. Whenever the pilot sees the strip lights in a symmetrical fashion, he is either flying dangerously high on lead's wing or, worse yet, he discovers that lead has rolled into him. Pilots reported a tendency to fly further out from lead in order to provide a safety margin since the strip lights were somewhat inadequate with respect to providing a readily discernible reference to the wingman when lead rolls his aircraft. It was suggested by several pilots that a vertical strip light on the leading edges of the two tails would assist considerable in detecting leads attitude and relative closure rates. Another idea proposed was to install a shielded light in the wings that would illuminate the aircraft fuselage.

3. Tail Lights - A prevalent concern of the F-15 pilots was the frequency with which the aircraft tail position lights were inoperative. This problem arises apparently because of tail flutter and, of course, significant dynamic loading during ACM. The effect is to create at least a difficult situation and, at time, even a dangerous overrun situation whenever a stern formation rejoin is attempted with the tail position lights inoperative. There is insufficient illumination on the F-15 with the lights out that closure rates cannot be accurately determined during a stern rejoin. TAC is well aware of the tail light problem and corrective action has been initiated.

OTHER COMMENTS

1. Day Formation References - The F-15 is a large tactical aircraft which means the wingman is flying at quite a distance from the fuselage and canopy of the lead aircraft. Pilots commented that when lead rolls his aircraft the wingman perceives he is on a very long moment arm that requires large control

movements in order to maintain proper wing formation position. Furthermore, the pilot's head must be turned considerably to the side in order to fly good wing formation position, which results in a large angular difference between the outside formation references and his HUD or ADI. This, of course, necessitates significant head movements by the wingman whenever he wishes to cross-check the cockpit instruments, which pilots and physiologists know that large head movements in the cockpit can reduce vertigo. In order to minimize these head movements, the wingmen prefer to slide down and back from the normal formation position. However, if the wingman drops too far down and aft and in toward lead during intense weather formation flight, the wingman's aircraft wing overlaps with the horizontal stabilizer of the lead aircraft. This is to be avoided since it is somewhat dangerous and can interfere with the normal flight dynamics of the lead aircraft to the extent that lead can "feel" when the wingman is in too tight. Pilots also reported that they lose the F-15 when flying formation during day weather conditions more than any other tactical fighter they have flown. Apparently this is attributed to the gray paint scheme of the F-15 being of minimal color contrast with the weather, which results in the aircraft easily blending into the weather.

2. Cockpit Lighting - Considerable comments were generated on the white interior cockpit lighting causing reflections in the canopy at night at the higher illumination levels, which are required to read the instruments. Further, the pilots desired the capability to individually adjust the lighting for the more important instruments utilized, such as ADI, HSI, airspeed, altimeter, UHF, IFF and fuel gage. The requirement to continually adjust the cockpit lights at night, that in turn the lights up to read the instruments and then down to reduce the glare, canopy reflections and enhance outside the cockpit visual scanning, increases the pilot workload unnecessarily. The F-4E was cited as a good example of individually adjusted cockpit instrument lighting.

3. Aircraft Dynamics - The F-15 pilots universally reported that the aircraft is extremely light and smooth in terms of control stick input required and feedback provided. Perhaps this contributes to a lesser degree to disorientation problems, particularly when flying on the wing in a homogenous external visual environment similar to that encountered in a cirrus cloud deck or on a clear night. Pilots also commented on the difficulty in trimming the aircraft to a hands-off neutral state in the roll axis.

4. Canopy Scratches - Scratches and dirt on the canopy were reported to cause the pilots problems in achieving unobstructed vision. This problem is not unique to the F-15, but indeed may cause more interference effects to the F-15 pilot due his primary air-to-air mission since target detection, identification and tracking are paramount to mission success.

/S/
WILLIAM L. WELDE
Plans and Programs Branch
Technical Services Division

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APPENDIX C

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01 99 PP UUUU 271705Z Sep 79

ASD WPAFB OH/YFE//

57 TTW NELLIS AFB NV//SEF// (F-15 SAFETY INVESTIGATION BOARD)

UNCLAS

SUBJECT: F-15 EXTERIOR LIGHTING CHANGES

1. IN RESPONSE TO YOUR VERBAL REQUEST CONCERNING F-15 EXTERIOR LIGHTING DR 191-175, THE FOLLOWING IS SUBMITTED.

2. AS A RESULT OF AFFTC CATEGORY II TEST PROGRAM DR 191-195, THREE MAIN ENDEAVORS WERE PURSUED AS FOLLOWS:

A. THE EXTERIOR LIGHTS CONTROL PANEL WAS REDESIGNED TO PROVIDE CONTINUOUS DIMMING CAPABILITY AND TO PROVIDE THE PILOT WITH TACTILE FEEDBACK CONTROLS. THOSE CONTROLS RESULTED IN A FIVE DETENT ROTARY SWITCH FOR BOTH THE POSITION AND FORMATION LIGHTS (EFFECTIVITY: BLOCK 7 AND UP).

B. THE GREEN WING-TIP LIGHT/LENS ASSEMBLY WAS REVIEWED BY MCAIR AND BY THE LIGHT VENDOR (GRIMES) AND IT WAS DETERMINED THAT IT MET AF REQUIREMENTS. THE WHITE APPEARANCE AT FULL BRIGHT SETTINGS AT CERTAIN VISUAL ANGLES WAS NOT VERIFIED. NO FURTHER ACTION WAS PURSUED.

R.C. PANGBURN, ENGRG PSYCHOLOGIST,
54217, ASD/YFEC, 27 Sep 79

/s/
CHARLES CULLOM
Systems Engineering Director
Deputy for Engineering

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C. AN IMPROVED FORMATION STRIP LIGHTING PROGRAM WAS BEGUN AND ADDITIONAL STRIP LIGHTS WERE FLIGHT TESTED AT EAFB BY THE AFFTC/JTF FOR F-15. A REQUEST FOR AN ECP WAS SENT TO MCAIR TO IMPROVE THE EXTERIOR FORMATION LIGHTS.

BASED ON THE ABOVE ACTION, THE DR 191-175 WAS OFFICIALLY CLOSED IN MAR 74.

3. AS A RESULT OF THE REQUEST FOR THE EXTERIOR LIGHTS IMPROVEMENT CHANGE, ECP 0292 TO ADD ADDITIONAL FORMATION STRIP LIGHTS TO THE F-15 WAS SUBMITTED TO THE SPO AND DISAPPROVED BY ALL MEMBERS OF THE CONFIGURATION BOARD CONTROL BOARD (CCB) ON 5 SEP 75. DISAPPROVAL WAS BASED ON HQ TAC NON-CONCURRENCE AND AFSC DIRECTION TO ASD TO STUDY AIR FORCE AIRCRAFT VISIBILITY IN GENERAL AND THE APPLICATION OF STROBE LIGHTS. THE THRUST OF THIS STUDY WAS COLLISION AVOIDANCE. RESULTS OF THIS AFSC DIRECTED STUDY WAS THE ESTABLISHING OF THE USAF MIDAIR PREVENTION SYSTEMS (MAPS) PROGRAM. THIS MAPS PROGRAM WAS AN OUTGROWTH OF THE ASD-TR-77-33 ASD STROBE LIGHT EVALUATION AND THE ASD-TR-77-76 INVESTIGATIONS TO SUPPORT PHASE I OF THE USAF MAPS PROGAM, DEC 77, WHICH DEFINED A USAF PROGRAM TO REDUCE MIDAIR COLLISION POTENTIALS. IT IS OUR UNDERSTANDING THAT A PROGRAM

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MANAGEMENT PLAN WAS WRITTEN AND PRESENTED TO USAF FOR IMPLEMENTATION IN EARLY CY 78. TO DATE NO PROGRAM MANAGEMENT DIRECTIVE (PMD) HAS BEEN ISSUED FOR THIS MAPS PROGRAM.

4. AFTEC DR 15-164 IN THE F-15 FOT&E FINAL REPORT WAS ALSO CLOSED BY THE CCB ACTION ON ECP 0292.

5. EARLIER THIS YEAR THE F-15 SPO BEGAN AN EXTERIOR LIGHTS REVIEW IN RESPONSE TO A COMMENT OF CONCERN BY USAFE PILOTS DURING A VISIT TO BITBURG AF GE. THIS HAS RESULTED IN A MODIFIED NAVIGATION LIGHTS PACKAGE WHICH INCREASE INTENSITY LEVELS AND ANGULAR RANGE OF COVERAGE AND WILL BE TEST FLOWN AT BITBURG BEGINNING IN OCT 79.

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APPENDIX D

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01 99 RR UUUU 0611002 Dec 79

ASD WPAFB OH/YF//

HQ TAC LANGLEY AFB VA//DO/DR//

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SUBJECT: F-15 NIGHT/WEATHER FORMATION VISIBILITY

REFERENCE: TAC/DO/DR 220030Z NOV 79 MSG

1. CONCERNS VOICED IN THE REFERENCED MESSAGE ARE UNDER CONSIDERATION BY THE F-15 SPO. DURING OUR INITIAL INFORMATION GATHERING, WE HAVE RECEIVED SOME CONFLICTING INFORMATION ABOUT THE SPECIFIC OPERATIONAL PROBLEM AND ARE ATTEMPTING TO RESOLVE THE ISSUES.

2. SEVERAL ACTIONS ARE UNDERWAY TO CONCURRENTLY DEFINE THE PROBLEM AND DETERMINE THE FEASIBILITY OF POSSIBLE ALTERNATIVES:

A. ASD ENGINEERING (ASD/EN) HAS BEEN REQUESTED TO EVALUATE THE EFFECTIVENESS OF EXTERIOR LIGHTING SYSTEMS USED ON OTHER AIRCRAFT VERSUS THE CURRENT F-15 SYSTEMS.

B. WINGTIP/VERTICAL TAIL LIGHTS WITH EXPANDED ANGULAR COVERAGE AND INCREASED BRIGHTNESS ARE BEING SUBJECTED TO AN IN-SERVICE EVALUATION IN USAFE.

C. AN INFORMAL EVALUATION OF THE BENEFIT OF AN UPPER FUSELAGE LIGHT IS BEING CONDUCTED USING THE AERIAL REFUELING FLOOD LIGHT.

LT COL JOHN L. SMITH/CHIEF, SYSTEMS
DIV/ASD/YFA/54112/EJA/3 Dec 79

/s/
RONALD W. YATES, Colonel, USAF
Deputy F-15 System Program Director

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D. THE SPO CONCURS WITH THE EVALUATION OF CONTRASTING PAINT AROUND EXISTING LIGHTS AND WILL WORK WITH TAC TO OBTAIN AN INFORMAL EVALUATION AS AN INITIAL STEP.

E. THE UPDATING OF ECP 292, DISAPPROVED IN 1975, IS BEING HELD IN ABEYANCE PENDING FURTHER DEFINITION OF THE PROBLEM. PART OF THE CONFLICTING DATA RECEIVED CONCERNS THE EFFECTIVENESS OF INCREASED LIGHTING ON THE VERTICAL TAIL.

3. A NUMBER OF FACTORS AFFECT THE PROBLEM DEFINITION.

A. ASD ENGINEERING HAS BEEN REQUESTED TO CONDUCT A SURVEY OF AIRCREWS TO DETERMINE THE POSSIBLE CAUSES FOR AIRCREW DISORIENTATION.

B. SURVEY RESULTS PRESENTED TO DATE SHOW LITTLE AGREEMENT ON THE CAUSE OF DISORIENTATION OR MEANS TO IMPROVE AIRCREW RESISTANCE TO DISORIENTATION.

C. THERE IS A SIGNIFICANT DIFFERENCE IN THE REQUIREMENTS FOR CAVU NIGHT, NIGHT WEATHER, AND DAY WEATHER.

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4. WE CONSIDER THE ACCURATE DEFINITION OF THE PROBLEM TO BE AN ESSENTIAL FIRST STEP FOR RESOLUTION. TO THIS END, WE PROPOSE THE ESTABLISHMENT OF A TEAM TO CONDUCT THE INVESTIGATION. THE TEAM WOULD BE COMPRISED OF MEMBERS FROM TAC, THE F-15 SPO, ASD/EN, AND THE HUMAN RESOURCES LABORATORY (HRL) WITH CONTRACTOR PARTICIPATION AS NECESSARY. AS ENVISIONED:

A. ASD/EN WILL CHAIR THE GROUP.

B. TAC WILL PROVIDE A SPECIFIC DEFINITION OF THE PROBLEM TO BE INVESTIGATED.

C. FOLLOWING THE INVESTIGATION, TAC AND THE F-15 SPO WILL REVIEW THE RESULTS FOR IMPLEMENTATION.

D. THE FIRST MEETING OF THE GROUP WILL BE IN EARLY JANUARY 1980.

5. WE ARE PROCEEDING AS OUTLINED ABOVE AND REQUEST YOUR FORMAL CONCURRENCE IN THE PROPOSAL IN PARAGRAPH 4. YOUR CONTINUED ASSISTANCE IS APPRECIATED.

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APPENDIX E

YF 7 Dec 1979

F-15 Disorientation/Vertigo Investigation

ASD/EN

1. The F-15 SPO is concerned about pilot experiences with disorientation/vertigo phenomena. There is some suggestion that aircraft design may contribute to this situation (i.e., large bubble canopies (F-15, F-16, and A-10), relatively high-in-the-cockpit seating, etc). Also, there are questions about the differences and the respective attributes of the various exterior lighting schemes and the role exterior lighting plays in the disorientation phenomenon.

2. This office requests your organization establish an investigating team to review this phenomenon with respect to the above concerns and make recommendations to reduce the potential for disorientation. It is suggested that in addition to people from your organization and the F-15 SPO, the team include an HRL F-16 and A-10 representative. The initial meeting of the team should establish an outline of approach, guidelines, and reporting schedule for a program with a three to six month duration. It is further sugggested that responses from F-15, F-16, and A-10 pilots be solicited throughout this investigation effort.

3. We are available to discuss this subject further at your convenience. The F-15 SPO point of contact is Mr. Robert Pangburn, ASD/YFEC, Extensions 54217/52851.

/s/
RONALD W. YATES, Colonel, USAF
Deputy F-15 System Program Director

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APPENDIX F

ENE 9 January 1980

F-15 Disorientation/Vertigo Investigation Team

ASD/ENE (Mr. Gino Santi)
ASD/ENECC (Mr. Ronald Schwartz)
ASD/YEPC (Mr. Nat Davis)
ASD/EFEC (Mr. Robert Pangburn)
ASD/AELA (Lt Comdr Harry Hoffman)
AFHRL/ASR (Dr. Kenneth Boff)
AFAMRL/TSA (Mr. Bill Welde)
ASD/ENEGE (Mr. Phil Schmidlapp)

1. As noted in our letter of 20 December 1979, it was reported that in two recent F-15 aircraft incidents, there was some indication that pilot disorientation may have been a factor in causing loss of the aircraft and crew. Further investigation into this problem area has been requested by the F-15 SPO.

2. A meeting will be held in building 126, room 105, at 0930 on 15 January 1980. The purpose of this meeting is to discuss the F-15 problem, establish the goals and objectives of the investigation team, establish an overall schedule, and report date to the F-15 SPO.

3. Your participation on this investigation team is appreciated.

/s/
JOHN S. KUBIN, Colonel, USAF
Director, Equipment Engineering

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APPENDIX G

MEMORANDUM FOR RECORD 18 Jan 1980

SUBJECT: Minutes of 15 January 1980 Meeting of F-15 Disorientation/ Vertigo Investigation Team

1. A meeting of the F-15 Disorientation/Vergigo Investigation Team was held on 15 Jan 80 and attended by the following:

Mr. G. P. Santi, Chairman	ASD/ENE 52964
Dr. K. R. Boff	AFHRL/ASR 52606
Mr. R. C. Brashears	ASD/ENECC 52840
Lt Col C. J. Evans	ASD/ENEC 52006
Mr. C. J. Fabian	ASD/YPEC 53848
Maj D. W. Jarvi	ASD/ENECE 52165
Mr. R. C. Pangburn	ASD/YFEC 54217
Mr. R. W. Schwartz	ASD/EXEC 55692
Mr. P. L. Schmidlapp	ASD/ENEGE 55192
Mr. W. L. Welde	AFAMRL/TSZ 52423

2. As an introduction to the purposes and objectives of the Investigation Team, a brief review and discussion was held of the F-15 flight incidents in which there was some indication pilot disorientation was involved.

3. It is widely recognized that there is a long history of flight incidents in which disorientation/vertigo has affected pilot performance in maintaining control of the aircraft. There is considerable literature in this area, prepared by both military and civilian agencies, in which various flight elements and characteristics have been identified as inducing pilot disorientation.

4. Disorientation simulators or demonstrators have been built by both the Navy and the Air Force. American Airlines is currently constructing a disorientation demonstrator for delivery in March 1981 to the Naval Training Equipment Center. The Navy feels that the reduction in actual aircraft training flight hours and the greater use of flight simulators have resulted in less awareness among crews of those flight factors which are associated with disorientation. The disorientation demonstrator being built would be used to expose ten pilots at a time to various motions and cues which would induce disorientation as a method of training for recognition of disorientation to avoid loss of aircraft control.

5. The configuration of the F-15 aircraft crew station was discussed in an attempt to determine distinguishing features which might be related to disorientation phenomena. Those features throught to be significantly different from most other aircraft were the relatively high sitting position with the lower cockpit sills, the bubble canopy, the heads up display (HUD) and the light reflections associated therewith and the lower position of the attitude director indicator (ADI) made necessary because of the HUD installation.

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6. The following approach was developed to obtain information applicable to F-15 aircraft flight operations:

a. A data base would first be established of Air Force aircraft flight incidents in which disorientation/vertigo was found or suspected to be a factor. Ron Schwartz and Nat Davis will contact Norton Safety Center and other sources to obtain the data. About three weeks would be required to obtain and compile this information.

b. Operational flight experience data would be obtained by a survey of F-15 pilots. Dr. Boff and Mr. Welde will brief Major Jarvi on disorientation phenomena. Major Jarvi will then arrange for a visit to TAC Langley to talk with F-15 pilots.

c. The external lighting features of the F-15 would be compared with other aircraft systems. Mr. Schmidlapp will identify the various lighting systems used in Air Force aircraft.

d. Dr. Boff and Mr. Welde will review current literature on disorientation. Using the data referenced in paragraphs a, b and c above, Dr. Boff Mr. Welde and Mr. Pangburn will conduct an analysis to relate disorientation phenomena with F-15 operational flight conditions.

e. The data and analysis developed will be reviewed and critiqued by the investigation team. The conclusions derived would then be discussed with such area experts as Dr. Herschel Leibowitz of The Penn State Unviversity, Dr. Conrad Kraft of Boeing Seattle, Dr. Richard Gilson of Ohio State University and Dr. Kent Gillingham of USAF, School of Aerospace Medicine.

f. Data, conclusions and recommendations would then be presented to the F-15 SPO.

/s/
G. P. SANTI
Chairman, F-15 Disorientation/Vertigo
Investigation Team

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APPENDIX H

MEMORANDUM FOR RECORD 15 Feb 80

SUBJECT: Minutes of 6 February 1980 Meeting of F-15 Disorientation/ Vertigo Investigation Team

1. A meeting of the F-15 Disorientation/Vertigo Investigation Team was held on 6 Feb 80 and attended by the following:

Mr. G. P. Santi, Chairman	ASD/ENE
Dr. K. R. Boff	AFHRL/ASR
Mr. N. W. Davis	ASD/YPEC
Lt Comdr H. P. Hoffman	ASD/AELA
Major D. W. Jarvi	ASD/ENEC
Dr. R. J. Schiffler	ASD/ENECH
Dr. R. W. Schwartz	ASD/YXEC
Mr. P. L. Schmidlapp	ASD/ENEGE
Mr. W. L. Welde	AFAMRL/TSZ
Mr. J. M. Wilson	ASD/YWE
Mr. R. C. Pangburn, Advisor	ASD/YFEC

2. The ASD/EN letter of 31 January 1980 to the F-15 SPO, ASD/YF, (copy previously provided to each team member) was discussed. On the basis of information received by the F-15 SPO from F-15 pilots, the investigation will be extended to include a review of the external visibility characteristics as they might affect formation flying tactics.

3. Mr. Schwartz reported that he had received computer printout data from the Norton Safety Center on all aircraft accidents for the F-15, F-16 and A-10 aircraft. These data are being analysed to identify any circumstances which might be associated with disorientation or visibility problems. In addition, an attempt will be made to determine if the recent F-15 incidents (   ) involve more or less of these attributes associated with disorientation.

4. Mr. Schmidlapp and Mr. Pangburn have accumulated data on external visibility characteristics of various aircraft. These data are being compiled in a matrix form to permit comparative analysis for the F-15.

5. A discussion was then held from which the following revised milestone structure was developed:

A. Determination of F-15 aircraft characteristics which might be associated with disorientation.

1. Acquisition of data base from Norton Safety Center computer records on aircraft flight incidents in which disorientation/vertigo was found or suspected to be a factor.

Action for Messrs Schwartz, Davis. Completion of analysis of computer printout accident data is estimated for 1 Mar 80. Submission of additional data from Norton Safety Center on aircraft disorientation incidents is expected by 4 April 1980.

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2. Completion of survey of F-15 pilots to obtain operational flight experience data.

Action for Lt Comdr Hoffman, Major Jarvi and Messrs Welde and Wilson. Estimated completion date is 15 Mar 80.

3. Review of F-15 configuration features which could be associated with disorientation phenomena.

Action for Messrs Schwartz, Pangburn on F-15 design data; Lt Comdr Hoffman, Major Jarvi, Messrs Welde, Wilson on pilot survey data; Dr. Boff, who, in coordination with the foregoing, would analyze all data for determination of associative relationships. Estimate completion date is 30 Apr 80.

B. Identification of exterior lighting features or lack thereof which might enhance probability of disorientation occurrence or affect pilot performance for formation flying.

1. Review of literature on exterior lighting effects and technology.

Action for Dr. Schiffler and Mr. Schmidlapp. Estimated completion date is 1 Mar 80.

2. Comparative analysis of exterior lighting on F-15 and other aircraft.

Action for Dr. Schiffler, Messrs Pangburn, Schmidlapp. Estimated completion date is 10 Apr 80.

3. Review of technical history of F-15 aircraft exterior lighting design.

Action for Messrs Pangburn, Schwartz. Estimated completion date is 1 Apr 80.

C. Preparation of report. Estimated completion date is 2 Jun 80.

D. Review of report with area experts identified in minutes of 14 Jan 80 meeting. Estimated completion date is 16 Jun80.

E. Presentation of results to F-15 SPO. Estimated date is 1 Jul 80.

/s/
G. P. SANTI
Chairman, F-15 Disorientation/Vertigo
Investigation Team

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APPENDIX I

MINUTES FOR RECORD 13 March 1980

SUBJECT: Minutes of 29 February 1980 Meeting of F-15 Disorientation/ Vertigo Investigation Team

1. A meeting of the F-15 Disorientation/Vertigo Investigation Team was held on 29 February 1980 and was attended by the following:

Mr. G. P. Santi, Chairman	- ASD/ENE
Dr. K. R. Boff	- AFHRL/ASR
Mr. N. W. Davis	- ASD/YPCC
Lt Comdr H. P. Hoffman	- ASD/AELA
Major D. W. Jarvi	- ASD/ENEC
Mr. R. W. Schwartz	- ASD/ENECC/YXEC
Mr. W. L. Welde	- AFAMRL/YWE
Mr. J. M. Wilson	- ASD/YWE
Mr. R. C. Pangburn, Advisor	- ASD/YFEC

2. The primary purpose of this meeting was to review the results of the recent trip by Messrs Wilson and Welde to Langley AFB to survey F-15 pilots to obtain operational flight experience data. Seventeen pilots were interviewed, of which 10 had lead experience, and all 17 had experience flying wing during formation flight. In addition, Cmdr Hoffman interviewed F-15 pilots at MacDill AFB. The basic comments have been categorized into general problem areas and are contained in the following paragraphs.

3. HUD: There is a general feeling expressed by the pilots of their overdependence on the HUD. This has resulted in a loss of proficiency with the conventional instruments and a reluctance to convert back to them during an emergency. During certain situations the "RUSH" of information on the HUD can be disorienting. The more experienced pilots tended to convert to instruments more quickly if any problems were encountered. Brightness of HUD imagery was a problem at night that helped cause loss of outside reference. Visual accommodation tended to be a problem with the HUD. It was considered a "compelling" display in that it tended to attract and fascinate the eye. Finally, there is the continuing controversy regarding use of the HUD as a primary flight instrument.

4. EXTERIOR LIGHTING: The pilots interviewed were flying an average of 12 sorties per month, of which one per month was a night sortie. Night/weather conditions were, therefore, encountered infrequently inoperative, which made formation join-up difficult since there was no reference for a stern appraoch. This problem is being corrected. Day formation references are not available at night. There are some differences among pilots regarding the daylight references on the F-15 for formation flying.

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5. <u>OTHER COMMENTS</u>: Aircraft dynamics may be a factor. The F-15 is very smooth on the controls and small inadvertent control inputs may go undetected. The F-15 is very hard to trim in roll. Scratches and dirt on the canopy tend to be distracting. The aircraft color and its lack of contrast with the background, particularly in weather, is a problem. There appears to be some controversy regarding evenness of cockpit lighting and pilot workload in setting the lighting. This indicates that the "fine tuning" controls available to control evenness of lighting on the ground are not being used.

6. <u>CONCLUSIONS</u>:

a. HUD -

(1) Avoid use when disoriented

(2) When in doubt go head down

(3) Practice on instruments with HDU out

b. Exterior Lights -

(1) Differences of opinion regarding effectiveness

(2) Failure rate on tail lights unacceptable

(3) Formation/position references inadequate.

7. Mr. Santi announced he was retiring. Lt Col Jarvi was subsequently appointed as Chairman of the committee.

/s/
DENNIS W. JARVI, Lt Col, USAF
Chairman, F-15 Disorientation/Vertigo
Investigation Team

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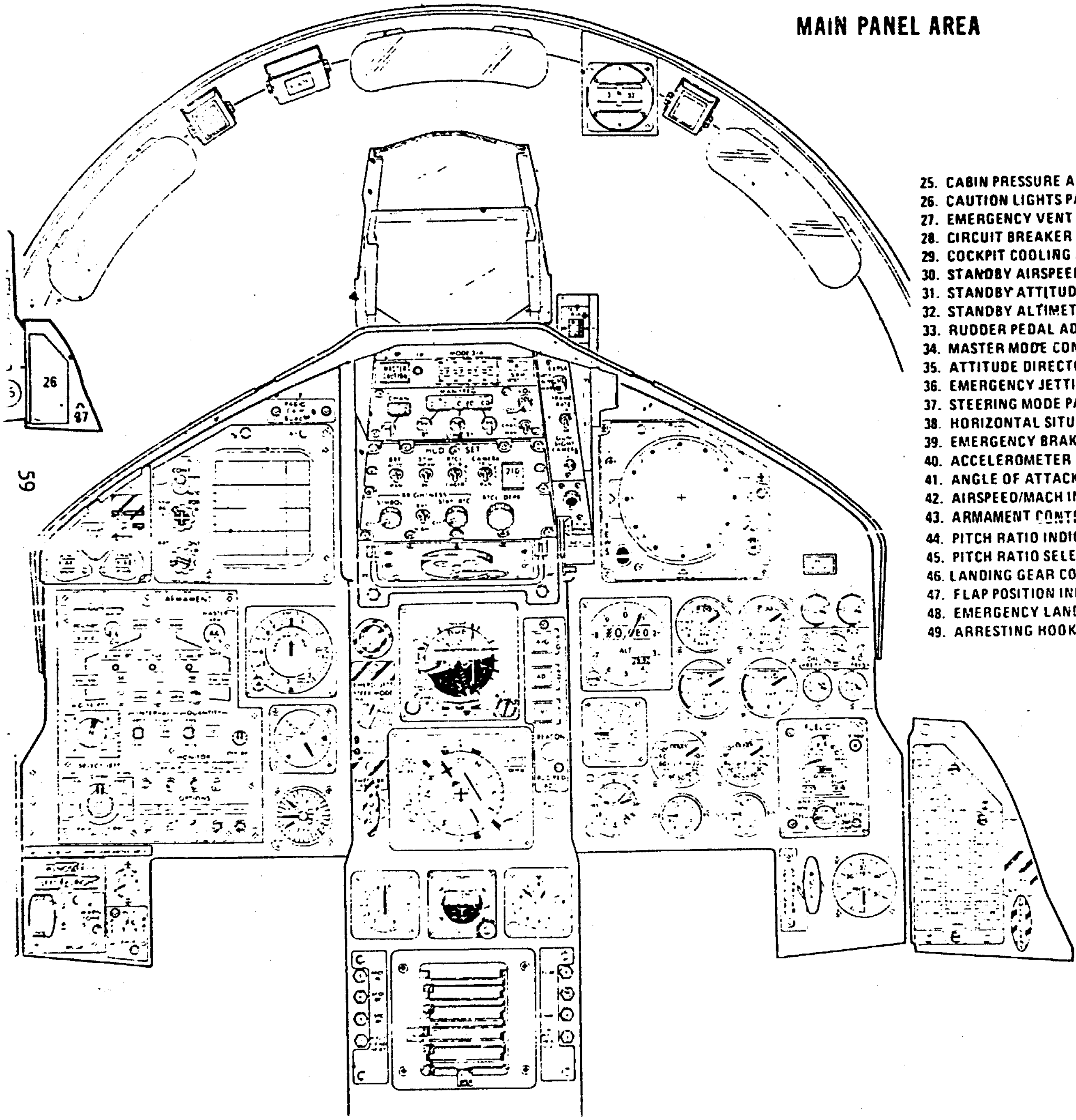
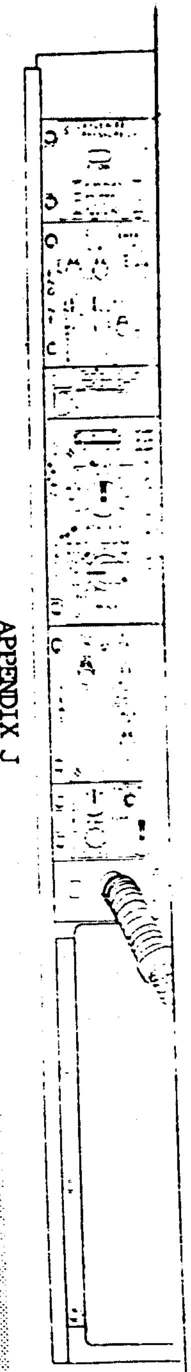
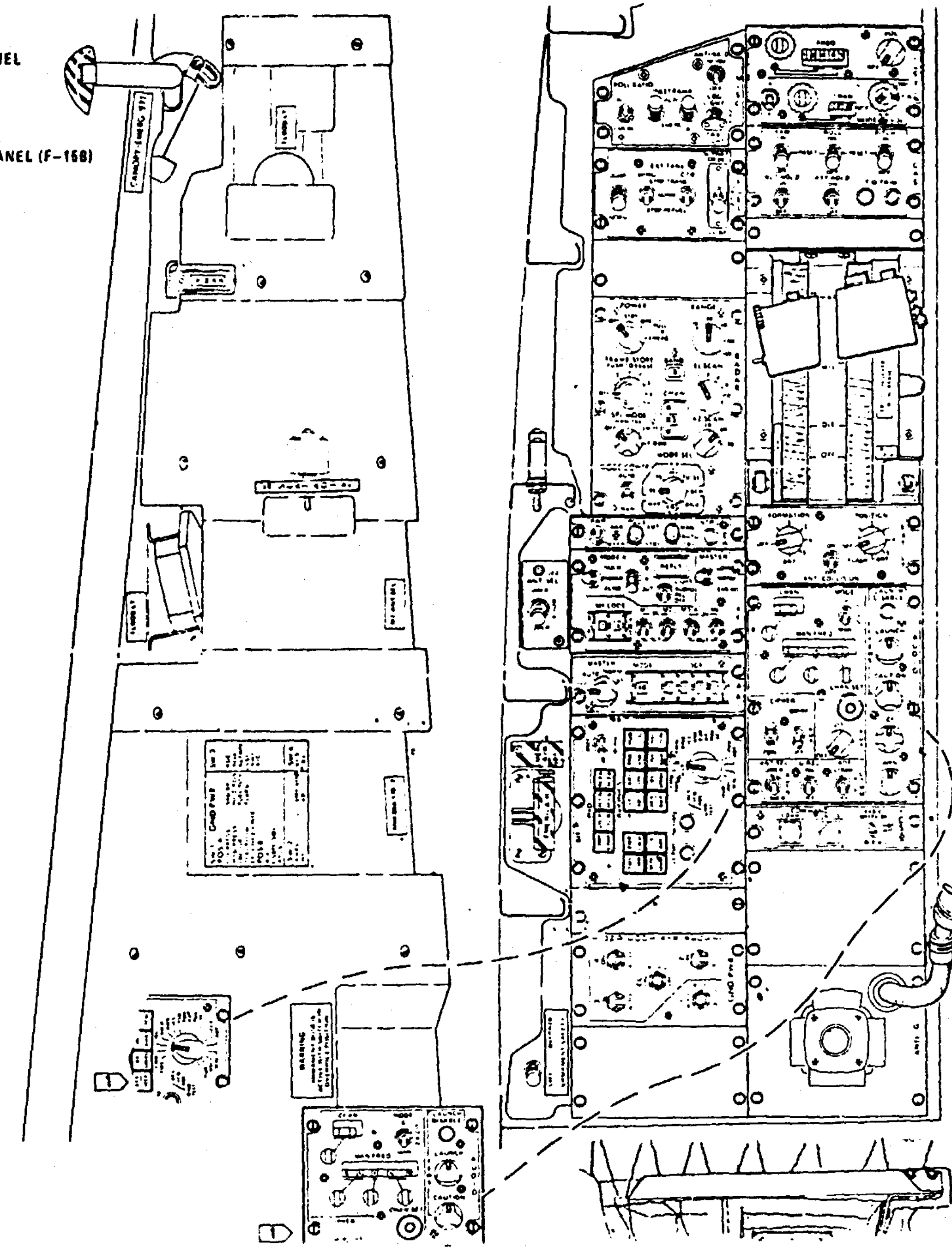
MAIN PANEL AREA



25. CABIN PRESSURE ALTIMETER
26. CAUTION LIGHTS PANEL
27. EMERGENCY VENT CONTROL HANDLE
28. CIRCUIT BREAKER PANELS
29. COCKPIT COOLING AND PRESSURIZATION OUTLET
30. STANDBY AIRSPEED INDICATOR
31. STANDBY ATTITUDE INDICATOR
32. STANDBY ALTIMETER
33. RUDDER PEDAL ADJUST RELEASE KNOB
34. MASTER MODE CONTROLS/MARKER BEACON PANEL.
35. ATTITUDE DIRECTOR INDICATOR
36. EMERGENCY JETTISON SWITCH
37. STEERING MODE PANEL
38. HORIZONTAL SITUATION INDICATOR
39. EMERGENCY BRAKE/STEERING CONTROL HANDLE
40. ACCELEROMETER
41. ANGLE OF ATTACK INDICATOR
42. AIRSPEED/MACH INDICATOR
43. ARMAMENT CONTROL PANEL
44. PITCH RATIO INDICATOR
45. PITCH RATIO SELECT SWITCH
46. LANDING GEAR CONTROL HANDLE
47. FLAP POSITION INDICATOR
48. EMERGENCY LANDING GEAR HANDLE
49. ARRESTING HOOK CONTROL SWITCH

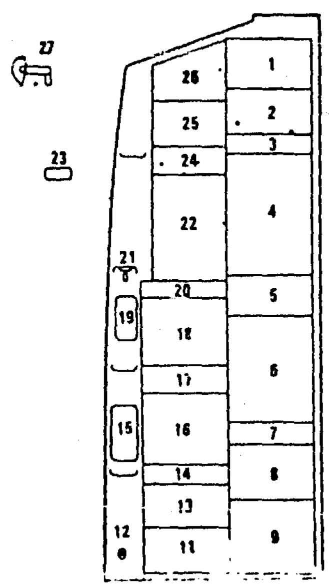




1. ILS/TACAN CONTROL PANEL
2. CONTROL AUGMENTATION SYSTEM CONTROL PANEL
3. BLANK
4. THROTTLE QUADRANT
5. EXTERIOR LIGHTS CONTROL PANEL
6. INTEGRATED COMMUNICATIONS CONTROL PANEL
7. BLANK (F-15A); TAKE COMMAND/ICS CONTROL PANEL (F-15B)
8. BLANK
9. ANTI-G PANEL
10. BOARDING STEPS POSITION INDICATOR
11. BLANK
12. ARMAMENT SAFETY OVERRIDE SWITCH
13. GROUND POWER PANEL
14. BLANK
15. EMERGENCY AIR REFUELING HANDLE
16. BIT PANEL
17. INTERROGATOR CONTROL PANEL
18. IFF CONTROL PANEL
18. IFF ANTENNA SELECT SWITCH
20. TEWS PANEL
21. SEAT ADJUST SWITCH
22. RADAR CONTROL PANEL
23. VMAX SWITCH
24. BLANK
25. FUEL CONTROL PANEL
26. MISCELLANEOUS CONTROL PANEL
27. CANOPY JETTISON HANDLE

NOTE

1 (F-15A) 77-0061 AND UP; (F-15B) 77-0154 AND UP.



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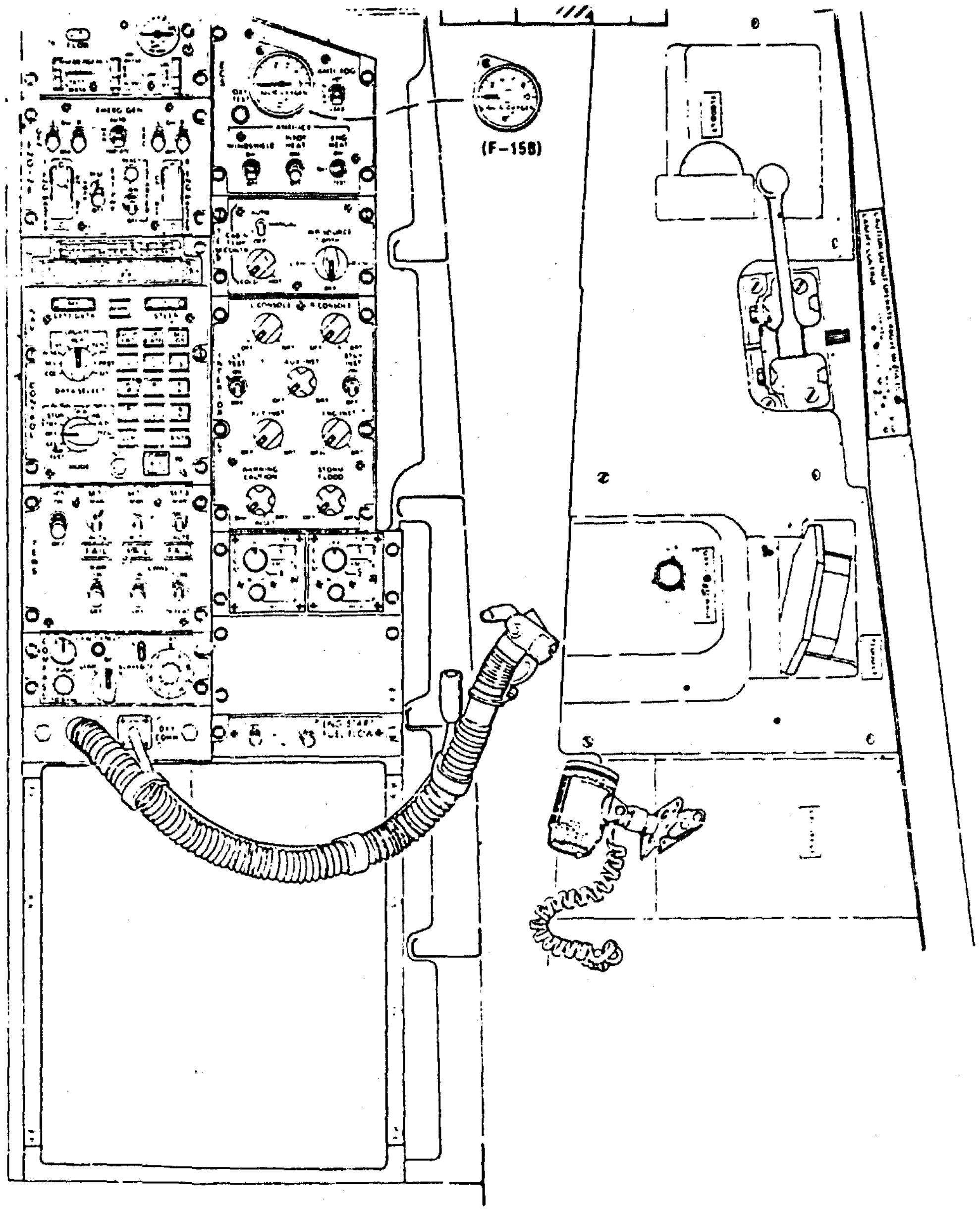
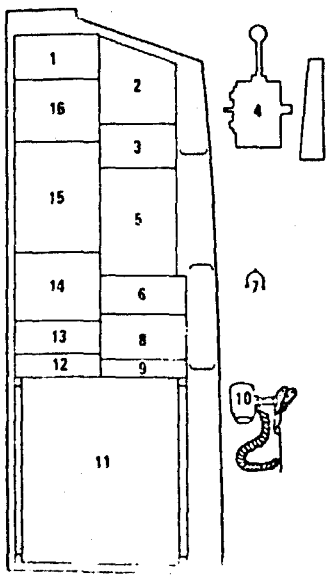


1. OXYGEN REGULATOR
2. ECS PANEL
3. TEMPERATURE PANEL
4. CANOPY CONTROL HANDLE
5. INTERIOR LIGHTS CONTROL PANEL
6. TEWS POD CONTROL PANEL
7. OXYGEN HOSE STOWAGE FITTING
8. BLANK
9. ENGINE START FUEL SWITCHES
10. UTILITY LIGHT
11. STOWAGE COMPARTMENT
12. OXYGEN/COMMUNICATION OUTLET PANEL
13. COMPASS CONTROL PANEL
14. TEWS POWER CONTROL PANEL
15. NAVIGATION CONTROL PANEL
16. ENGINE CONTROL PANEL



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