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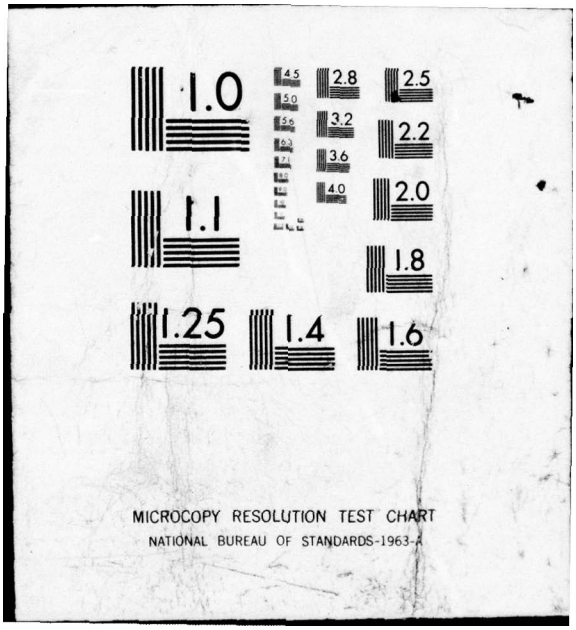
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IFC-TR-76-4

DETERMINING THE UTILITY OF EXPANDED PITCH SCALE AND FLIGHTPATH ANGLE AS DISPLAY PARAMETERS

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OCTOBER 1976

FINAL REPORT

USAF INSTRUMENT FLIGHT CENTER
Randolph AFB, Texas 78148

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The Research and Development Division of the USAF Instrument Flight Center (USAFIFC/RD) conducted a pilot factors evaluation to determine the utility of expanded pitch scale and flightpath angle (FPA) as display parameters. Ten subject pilots from the Instrument Flight Center participated in this evaluation. Each subject pilot flew three sorties of approximately 1.3 hours duration in the RD NT-38 aircraft.

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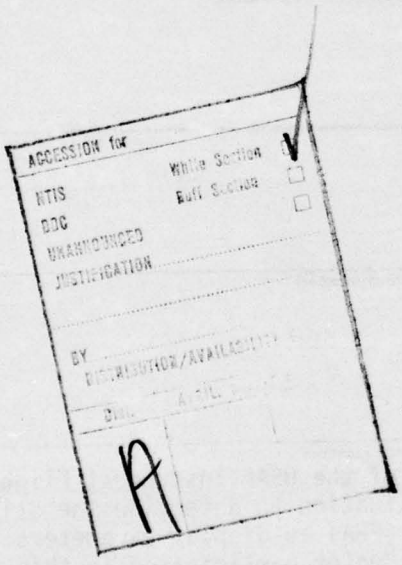
Based on the responses of the subject pilots and observations of the project pilot, the Instrument Flight Center recommends expanded pitch be displayed on the ADI and FPA be displayed on the right side of the ADI. If a Head-Up Display (HUD) is available, then FPA should be displayed on the HUD. A further study should be conducted to determine the use of flightpath angle and expanded pitch in the high dynamic flight environment.



PREFACE

This report (IFC-TR-76-4) presents the findings of project CDG-ADR-6 entitled, "Determining the Utility of Expanded Pitch Scale and Flightpath Angle as Display Parameters," conducted by the Research and Development Division of the USAF Instrument Flight Center. A subjective pilot factors flight test evaluation was undertaken at the request of the Flight Control Division of the Air Force Flight Dynamics Laboratory.

Flying activities on this project were conducted at Randolph AFB TX. Human factors engineering support was performed by Mr Gabriel P. Intano, IFC Research Psychologist; systems engineering support was performed by Capt William B. Orcutt and Mr George A. Rex, IFC Aerospace Engineers; secretarial support was performed by Mrs Shirley W. Pauley; and installation of the project equipment was performed by Mr Orrin C. Kopff and Mr Raoul G. Canamar, IFC Avionics Technicians.

This technical report has been reviewed and approved.

JOHN H. CARPENTER, Lt Col, USAF
Chief, Research and Development Division

DONALD F. ROBILLARD, Colonel, USAF
Commander
USAF Instrument Flight Center

TABLE OF CONTENTS

INTRODUCTION

The USAF Instrument Flight Center, Research and Development Division (USAFIFC/RD) conducted a pilot factors evaluation to determine the utility of expanded pitch scale and flightpath angle as display parameters. To accomplish this evaluation, a 4058E Attitude Director Indicator (ADI) was used.

The 4058E is a continuum of the pilot factors program conducted by the USAFIFC in conjunction with the Air Force Flight Dynamics Laboratory (AFFDL). Early stages of the pilot factors program were concerned with defining the pilot's control-display requirements while making instrument approaches in low visibility conditions. It was determined that the standard Air Force ADI (ARU-2B/A) was inadequate for the conduct of low visiblity research; and, therefore, needed redesigning to enhance interpretability. It was further determined that presentation of an additional parameter (flight-path angle)(1) would favorably augment the information available to the pilot. Therefore, the AFFDL developed a 4058E ADI which provided the pilot a better display which included a flightpath angle scale. Major emphasis in previous investigations has been restricted to the terminal area/final approach environment, and these have been conducted using low performance vehicles. These early studies left several questions unanswered:

1. Is the 4058E ADI display suited to high performance aircraft and environment?

2. Which is the more desirable course: To display flightpath angle (FPA) directly to the pilot; or to assist him in controlling this parameter through angle of attack and pitch attitude by presenting him pitch information on a greatly expanded scale?(2)

To answer these questions, AFFDL initiated a two-phase study. The USAFIFC Research and Development Division conducted a preliminary study using a T-38 "Talon" aircraft to determine suitability and pilot acceptability of the 4058E ADI basic display in the environment of a high performance vehicle. Results of this preliminary study (IFC TR-73-3) indicated universal pilot acceptance of the basic elements of the 4058E ADI display. Remaining questions relate to the utility of expanded pitch and flightpath angle as display elements and the relative merits of these two parameters.

(1) Flightpath Angle - Angular difference between the velocity vector of the aircraft through the air mass and the true horizon. Flightpath angle is derived in this evaluation by subtracting angle of attack from aircraft pitch which is modified by roll.

(2) Expanded Pitch - The relative movement of aircraft's pitch gyro displayed in expanded tape format by a factor of 10 to 1.

The objectives of this evaluation were to:

a. Determine the utility of an expanded pitch scale on the 4058E ADI or any ADI.

b. Determine the utility of flightpath angle as a display parameter in high performance aircraft.

c. Compare the relative merits of an expanded pitch scale and flightpath angle as display elements.

DESCRIPTION OF TEST ITEMS

No specific item of equipment was evaluated; rather, the concept of displaying flightpath angle or pitch on an expanded scale was investigated, and a determination was made as to which is the most desirable parameter from a pilot factors standpoint. A Lear Siegler, Inc., 4058 series Attitude Director Indicator (ADI) was used to present the parameters in question to the pilot (figure 1). The 4058 series ADI is mechanically similar to the standard ARU-2B/A attitude director indicator; however, there are numerous differences in the display. Significant differences are:

a. A tape scale at the right of the display is calibrated to $\pm$ 30°. This function was used to present flightpath angle and pitch attitude alternately during the investigation.

b. The attitude sphere is distinctively color coded for climb/dive pitch attitudes. For climb indication, a light blue color is used which increases in depth of color from a light to a darker blue as the pitch attitude increases. A tan color is used for nose low. The horizon is defined by the meeting of the blue and tan.

c. The attitude sphere has a 2° pitch reference scale for the first 10° of climb and dive with a dot representing the $\pm$ 5° point.

d. The miniature aircraft symbol is a winged semicircle with a 1° thick fuselage reference dot. The dot has a black line through the center which provides the pilot a continuous black line when superimposed on the even reference pitch scale. Additionally, the center of the wings of the aircraft symbol is transparent.

e. The glide slope indicator and scale is on the right side of the ADI, adjacent to the FPA tape.

f. The flight director command bars are orange to provide improved visual acuity. The center one-third of each command bar has been reduced in diameter to improve visual access to the attitude sphere pitch scale markings and miniature aircraft fuselage dot.

g. A fast/slow indicator is incorporated on the left side of the ADI providing the pilot the additional cue of speed (angle of attack) information in a more central location.

h. The rate of turn indicator is closer to the bank scale/pointer.

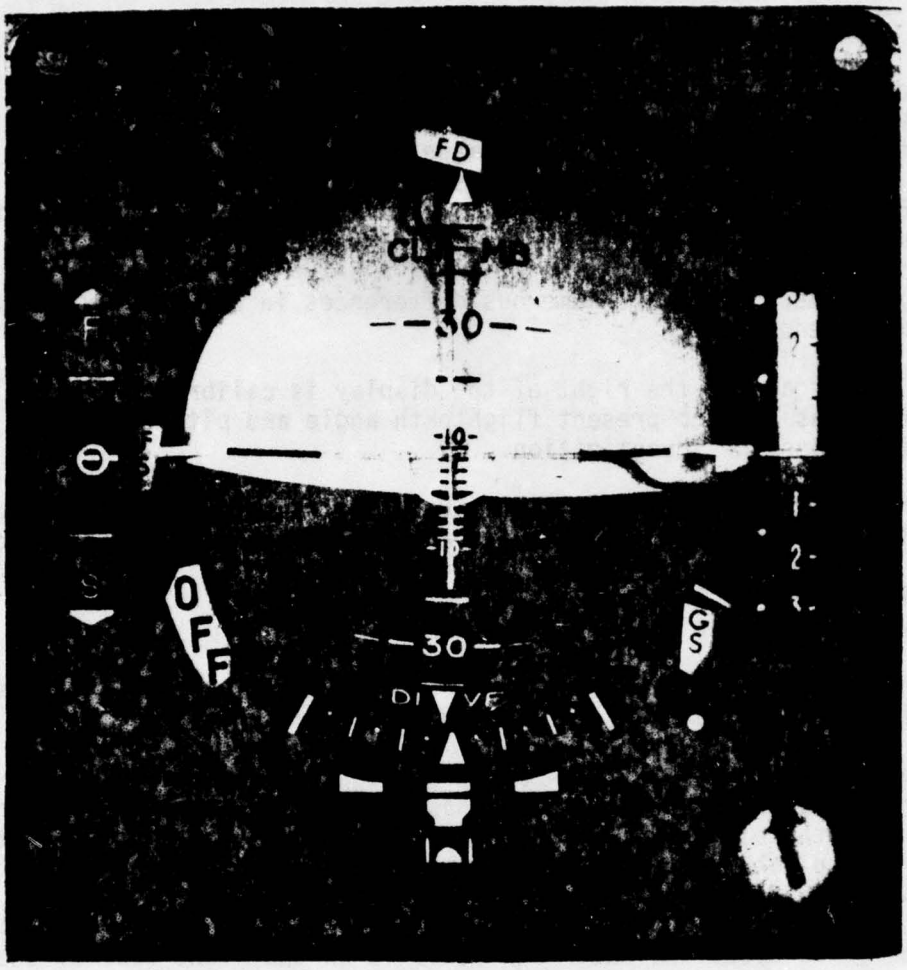


Figure 1. Advanced 4058E ADI

Display Mechanization

The pitch parameter inputs were provided by the aircraft attitude/heading reference system. The attitude sphere displayed aircraft pitch attitude, throughout 360°, at all times while the tape display showed only aircraft pitch attitude up to ± 30°. Flightpath angle information was displayed on the same tape, and limited to ± 30°.

Selection of either parameter was provided by a three-position (PITCH-OFF-FPA) switch on the pilot's console. The OFF position was required so that the tape display can be switched off to prevent possible damage to the tape during attitudes exceeding ± 30°.

TEST METHODOLOGY

The pilot factors evaluation to determine the utility of expanded pitch scale and flightpath angle as display parameters was conducted by USAFIFC/RDF at Randolph AFB TX. Subject pilots selected to fly this evaluation were IFC instructor pilots and Instrument Pilot Instructor School (IPIS) students. This selection allowed the project pilot to gather data from highly experienced pilots current in many different aircraft in the USAF inventory, and from various major commands.

Ten subject pilots flew a three-sortie series for this evaluation. During the test the subjects used both flightpath angle and expanded pitch presentation during high altitude flight, during approaches, and in a dynamic environment. The two high altitude sorties were flown as navigation missions which exposed the subjects to enroute environment (FL350 and above, .90 IMN) and precision approaches. The following flight profiles were utilized:

a. Takeoff.

b. Military power climb.

c. Leveloff (FL 350 - 390).

d. Accelerate/cruise (.90 IMN).

e. Penetration/enroute descent.

f. Multiple precision approaches (fuel and traffic permitting).

To obviate any learning tendencies regarding the tape portion of the ADI, the following procedures were closely adhered to:

a. Odd numbered subjects, that is, 1, 3, 5, etc., used expanded pitch information during their first sortie, and flightpath angle during their second sortie.

b. Even numbered subjects used flightpath angle during their first sortie, and expanded pitch information during their second sortie.

c. The third sortie was dedicated to explore the uses of FPA/expanded pitch in a high dynamic environment. The objective of this sortie was to define and identify, if possible, the procedures and techniques which the pilot can use FPA/expanded pitch in a high dynamic environment. Although air-to-air formation and similar maneuvers were not performed due to aircraft limitations and area restrictions, subject pilots were asked to conceptually evaluate the potential of FPA and expanded pitch for these flight regimes. To explore the full potential of these parameters, it was necessary to perform various maneuvers which closely simulate air-to-ground tactics. The following profile was used:

(1) Takeoff.

(2) Military power climb.

(3) Leveloff 10M - FL 230.

(4) High bank angle turns (30, 45, and 60°).

(5) Simulated air-to-ground.

d. To investigate various procedures or techniques for using FPA/expanded pitch to maintain a constant dive angle, pilots performed the maneuvers below. Each maneuver was flown using FPA and expanded pitch. These maneuvers provided a basis for evaluating the potential of FPA/expanded pitch in highly dynamic situations and methodologies for their use.

(a) First Maneuver.

1. Establish 25° dive attitude on ADI.

2. Cross-check FPA/expanded pitch.

3. If other than 25° pitch down, readjust dive angle on ADI.

4. Cross-check FPA/expanded pitch scale.

NOTE: Use FPA/expanded scale as an additional reference/cue.

(b) Second Maneuver.

1. Establish 25° dive on ADI.

2. Cross-check FPA/expanded pitch scale for 25° pitch indications.

3. If other than 25°, adjust aircraft attitude using FPA/expanded pitch scale.

(c) Third Maneuver.

1. Establish 25° dive using FPA/expanded pitch.

2. Adjust aircraft attitude by reference to FPA/expanded pitch scale.

(6) Normal recovery followed by precision approaches (fuel and traffic permitting).

Data Collection

Data collection was accomplished by each subject pilot being thoroughly debriefed following the sorties, and immediately completing the appropriate part of the questionnaire (atch 1). Any significant verbal comments noted during mission debriefing were recorded and added to the subject pilot's completed questionnaire.

RESULTS AND DISCUSSION

The problem of gyro precession in the standard T-38's gyro platform caused both expanded pitch and FPA displays to be degraded. The expanded pitch display exaggerated the gyro precession, and the FPA display at times would display erroneous information caused by gyro precession. Even with this problem the subject pilots still considered both displays of some value. A discussion of expanded pitch will be presented first, followed by the FPA discussion. Then a discussion of both expanded pitch and FPA use in high dynamic flight will follow. A table comparing expanded pitch to FPA in standard flight maneuvers performed is presented next.

Expanded Pitch Display

Expanded pitch as displayed was considered to be of limited value. Half of the subject pilots felt expanded pitch was an aid in pitch control. The remaining subjects had varying opinions as to the value of expanded pitch. For high altitude/high mach number maneuvers, 60% of the subject pilots stated the expanded pitch enabled them to maintain more precise attitude control. The differences in pilot opinion are related to the sensitivity of the expanded pitch display. The ability of the tape to display small deviations and thereby allowing the pilots to make corrections as small as 1/4° was considered a distinct advantage. However, at the same time, the sensitivity of the display to small aircraft deviation and resultant display movement, especially in other than calm conditions was cited as being both a disadvantage and a distraction.

Additional pilot comments regarding display usage were also presented. Gyro precession reduced the usefulness of the tape display since the precession was magnified on the tape. The tape display required an additional instrument to be cross-checked, and was considered to have increased workload by some of the subject pilots.

The expanded pitch display usefulness during instrument approaches also received a mixed reaction from the subject pilots. Small pitch changes were easily detected and corrected, and rate of descent was stated as easier to maintain with the tape display. Gyro precession and sensitivity in tape movement, especially in turbulence, were cited as problem areas. The additional cross-check requirements of the tape display also received negative comments, especially when the subject pilots were concentrating on the attitude indicator and glide slope indicator.

The expanded pitch display was rated most beneficial by half the subject pilots for penetration/enroute descent maneuvers. The display was rated most beneficial by 40% of the pilots for leveloffs, cruise, and precision approaches. Half the subject pilots rated the display as a disadvantage for takeoff, mainly due to excessive tape movements. Although not rated as a disadvantage during precision approaches, the tape display was considered least beneficial for this maneuver by half the subject pilots. The display received scattered ratings of most/least beneficial and disadvantages for all maneuvers.

The displaying of actual aircraft pitch by the tape was considered confusing by only four subject pilots. This aspect of the display also related to zeroing the ADI without the capability of zeroing the expanded pitch tape. This situation, ADI zeroed-tape displaying pitch, did not cause any problems for the majority of the subject pilots after a period of adjustment. However, the majority also believed an interconnect system should be incorporated to zero both systems at one time.

In spite of the generally negative responses to various aspects of the expanded pitch display, 70% of the subject pilots considered the method of displaying expanded pitch as satisfactory. Sixty percent of the subject pilots stated they would like to have an expanded pitch attitude display in their aircraft. These opinions appear to be based on the subject pilots' evaluation of the concept of displaying expanded pitch rather than the tape display itself. Their comments appear to indicate if expanded pitch is displayed properly without excessive sensitivity and movement; the concept would be satisfactory for inclusion in their aircraft.

Flightpath Angle Display

Displaying flightpath angle on a tape beside the ADI was considered an overall advantage by half the subject pilots. For three subject pilots it was neither an advantage nor a disadvantage, and only one subject pilot considered flightpath angle as a disadvantage. Seventy percent of the subject pilots considered the display as being useful during instrument approaches. Six pilots stated flightpath angle assisted them in maintaining altitude at high altitude/airspeed while eight stated it assisted them at low altitude/airspeed.

No consistent reasons were provided by the subject pilots for their opinions regarding the flightpath angle display. Some pilots considered the flightpath angle as an aid during penetration and approaches since small deviations could be readily observed, and precise adjustments made. Other pilots used the flightpath angle only as a reference after establishing their descent angle with the attitude indicator. The same type of comments were made for leveloffs and level flight. Some pilots considered the ability to make precise adjustments a distinct advantage while others considered the sensitivity as being too high, and providing little aid over the standard instrumentation. Another fairly common desire was to have flightpath angle ground based rather than air based. The subject pilots requesting this concept believed pilots could more easily relate to a ground based system and visualize the flightpath of the aircraft relative to ground rather than to the air mass surrounding the aircraft.

Flightpath angle was considered most beneficial by six pilots during precision approaches while five subject pilots considered the displays to be most beneficial during leveloffs and penetration/enroute descents. The display was considered to be of least benefit by six pilots for cruise, and by four pilots during takeoffs, military power climbs, and leveloffs. The flightpath angle display was considered a disadvantage for takeoffs

by four subject pilots. As with the expanded pitch display, all phases of flight received scattered responses relating to the benefit of flightpath angle.

Gyro precession was consistently stated as a major problem by the subject pilots, and this may have contributed to the varied opinions expressed by the pilots.

The flightpath angle tape movement opposite the direction of movement of the pitch steering bars did not cause any visual problems for the subject pilots. The method of presenting flightpath angle (vertical tape within ADI) was also considered satisfactory by all subject pilots. Despite the negative comments regarding the flightpath angle display only two subject pilots did not want a flightpath angle display in their aircraft. Three subject pilots stated the display affected their instrument cross-check. One had some difficulty incorporating the display in his normal cross-check; another dropped the VVI from his cross-check, and the third believed the flightpath angle tape should be separated from the glide slope indicator to avoid possible confusion. Three subject pilots wanted the amount of degrees, $\pm$ 30°, displayed to be expanded. Each considered a different angle to be acceptable, 45, 60, and 90°. The only reason for increasing the angle was for possible use in tactical operations.

The scale size (distance between degrees) was judged to be just right by six pilots, and too large by four pilots. Rate of tape movement was considered too fast by four pilots.

High Dynamic Maneuvers

A third sortie was flown to conceptually evaluate the potential of flightpath angle and expanded pitch in simulated air-to-air and air-to-ground flight regimes. Table 1 presents the subject pilots' ratings regarding the aid provided by FPA and expanded pitch in maintaining a constant altitude during high bank angle turns.

Table 1. Pilot ratings regarding helpfulness of FPA/expanded pitch for maintaining constant altitude during high bank angle turns.

	FPA	Expanded Pitch
Did not use	2	1
Cross-checked - did not help		2
Cross-checked - slight help	5	4
Cross-checked - significant help	2	2
Used as primary - slight help	3	2
Used as primary - significant help		1

The most commonly rated aspect for this maneuver was "cross-checked - slight help," (five for FPA, and four for expanded pitch). The remaining pilot ratings were scattered from "did not use" to "used as primary - significant help." Only one subject pilot considered the FPA could be used as a primary parameter in place of the ADI pitch attitude while two believed the expanded pitch could perform this function. However, almost all the subject pilots believed that both the FPA and expanded pitch could be used as a secondary parameter as an aid for pitch attitude control. Although half the subject pilots stated some special techniques or procedures would be required to better utilize either FPA or expanded pitch for high bank angle turns, the only suggestions presented were: adaption time for the displays, changing cross-check procedures and knowing gyro precession rate.

The major reason presented by the subject pilots as to why both FPA and expanded pitch were only a slight help in maintaining a constant altitude was gyro precession. The higher the bank angle the greater gyro precession error; therefore, the greater difficulty in using either FPA or expanded pitch for altitude maintenance.

The first dive maneuver performed to evaluate the potential of the displays in air-to-ground regimes consisted of setting in a 25° dive angle with the ADI, cross-checking the angle with either the FPA or expanded pitch and readjusted the angle with the ADI. For this maneuver the FPA was considered to have helped significantly by seven pilots and was easy to use, while five stated the same for expanded pitch. Tape sensitivity and the different indications of the tapes versus the ADI were cited as the only negative areas in this maneuver. Both FPA and expanded pitch were rated as better for cross-checking the ADI by three pilots. The remaining pilots did not consider one display as better than the other.

The second dive maneuver required setting the dive angle with the ADI, and then adjusting the angle with FPA or expanded pitch. Six pilots stated that by using the FPA, the dive angle could be adjusted with good accuracy and was procedurally easy. Five pilots stated the same for expanded pitch. However, when directly compared, each display was considered superior for this task by only two pilots.

The third dive maneuver required establishing, adjusting, and maintaining the 25° dive angle with the FPA and expanded pitch. For establishing the dive, seven pilots considered FPA as procedurally easy to use with four believing accuracy as marginal, and three stated accuracy to be good. For adjusting and maintaining, seven pilots stated FPA as procedurally easy with six stating accuracy as good. Expanded pitch was also thought to be procedurally easy for establishing the dive by seven subject pilots, with four considering accuracy as good, and three considering accuracy as marginal. For adjusting and maintaining, seven pilots considered the procedures as easy, while five pilots considered the accuracy to be good.

When directly compared, FPA versus expanded pitch, three pilots considered expanded pitch better for establishing the dive, while two considered FPA better, and five did not see any difference between the two. For maintaining the dive, four subject pilots considered FPA as better, and only one considered expanded pitch as better. Five subject pilots did not see any difference between the two displays. As with many other aspects of the FPA/expanded pitch evaluation, the subject pilots did not see significant overall differences between the two displays.

For the three dive maneuvers only two subject pilots stated different techniques or procedures would better utilize the FPA or expanded pitch. However, the only suggestion offered was to put the display on a head-up display. The only other maneuvers the subject pilots considered within the realm of FPA/expanded pitch as they were evaluated were GCAs, missed approaches, and SIDs. The only suggested modifications presented by the subject pilots for use on FPA/expanded pitch in air-to-ground tactics were to make FPA ground based, use a HUD, and increase the scale increments to 30°, 45°, and 60°. The only way the FPA/expanded pitch was thought to be useful in air-to-air maneuvers was if the information was put on a HUD. No additional modifications other than those already presented were suggested to perform air-to-air maneuvers.

Comparison of Expanded Pitch and Flightpath Angle

Subject pilots were asked to compare the expanded pitch display with the flightpath angle display for each of the standard flight maneuvers performed. These results are provided in Table 2. Only takeoffs, acceleration/cruise, and penetration/enroute descent showed clear distinctions between the two displays. These ratings appear to be related only to the personal preferences by the subject pilots. The subject pilots' comments regarding each system are basically identical. The same type of useful information appears to have been provided by each display and sufficient problems exist with each display so that neither is considered superior to the other for normal flight operations.

Table 2. Pilot Preference - Flightpath Angle versus Expanded Pitch for Flight Maneuvers.

	BETTER	NO DIFFERENCE
Takeoff		
Flightpath Angle	2	
		2
Expanded Pitch	6	
Military Power Climb		
Flightpath Angle	5	
		1
Expanded Pitch	4	
Leveloff		
Flightpath Angle	4	
		2
Expanded Pitch	4	
Accelerate/Cruise		
Flightpath Angle	4	
		4
Expanded Pitch	1	
High Altitude/High Airspeed		
Flightpath Angle	4	
		3
Expanded Pitch	2	
Penetration/Enroute Descent		
Flightpath Angle	7	
		1
Expanded Pitch	2	
Instrument Approaches		
Flightpath Angle	6	
Expanded Pitch	4	
Low Altitude		
Flightpath Angle	3	
		3
Expanded Pitch	4	
Overall for Future Installation		
Flightpath Angle	4	
Expanded Pitch	6	

CONCLUSIONS

The following conclusions are based on the subjective data obtained from subject pilots and the observations of the project pilots. The conclusions of expanded pitch will be presented first, followed by the flightpath angle conclusions, then the conclusions of the high dynamic maneuvers.

Expanded Pitch

1. Considered of limited overall value, but rated most beneficial for penetration/enroute descent and instrument approach maneuvers.

2. Subject pilots were able to maintain more precise attitude control with the display than with the ADI alone.

3. Increased workload was noted by the subject pilots due to the requirement to cross-check an additional instrument.

4. The displaying of actual aircraft pitch by the tape was considered confusing because the tape was not trimmed with the ADI.

5. Gyro precession was exaggerated on the tape, and resulted in varied subject pilot opinions regarding usefulness of the display.

Flightpath Angle

1. Displaying this parameter on the tape adjacent to the attitude indicator was considered satisfactory by all subject pilots.

2. Flightpath angle was considered an aid during penetration, approaches, leveloffs, and maintaining level flight, but unusable for takeoffs.

3. Gyro precession caused errors in the flightpath angle display. Such errors resulted in varied subject pilot opinions regarding usefulness of the display.

High Dynamic Maneuvers

1. Flightpath angle and expanded pitch were an aid in setting and maintaining precise dive angles. The subject pilots did not indicate any overall preference for either display for use in the high dynamic flight regimes evaluated.

2. In a comparison of the two systems, neither system was considered superior to the other for performance of the high dynamic flight maneuvers. Both systems were regarded as basically identical in terms of information presented, changes in workload, and ease of use.

RECOMMENDATIONS

Although problems were encountered with both the expanded pitch and flightpath angle display, these problems do not appear to be related to the actual display of information, but rather to the methods of presentation and gyro precession problems. Therefore, the following recommendations are presented:

1. Expanded pitch should be displayed on an expanded pitch attitude indicator. An expanded pitch attitude indicator is well accepted by pilots utilizing such a system in other aircraft.

2. Flightpath angle should be ground based and displayed on a head-up display (HUD). If a HUD is not available, then flightpath angle should be displayed on a tape adjacent to the attitude indicator.

3. A further evaluation should be conducted in the high dynamic flight regime to fully develop the potential of both expanded pitch and flightpath angle. Expanded pitch and flightpath angle could not be defined adequately by this evaluation. However, this evaluation did indicate both expanded pitch and flightpath angle may have significant usefulness in high dynamic flight environment.

QUESTIONNAIRE

DETERMINING THE UTILITY OF EXPANDED PITCH SCALE AND FLIGHTPATH ANGLE AS DISPLAY PARAMETERS

DATE_____FLIGHT TIME_____DAY___NIGHT___IMC___VMC___

NAME_____RANK_____

Organization_____Command_____

Approximate instrument time _____

Approximate total time _____

Which operational aircraft have you flown?

What aircraft are you current in?

Atch 1

PART A

1. Have you ever flown an aircraft that had some form of expanded pitch presentation?

Yes_____ No_____

If yes, please state type of aircraft and kind of display.

a. If yes, which did you prefer?

Present display_____ Previous display_____

Why?

2. Displaying expanded pitch: (Check one)

a. Was a distinct advantage, greatly assisted precise pitch attitude control. _____

b. Was of limited value but aided in pitch attitude control. _____

c. Aided somewhat in pitch attitude control for very few maneuvers. _____

d. Was confusing due to the different rates of movement of the pitch tape and attitude sphere. Could be used. _____

e. Was a total disadvantage. Should not be considered at all. _____

Please comment giving examples.

3. Do you feel that expanded pitch display enabled you to maintain more precise altitude control at high altitude/high mach number?

Yes_____ No_____

Please explain:

4. What effect, if any, did expanded pitch have during instrument approaches?

5. Assuming some benefit, where was expanded pitch of most/least benefit to you?

(Use (1) for most, (2) for least, and (3) for disadvantage)

a. Takeoff_____

b. MP Climb_____

c. Leveloff_____

d. Cruise_____

e. Penetration/Enroute Descent_____

f. Precision approaches_____

g. Other_____

Please explain:

6. Did movement of the pitch tape adjacent to the attitude sphere distract your cross-check?

Yes_____ No_____

Please explain:

7. Was the method of displaying expanded pitch attitude satisfactory? i.e., TAPE ON ADI. Yes_____ No_____

Please comment:

8. Based upon your experience, would you like to have an expanded pitch attitude display in your own aircraft?

Yes_____ No_____

Please comment:

9. The expanded pitch scale tape indicates the actual pitch attitude of the aircraft. Did this cause any problems or confusion?

Yes_____ No_____

If Yes, please explain.

10. If you zeroed out the ADI by using the pitch trim knob to indicate level flight, the expanded pitch scale tape indicated the actual pitch attitude of the aircraft. Did this situation cause any problem or confusion?

Yes_____ No_____

If Yes, please explain.

11. Should there be a method of zeroing the expanded pitch scale tape similar to the ADI pitch trim knob?

Yes_____ No_____

If No, please explain.

12. If question 11 is yes, should the expanded pitch scale tape and ADI pitch trim knob be interconnected, i.e., if you adjust one, you adjust the other automatically?

Interconnect _____

Separate _____

PART B

1. Have you ever flown an aircraft that had a form of flightpath angle displayed?

Yes_____ No_____

If yes, please state type of aircraft and display.

a. If yes, which did you prefer?

Former display_____ Present display evaluated_____

Please explain:

b. Displaying flightpath angle was:

(1) An advantage_____ (2) Disadvantage_____ (3) Neither_____

Please explain:

2. Do you feel that you understand what is meant by the term "flightpath angle"?

Yes_____ No_____

Please comment:

3. Assuming some benefit, where was flightpath angle of most/least benefit to you? (Use (1) for most, (2) for least, and (3) for disadvantage)

a. Takeoff_____

b. MP Climb_____

c. Leveloff_____

d. Cruise_____

e. Penetration/Enroute Descent_____

f. Precision Approaches_____

g. Other_____

Please explain:

4. Was the parameter, flightpath angle, useful during instrument approaches?

Yes_____ No_____

Please explain:

5. Did the flightpath angle display assist you in maintaining altitude:

(Consider both high altitude/airspeed and low altitude/airspeed.)

	High Altitude/Airspeed	Low Altitude/Airspeed
Yes		
No		

Please explain:

6. Did you encounter any conflicting visual problems with the flightpath angle tape moving up while the pitch steering bar moved down?

Yes_____ No_____

Please explain:

7. Was this method of displaying flightpath angle (vertical tape within ADI) a satisfactory means of displaying this parameter?

Yes_____ No_____

Please comment:

8. Would you like to have flightpath angle displayed in your aircraft?

Yes_____ No_____

Please explain:

9. Did displaying flightpath angle affect your cross-check in any manner?

Yes_____ No_____

Please explain why and how:

10. The flightpath angle scale readout of $\pm$ 30 degrees was:

Adequate_____ Not enough displayed_____should be_____degrees.
Too much displayed_____should be_____degrees.

11. The scale size (distance between degrees) was:

Just right_____

Too large_____

Too small_____

12. The rate of movement of the flightpath angle scale tape was:

Just right_____

Too slow_____

Too fast_____

13. Do you have any additional comments regarding the flightpath angle evaluated or flightpath angle in general?

PART C

1. Did the test profiles enable you to equitably evaluate each display parameter?

Yes_____ No_____

Please explain:

2. Please compare expanded pitch and flightpath angle to each other in relation to the following profiles:

	BETTER	NO DIFFERENCE
Takeoff		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
Military Power Climb		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
Leveloff		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
Accelerate/Cruise		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
High Altitude/High Airspeed		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
Penetration/Enroute Descent		
Flightpath Angle	_____	_____
Expanded Pitch	_____	

	BETTER	NO DIFFERENCE
Instrument Approaches		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
Low Altitude		
Flightpath Angle	_____	_____
Expanded Pitch	_____	
Overall for Future Installation		
Flightpath Angle	_____	_____
Expanded Pitch	_____	

3. Did you have any problems adapting to:

Flightpath Angle - Yes_____ No_____

Expanded Pitch - Yes_____ No_____

If yes, please explain the problems and how you overcame them.

PART D

1. During high bank angle turns did you use either FPA or the expanded pitch scale to maintain a constant altitude? (Check appropriate boxes.)

	FPA	EXPANDED PITCH
Did not use		
Cross-checked - did not help		
Cross-checked - slight help		
Cross-checked - significant help		
Used as primary - slight help		
Used as primary - significant help		

Comments:

2. Could either the FPA or expanded pitch be used as:

a. Primary parameter in place of the ADI for pitch attitude?

	FPA	EXPANDED PITCH
Yes		
No		

b. Secondary parameter as an aid for pitch attitude control?

	FPA	EXPANDED PITCH
Yes		
No		

c. Would any special techniques or procedures be required to better use the FPA/expanded pitch for high bank angle turn?

	FPA	EXPANDED PITCH
Yes		
No		

2.c. (Cont)

Please explain how.

3. During the first dive maneuver could you use the FPA/expanded pitch as an additional reference cross-check to maintain the 25° dive attitude?

	FPA	EXPANDED PITCH
Not at all		
Helped slightly - difficult to use		
Helped slightly - easy to use		
Helped significantly - easy to use		
Other - (explain)		

Please explain problems encountered.

4. For this first maneuver which parameter was better for use as a cross-check?

FPA _____

Expanded Pitch _____

No Difference _____

Please explain.

5. During the second dive maneuver, could you use the FPA/expanded pitch to adjust the aircraft attitude after establishing the 25^{o} dive angle on the ADI?

	FPA	EXPANDED PITCH
Not at all		
Could be adjusted Accuracy marginal Procedure difficult		
Could be adjusted Accuracy good Procedure difficult		
Could be adjusted Accuracy good Procedure easy		
Other (explain)		

6. For this second maneuver which parameter was better for adjusting the dive angle?

FPA _____

Expanded Pitch _____

No Difference _____

Please explain.

7. During the third dive maneuver could you use the FAP/expanded pitch to establish and maintain the 25° dive angle?

	ESTABLISH		ADJUST/MAINTAIN	
	FPA	EXPANDED PITCH	FPA	EXPANDED PITCH
Could not be used				
Used - procedure difficult Accuracy marginal				
Used - procedure easy Accuracy marginal				
Used - procedure easy Accuracy good				
Other (explain)				

8. For the third maneuver which parameter was better for establishing and maintaining your dive angle?

	ESTABLISH	MAINTAIN
FPA		
Expanded Pitch		
No Difference		

Please explain.

9. For these three maneuvers would different techniques or procedures better utilize either the FPA or expanded pitch?

Yes_____ No_____

Please explain.

10. What other type maneuver or tactic could utilize the FPA/expanded pitch?

11. How could the FPA/expanded pitch be modified to be used for additional air-to-ground tactics?

12. Could the FPA/expanded pitch be used during air-to-air maneuvers (join-ups, refueling, etc.)?

Yes_____ No_____

Please explain.

a. What techniques or procedures would you use with FPA/expanded pitch to best perform such maneuvers?

b. How can the FPA/expanded pitch scale be modified to perform air-to-air maneuvers?

13. Are there any other areas of flight where FPA/expanded pitch can be utilized?

Yes_____ No_____

Please explain.