COMBAT AGILITY MANAGEMENT SYSTEM (CAMS)

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COMBAT AGILITY MANAGEMENT SYSTEM
(CAMS)

The proper management of energy becomes a complex task in fighter aircraft which have high AOA capability. Maneuvers at high AOA are accompanied by high bleed rates (velocity decrease), a characteristic that is usually undesirable in a typical combat arena. Eidetics has developed under NASA SBIR Phase I and NAVAIR SBIR Phase II contracts, a system which allows a pilot to more easily and effectively manage the trade-off of energy (airspeed or altitude) for turn rate while not imposing hard limits on the high AOA nose pointing capability that can be so important in certain air combat maneuver situations. This has been accomplished by incorporating a two-stage angle-of-attack limiter into the flight control laws. The first stage sets a limit on AOA to achieve a limit on the maximum bleed rate (selectable) by limiting AOA to values which are dependent on the aircraft attitude and dynamic pressure (or flight path, velocity and altitude). The second stage sets an AOA limit near the AOA for C_{lmax}. One of the principal benefits of such a system is that it enables a low-experience pilot to become much more proficient at managing his energy. The Phase II simulation work is complete, and an exploratory flight test on the F-18 HARV is planned for the Fall of 1994 to demonstrate/validate the concept. With flight test validation, the concept should be seriously considered for incorporation into future fighter aircraft.

COMBAT AGILITY MANAGEMENT SYSTEM
(CAMS)

PRESENTATION OUTLINE

- MOTIVATION

- CONCEPT DESCRIPTION

- DEVELOPMENT APPROACH

- CURRENT STATUS

- POTENTIAL FUTURE APPLICATIONS

COMBAT AGILITY MANAGEMENT SYSTEM (CAMS)

Fighter agility is sometimes expressed as the ability of an aircraft to change it's maneuver plane. The important parameters that determine the level of agility are typically expressed as a combination of energy-maneuverability and transient controllability or "point and shoot" capability. Energy-maneuverability is defined as the dynamic interchange between kinetic (based on velocity) and potential (based on altitude) energy gained or lost and the change in flight path or flight path curvature (turn rate, etc.). Managing the available energy optimally for any given combat situation is a very difficult and taxing task for all pilots, particularly for those who are relatively inexperienced. If a fighter is engrossed in high angle of attack maneuvers, it is very easy to lose velocity or "bleed energy" at a rate that will shortly put him at high risk. Bleed rates of 30 - 40 knots/sec^2 are not uncommon. One means of restricting the bleed rate is to limit angle of attack, and, therefore reduce the drag. But scheduling the AOA limit is not optimum for all flight attitudes (fight path angles). The "optimum" limit will depend on whether the maneuver is a level turn, a pull-up, slit-s, etc. And, usually, there is no override capability available to the pilot.

CAMS is designed to improve this situation and to make it easier for the pilot to manage his energy intelligently and to significantly reduce his work load. This concept utilizes a two-stage AOA limiter that is overridable by the pilot with an automatic reset under specific conditions. The following charts will review the development of CAMS and discuss the future potential for application.

COMBAT AGILITY MANAGEMENT SYSTEM

- *AGILITY* IS TYPICALLY THOUGHT OF AS A COMBINATION OF:

  - ENERGY-MANEUVERABILITY
  - TRANSIENT CONTROLLABILITY

- *ENERGY-MANEUVERABILITY* IS DEFINED AS THE DYNAMIC INTERCHANGE BETWEEN:

  - KINEMATIC AND POTENTIAL ENERGY GAIN OR LOSS
  - FLIGHT-PATH CURVATURE

- MANAGING YOUR AIRCRAFT'S AVAILABLE ENERGY WHILE MANEUVERING AGGRESSIVELY IN AIR-TO-AIR COMBAT AGAINST MULTIPLE ADVERSARIES IS A VERY DIFFICULT TASK.

  - AIRSPEED "BLEED" RATES OF GREATER THAN 30-40 KNOTS/SECOND ARE TYPICAL
  - TACTILE CUES ARE REDUCED DUE TO ADVANCED AERODYNAMICS

- ANGLE OF ATTACK LIMITERS CAN PROVIDE SOME "ENERGY MANAGEMENT" HELP TO A PILOT
  - SCHEDULING IS NOT OPTIMUM FOR ALL FLIGHT ATTITUDES
  - PILOT OVERRIDE IS USUALLY NOT POSSIBLE DUE TO DEPARTURE CONCERNS

- *COMBAT AGILITY MANAGEMENT SYSTEM (CAMS)* IS DESIGNED TO MAKE IT EASIER FOR A PILOT TO MANAGE THE DYNAMIC TRADE-OFF BETWEEN ENERGY AND MANEUVERABILITY

  - USES A THREE-STAGED "ADAPTIVE" ANGLE-OF-ATTACK LIMITER TO CONTROL AIRSPEED LOSS RATE
  - PROVIDES FOR PILOT OVERRIDE AND AUTOMATIC RESET

ams94048

F/A-18 MANEUVERING DIAGRAM
15,000 FT ALTITUDE

The F/A-18 maneuvering diagram for 15,000 ft altitude is shown below. If we initiate a level turn at maximum turn rate, or at M=0.63, as shown on the chart, we can consider that the aircraft is going to up the chart below at M=0.63 (with steadily increasing angle of attack) until it reaches the "corner speed" at a turn rate of approximately 20 deg/sec. From that point, holding the angle of attack for maximum lift (approximately 34°), the Mach number and turn rate decrease, for example, to 4 deg/sec at M=0.2. One of the important aspects of performing a level turn as just described is the loss in velocity, or bleed rate that accompanies it. The chart following this illustrates the change in turn rate with loss in bleed rate and will serve to illustrate why CAMS is important.

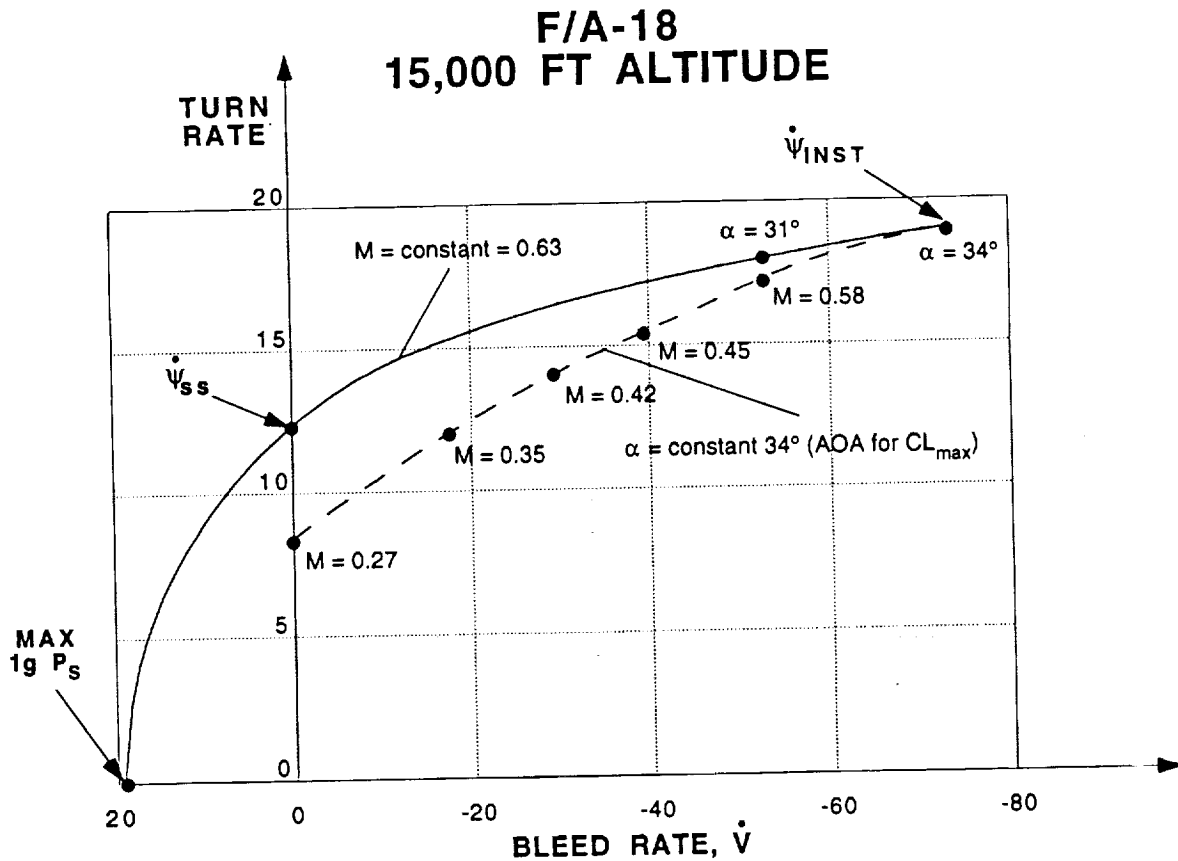# F/A-18 MANEUVERING DIAGRAM
15,000 FT ALTITUDE
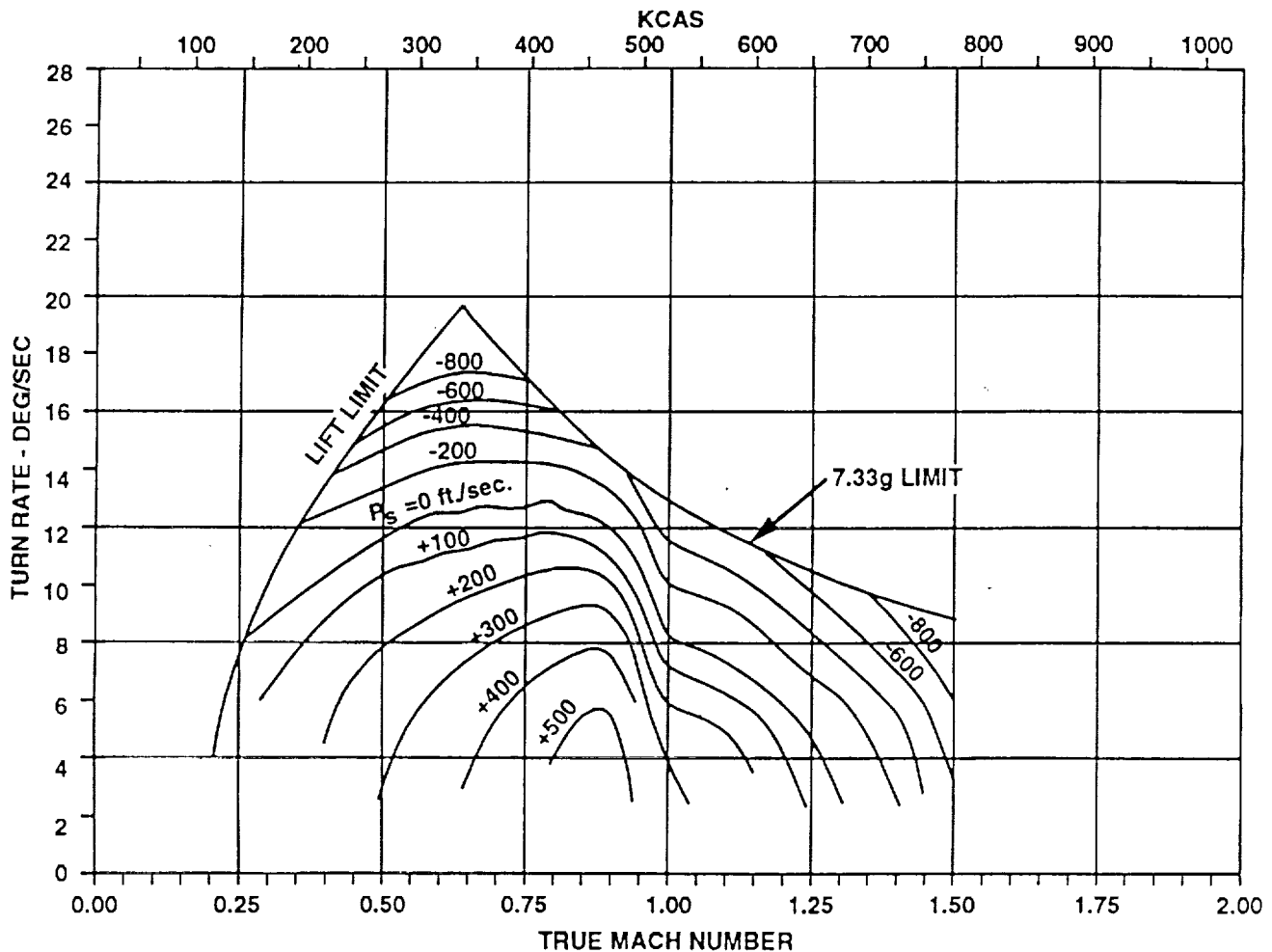
F/A-18
TURN RATE VS BLEED RATE
15,000 FT ALTITUDE

This chart shows the turn rate plotted versus bleed rate as a result of a level turn performed as described in the previous chart, i. e., rapidly increasing angle of attack at a constant Mach number of 0.47 (corner speed for 15,000 ft altitude) and then holding AOA for maximum lift (approximately 34°). The chart shows several important points. As you increase the turn rate the proportional penalty that must be paid in bleed rate is increasing. Increasing angle of attack beyond that for maximum lift (approximately 34°) would result only in an increase in bleed rate and no benefit in turn performance. Holding AOA for maximum lift results in a decreasing bleed rate, but at the expense of reduced turn rate. The purpose of CAMS is to help pilot to "optimize" his bleed rate so that he can accomplish the maximum turn rate integrated over the course of the entire maneuver. Obviously, increasing angle of attack prior to maximum lift will increase the turn rate, but will cost in terms of bleed rate, resulting in a final velocity that may be too low. CAMS can help by automatically limiting the maximum bleed rate (by limiting AOA, with pilot selectable override options).

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F/A-18
15,000 FT ALTITUDE

TURN RATE

$\dot{\psi}_{INST}$

20

M = constant = 0.63

$\alpha = 31°$

$\alpha = 34°$

M = 0.58

$\dot{\psi}_{SS}$

15

M = 0.45

M = 0.42

M = 0.35

α = constant 34° (AOA for CL_{max})

10

M = 0.27

MAX 1g P_S

5

0

20   0   -20   -40   -60   -80

BLEED RATE, $\dot{V}$

F/A-18 LIFT AND DRAG
M=0.6

The plots below show lift coefficient plotted versus angle of attack and drag coefficient. The primary point illustrated is related to the discussion in the last chart, which shows clearly that a small increase in angle of attack near maximum lift (to gain additional lift) can result in a large penalty in drag (resulting in a large increase in bleed rate). If angle of attack is pushed beyond maximum lift, of course there is a loss of lift (anc turn rate) and an excessive increase in drag. To maximize the effectiveness of a maneuver, and, in particular, to choose the best turn rate without losing excessive velocity, is difficult. CAMS is designed to prevent the pilot from flying into a situation that is far from the optimum and will leave him vulnerable.

F/A-18 LIFT AND DRAG
M=0.6
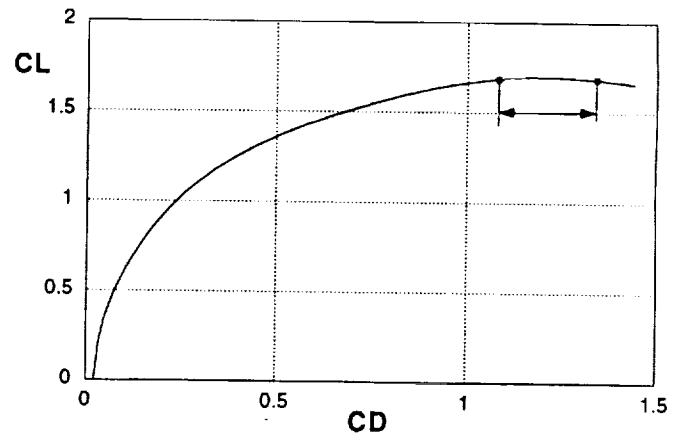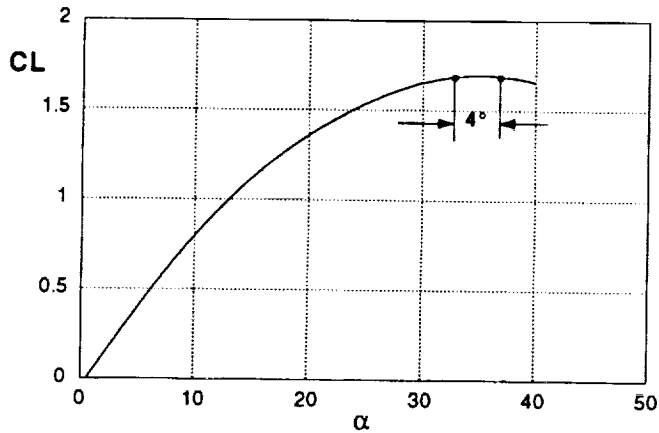
CAMS
MODES OF OPERATION

This chart illustrate the many modes of CAMS that were investigated and could be implemented. The key outcome of this study are highlighted by the shaded boxes. The first stage or mode is focused on limiting the bleed rate to some value chosen based on either simulation studies or by experience in flight. The second stage or mode is limiting angle of attack to that just below that for maximum lift. The third mode, related at post-stall (at angles of attack beyond maximum lift) is focused simply on limiting the angle of attack to a range where the aircraft is controllable.

CAMS

CAMS MODES OF OPERATION

Mode	Dynamic Characteristics					
	N_Z	α	C_L	$P_s - \dot{V}$	Turn Rate	Nose Rate
1. AOA - limiting for 'optimum' energy/ velocity bleed rate	Limited to less than $N_{Z_{MAX}}$ below some Mach No.	Limited to less than $C_{L_{MAX}}$, Typically 15° - 25°	Less than $C_{L_{MAX}}$ @ Typically L/D ≈ 4 - 6	Limited to 'optimum' bleed rate	Less than maximum	Less than maximum
2. AOA - limited to max turn rate	Structural Limit ($N_{Z_{MAX}}$) above corner, N_Z for max lift below corner	Limit to N_Z $N_{Z_{MAX}}$ or $C_{L_{MAX}}$	Maximum lift below corner	Large bleed rates when on limiter	Maximum capability throughout conventional envelope	Maximum available above corner -- equal to turn rate below corner
3. Post Stall Maneuvering	$N_{Z_{MAX}}$ above corner	Limit to controllable AOA (70°?)	Less than $C_{L_{MAX}}$ when above AOA for $C_{L_{MAX}}$	Very large bleed rates above AOA for C_{L_M}	Maximum capability throughout expanded envelope	Maximum capability throughout expanded envelope

DEVELOPMENT APPROACH

A number of algorithm approaches were discussed in the Phase I effort, but the most promising concepts resulted in the following approaches:

- Scheduled AOA limit as a function of flight condition.
- P_S limiting.
- Bleed rate limiting.

In the Phase I study, Eidetics demonstrated the feasibility of these three approaches by modifying the F-16 flight control system. The latter two concepts are effectively forms of an adaptive AOA control where AOA is commanded by an outer loop closure on P_S or bleed rate. The first concept is just a modification of the aircraft's nominal flight control system angle of attack limiter. For the Phased II effort, the three concepts were mechanized into an F-18 six degree of freedom real-time flight simulation. The control system design effort involved generating linear state space models at trim points throughout the flight envelope of the aircraft. Continuous system loop closure design was then done at each trim point using *EASY5*, a Boeing controls design software tool.

A comprehensive review of existing published data on the subject of agility management was done. Most of the reports discussed various metrics defining agility, however, did not address a flight controls application to agility management.

CONTROL LAW IMPLEMENTATION

The intended implementation objective of CAMS is that it be non-flight critical where the system is a stable addition to the aircraft's nominal control law set. The implementation is viewed as a separate stand-alone algorithm which does not interfere with the operation of the basic aircraft flight control system. The implementation also exhibits no adverse effects on the aircraft flight characteristics since the system acts as a limiter (not an augmenter) on the basic system. Stability and good handling qualities can easily be achieved with the variety of sensed quantities available on the F-18 and with good controls simulation and analysis tools at Eidetics. The implementation also allows override of CAMS and on/off capability as well.

CONTROL LAW IMPLEMENTATION

- **LOW RISK** - **CAMS IS A *STABLE* CONTROL SYSTEM ADDITION THAT OPERATES AS A LIMITER ON THE AIRCRAFT'S NOMINAL CONTROL LAWS.**

- **EXHIBITS NO ADVERSE EFFECTS ON THE AIRCRAFT FLIGHT CHARACTERISTICS.**

- **DOES NOT INTERFERE WITH THE OPERATION OF THE BASIC AIRCRAFT FLIGHT CONTROL SYSTEM.**

- **CAPABILITY TO OVERRIDE OR DISENGAGE CAMS IS PROVIDED.**

CAMS CONTROL LAW MECHANIZATION

The desired implementation of the CAMS algorithm is shown in the figure below. Input to the CAMS control law requires sensor information, bleed rate (or P_s) level, and override commands from the cockpit. The output from the algorithm supplies a limit value on the nominal system control laws. This limit value may be a total tail command or a forward path error limit, either of which could be mechanized. For the Phase II study, a limit on the forward path error implemented. When the limit is exceeded by the nominal system, the nominal system set of feedbacks and commands are cut off which allows the CAMS control law to close the loop around the airframe. The system returns to normal operating state when the signal drops below the CAMS limit value.

CAMS CONTROL LAW MECHANIZATION
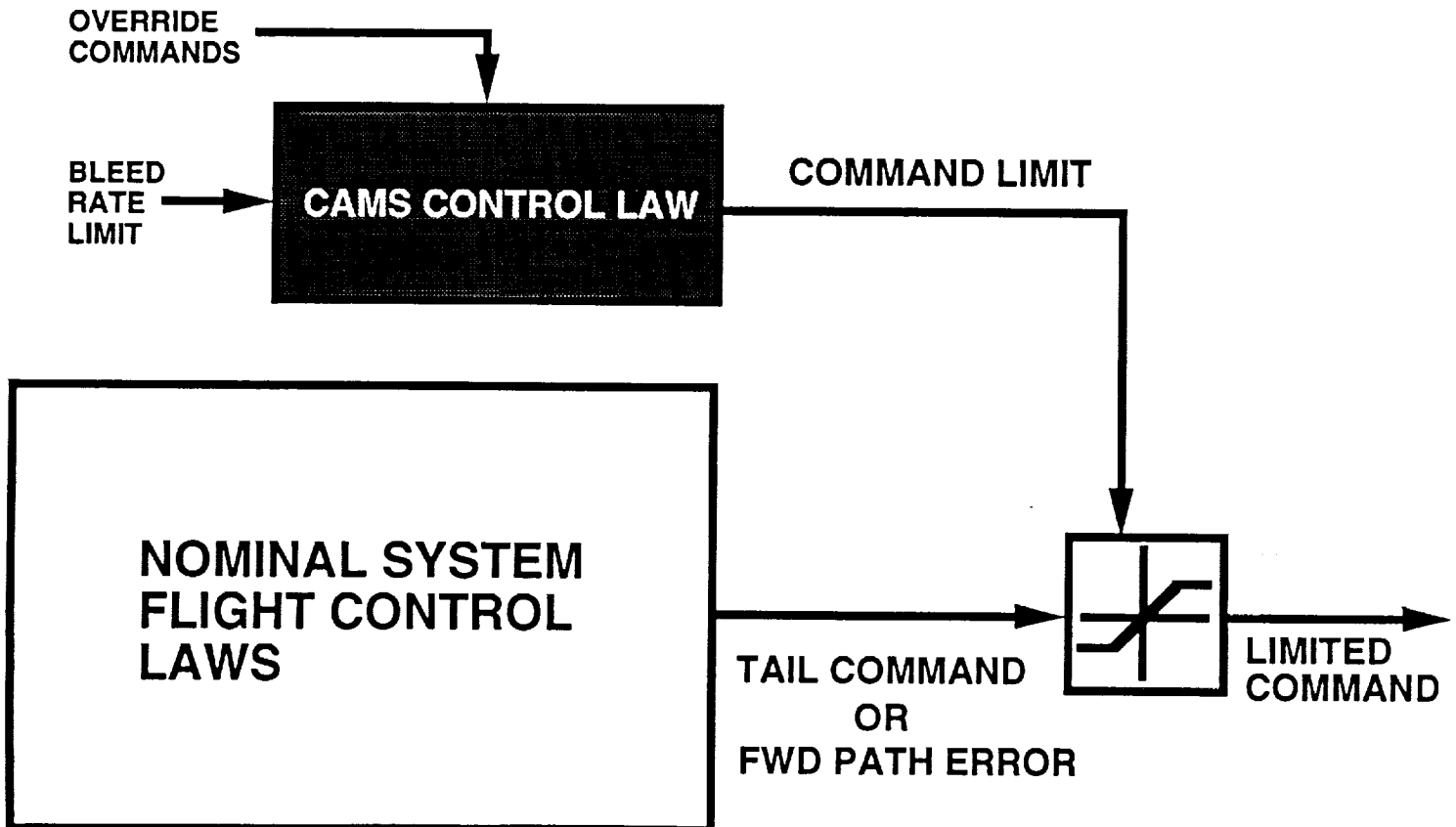
DESIGN APPROACHES CONSIDERED

The three types of limiters studied in the Phase II effort were designed and implemented in Eidetics F-18 simulator. It was found that the scheduled angle of attack limiter type, which does not directly control bleed rate or P_s, is non-adaptive to changes in atmospheric conditions, aircraft weight and cg, or changes in thrust level. The angle of attack limit is then based on off-line analysis for a fixed set of conditions. The implementation of this type of system may also require altering the nominal system flight control command path and/or feedback quantities.

The remaining two systems mentioned, direct P_s control and direct bleed rate control, are adaptive to changes in conditions. The system is implemented as a separate sub-system element that only acts as a limiter on the nominal flight control system. The P_s controller, however, does not modulate AOA with flight path orientation since P_s is a measure of applied forces on the vehicle only. The bleed rate controller, however, does modulate AOA with flight path orientation. As flight path increases, the AOA is commanded to lower values to hold a desired amount of bleed rate. In descending flight, the AOA command is increased.

E I D E T I C S

DESIGN APPROACHES CONSIDERED

- ## SCHEDULED ANGLE OF ATTACK LIMITER

  - DOES NOT DIRECTLY CONTROL BLEED RATE OR P_s.

  - NON-ADAPTIVE - BASED ON OFF-LINE ANALYSIS FOR A FIXED SET OF CONDITIONS.

  - BASIC SYSTEM COMMAND PATH AND/OR FEEDBACK QUANTITIES ARE ALTERED.

- ## DIRECT P_s CONTROL

  - IMPLEMENTED AS A SEPARATE SUB-SYSTEM CONTROL ALGORITHM.

  - ADAPTIVE CONTROL - LOOP CLOSURE ON P_s TO MODULATE AOA.

  - DOES NOT ALTER BASIC SYSTEM LOOP STRUCTURE.

  - DOES NOT ACCOUNT FOR CHANGES IN FLIGHT PATH ORIENTATION.

- ## DIRECT BLEED RATE CONTROL

  - IMPLEMENTED AS A SEPARATE SUB-SYSTEM CONTROL ALGORITHM.

  - ADAPTIVE CONTROL - LOOP CLOSURE ON BLEED RATE TO MODULATE AOA.

  - DOES NOT ALTER BASIC SYSTEM LOOP STRUCTURE.

  - ADAPTIVE TO FLIGHT PATH ORIENTATION.

PILOT-VEHICLE INTERFACE

A number of pilot-vehicle interface options were designed for evaluation in real-time combat simulations. These options consisted of the following:

- Override Options (switch locations and method of operation)
- Audio Cues
- Hud Symbology

Four different override options were explored to determine pilot preference and feasibility of implementation into an actual aircraft. Audio cues such as tones/voice call-outs and HUD symbology were incorporated as well. Subjective test data was gathered to determine the usefulness of these cues and displays.

PILOT-VEHICLE INTERFACE

- ## OVERRIDE OPTIONS

- ## CUES AND DISPLAYS

OVERRIDE OPTIONS

Four types of override options were mechanized in the simulation as follows:

- Two Position Toggle Switch
- Push-to-Override
- Push-to-Engage
- Latched Switch

The two position toggle was implemented as a select/de-select switch located in the center of the control stick. The switch when flipped in the "down" position overrode both the CAMS P_S (or bleed rate) and the AOA limit simultaneously. The switch in the "up" position engaged full operation of CAMS. The push-to-override version was implemented as two switches with CAMS being *engaged* as the default; the switch on the throttle overrode P_S only and the right button on the stick overrode both the P_S and the AOA limit.. The push-to-engage option also used the throttle and stick switches with CAMS being *disengaged* as the default; the throttle switch engaged the P_S limit only and the stick switch engaged the AOA limit only. Both the push-to-override and the push-to-engage options required the pilot to hold down the switches. With the latch switch version, CAMS was engaged by default. A momentary depression of the only the throttle switch disengaged a limit if on or approaching that limit (either P_S or AOA). A limit is re-engaged if either P_S or AOA drops some percentage below its respective limit. Both limits are re-engaged if the stick is displaced more than 80% forward as well.
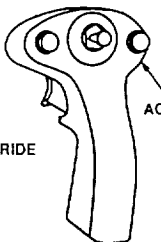
OVERRIDE OPTIONS
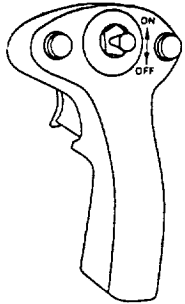
- ## TWO POSITION TOGGLE

  - SELECT / DE-SELECT TYPE.
  - OVERRIDES BOTH P_S AND AOA LIMITS SIMULTANEOUSLY.

- ## PUSH-TO-OVERRIDE

  AOA OVERRIDE
  P_S OVERRIDE

  - P_S AND AOA LIMITS ARE ENGAGED BY DEFAULT.
  - PUSH AND HOLD THROTTLE SWITCH TO OVERRIDE THE P_S LIMIT ONLY.
  - PUSH AND HOLD STICK SWITCH TO OVERRIDE BOTH P_S AND AOA LIMITS.

- ## PUSH-TO-ENGAGE

  PUSH AND HOLD TO ENGAGE AOA LIMITER
  PUSH AND HOLD TO ENGAGE P_S LIMITER
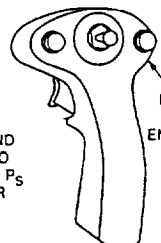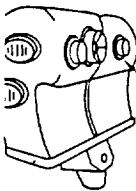
  - P_S AND AOA LIMITS ARE DISENGAGED BY DEFAULT.
  - PUSH AND HOLD THROTTLE SWITCH TO ENGAGE P_S LIMIT.
  - PUSH AND HOLD STICK SWITCH TO ENGAGE AOA LIMIT.

- ## LATCHED

  P_S /AOA LIMIT OVERRIDE
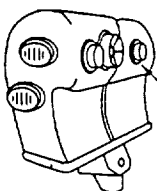
  - P_S AND AOA LIMITS ARE ENGAGED BY DEFAULT.
  - DEPRESS MOMENTARILY TO DISENGAGE A LIMIT IF ON OR APPROACHING THE LIMIT.

  - A LIMIT IS RE-ENGAGED IF EITHER P_S OR AOA FALLS BELOW ITS LIMIT.

  - BOTH LIMITS ARE RE-ENGAGED IF THE STICK IS DISPLACED MORE THAN 80% FORWARD.

CUES AND DISPLAYS

Aural cues were mechanized in the simulation. Tones were incorporated to indicate to the pilot that he was either approaching or riding on a CAMS limit. The following tones were incorporated as follows:

- Pulsing Low: Approaching a P_S limit.
- Steady Low: Riding a P_S limit.
- Pulsing High: Approaching AOA limit.
- Steady High: Riding AOA limit.
- No Tones: Post stall or well below CAMS limits.

Steady tones take precedence over the pulsing tones. AOA limit tones take precedence over the P_S tones.

CUES AND DISPLAYS

- ## AURAL CUES

    - ### CAMS LIMITER TONES:

        - **PULSING LOW: APPROACHING P_S LIMIT.**
        - **STEADY LOW: RIDING P_S LIMIT.**
        - **PULSING HIGH: APPROACHING AOA LIMIT.**
        - **STEADY HIGH: RIDING AOA LIMIT.**
        - **NO TONES: POST STALL OR WELL BELOW CAMS LIMITS.**

        - *STEADY TONES TAKE PRECEDENCE OVER PULSING TONES.*
        - *AOA TONES TAKE PRECEDENCE OVER P_S TONES.*

    - ### AIRSPEED CALLOUT:

        - **VOICE CALLOUT OF AIRSPEED IS COMMANDED FOR BLEED RATES GREATER THAN KNOTS/SEC.**

        - **AIRSPEED CALLOUT IS DONE IN 50 KNOT INTERVALS.**

The HUD symbology concept was drafted to allow pilots visual feedback as to how far they are from a CAMS limit. The symbology flashed to indicate when the pilot was "riding" on a limit. Characters and lines were minimized for easy addition to current air-to-air HUD combat displays.

The P_S bar was aligned on the throttle side of the display. The bar was normalized between zero and the selected bleed rate. If the pilot was riding on the limit, the P_S limit basket flashed and the pilot had to override the limit to allow greater bleed rate.

The AOA limiter symbol was centered around the aircraft velocity vector marker. For slowing approaching Alpha C_{LMAX}, a collapsing equilateral triangle was used which began as a straight line with rotating ends. As Alpha C_{LMAX} was approached, the triangle closed, and the triangle continued to flash as the pilot rode the limit.

E I D E T I C S

CUES AND DISPLAYS (cont.)

• HUD SYMBOLOGY
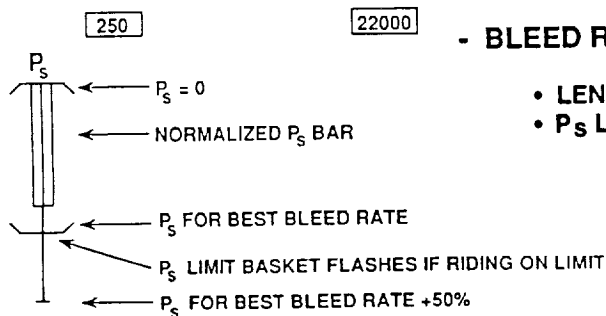
- BLEED RATE OR P_S ANALOG BAR

  • LENGTH OF BAR INDICATES HOW FAR FROM P_S LIMIT.
  • P_S LIMIT "BASKET" FLASHES TO INDICATE RIDING THE LIMIT.

$P_S = 0$

NORMALIZED P_S BAR

P_S FOR BEST BLEED RATE

P_S LIMIT BASKET FLASHES IF RIDING ON LIMIT

P_S FOR BEST BLEED RATE +50%

- AOA LIMITER SYMBOL

ASKET COLLAPSES TO A TRIANGLE AS MIT IS APPROACHED. TRIANGLE _ASHES IF RIDING ON LIMIT.

αC_L MAX
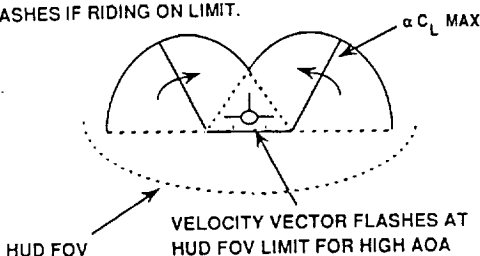
  • CLOSING TRIANGLE AROUND VELOCITY VECTOR INDICATES APPROACHING THE AOA LIMIT.

  • VELOCITY VECTOR AND TRIANGLE FLASHES WHEN RIDING THE AOA LIMIT.

HUD FOV

VELOCITY VECTOR FLASHES AT HUD FOV LIMIT FOR HIGH AOA

PVI EVALUATION

In order to determine and recommend an optimum PVI design and validate it for final implementation for final testing, many elements where considered in the analysis. The areas which were included in the analysis flow where, hardware availability in a typical operational fighter aircraft, human factors considerations which involved pros and cons of the PVI options, subjective data which included pilot questionnaires and pilot comments, and finally objective data which showed combat performance of each option.

The hardware availability portion of the analysis consisted of reviewing different flight manuals and talking to operational pilots to get recommendations. Consideration was given to unused or scarcely used switches which do not to interfere with any systems operations, and the use of a switch where mistaken identity is less likely to occur. The F-18 was chosen as a good example of a current fighter with a typical set of complicated switchology, to be used for comparison with the CAMS PVI options tested. A switch on the throttle, the "Raid" switch, is rarely used in close-in combat, is the best candidate for override implementation .

In conclusion of the PVI test the Latched PVI system was determined as the overall best compromise based on hardware availability, pilot comments and combat performance.
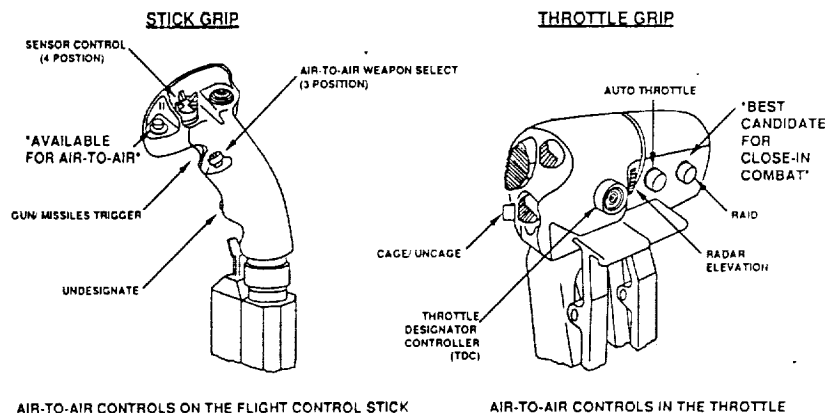
PVI EVALUATION

CONSIDERATIONS

- HARDWARE AVAILABILITY
- HUMAN FACTORS - PROS AND CONS OF PVI TYPE
- SUBJECTIVE DATA - PILOT QUESTIONNAIRES
- OBJECTIVE DATA - COMBAT PERFORMANCE

STUDY RESULTS

- LATCH TYPE OVERRIDE AS THE BEST CANDIDATE.

- "RAID" SWITCH ON THROTTLE GRIP OR LEFT BUTTON ON STICK AS AVAILABLE SWITCH LOCATIONS FOR OVERRIDE ON THE F-18.

STICK GRIP

SENSOR CONTROL (4 POSTION)

AIR-TO-AIR WEAPON SELECT (3 POSITION)

"AVAILABLE FOR AIR-TO-AIR"

GUN/ MISSILES TRIGGER

UNDESIGNATE

THROTTLE GRIP

AUTO THROTTLE

"BEST CANDIDATE FOR CLOSE-IN COMBAT"

RAID

CAGE/ UNCAGE

RADAR ELEVATION

THROTTLE DESIGNATOR CONTROLLER (TDC)

AIR-TO-AIR CONTROLS ON THE FLIGHT CONTROL STICK

AIR-TO-AIR CONTROLS IN THE THROTTLE

GROUND BASED SIMULATOR TESTING

Three ground based simulator tests were performed in order to measure the combat effectiveness of CAMS. The tests were run against a digital adversary with identical aerodynamic and thrust performance as the F-18 but did not have CAMS. The principle reason for using the digital adversary was that it provided a stable opponent, free from variability and performance errors. In order to keep the pilots from repeating the same behavior every trial, the starting conditions were varied from trial to trial. The following tests were done:

    1) PVI Test: Evaluated each PVI option and effectiveness of cues/displays.
    2) Limiter Test: Evaluated three limiter types optimized for the type of scenarios flown.
    3) Preferred Concept: Tested candidates from 1) and 2) to determine combat effectiveness.

The combat effectiveness of CAMS was then determined by collecting subjective data (questionnaires) and objective data (wins & losses).

GROUND BASED SIMULATOR TESTING

1)   **PVI TEST - 1 v 1**

- **450 TRIALS WITH 3 PILOTS AND 5 CONFIGURATIONS**
  - BASELINE F-18
  - 2 POSITION TOGGLE
  - PUSH-TO-OVERRIDE
  - PUSH-TO-ENGAGE
  - LATCH

2)   **LIMITER TEST - 1 v 1**

- **288 TRIALS WITH 2 PILOTS AND 4 CONFIGURATIONS**
  - BASELINE F-18
  - HARD AOA LIMIT
  - P_S LIMIT
  - BLEED RATE (VTDOT) LIMIT

3)   **PREFERRED CONCEPT TEST - 1 v 2**

- **270 TRIALS WITH 3 PILOTS AND 3 CONFIGURATIONS**
  - BASELINE F-18
  - CAMS WITH OVERRIDE
  - CAMS WITH NO OVERRIDE

CURRENT STATUS

The CAMS system has been shown, by conducting many piloted simulator runs with F-16 and F/A-18 aircraft, to significantly enhance combat effectiveness when properly used. These simulator studies showed that one of the key ingredients to the success of CAMS is pilot acceptance of a bleed rate limiter and, also, the choice of the proper Pilot/Vehicle interface, or "switchology" to set and override the limiter. The Phase II simulation work is complete and shows strong evidence that CAMS is a technology that has great potential benefits. The planned flight validation effort on the F-18 HARV is a necessary next step to provide the confidence to seriously consider the application of the technology to future aircraft. Combat maneuvers defined from simulation studies will be flown by HARV with and without the CAMS system operational, and an evaluation will be made to assess the benefits of CAMS for a typical combat scenario.

EIDETIC

CURRENT STATUS

1) GROUND BASED SIMULATOR RESULTS - COMPLETE (SBIR II)

2) EXPLORATORY FLIGHT TESTS WITH F-18 HARV - FALL 1994

DRYDEN CONTRACT TO EIDETICS

OBJECTIVE

DEMONSTRATE/VALIDATE THE SBIR II "CAMS" SIMULATION RESULTS - SHOW POTENTIAL FOR LOW-RISK APPLICATION TO FUTURE (OR PRESENT) FIGHTER AIRCRAFT

APPROACH

INCORPORATE CAMS SYSTEM LOGIC INTO HARV'S RESEARCH FLIGHT CONTROL SYSTEM (RFCS)

USE EIDETICS VIRTUAL DOME SIMULATOR (ARENA) TO SELECT SPECIFIC COMBAT-TYPE MANEUVERS TO BE FLOWN WITH HARV

COMPARE ABILITY TO PERFORM SPECIFIC FLIGHT TASKS WITH AND WITHOUT CAMS IN OPERATION

ASSESS THE ADVANTAGES (DISADVANTAGES) OF CAMS FOR AIR COMBAT - HEAVY RELIANCE ON PILOT COMMENTS AND ASSESSMENTS

POTENTIAL FUTURE APPLICATIONS

Potential application of CAMS on near-future fighter aircraft include the F-22 and F-18 E/F, and, in the more distant future, JAST. It can also be considered for application to existing fighter aircraft through modest changes to existing flight control systems. The workload for modern fighter pilots is not decreasing. The continuing addition of more information to assimilate and process in the heat of combat is taxing the ability of most modern pilots to keep up. For the inexperienced pilot, in particular, one of the major and most important task, of course, is keeping tabs on his energy state. Getting too slow while maneuvering can be very high risk. CAMS provides a means to manage aircraft energy efficiently, while, at the same time, does not impose hard angle of attack limits.

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POTENTIAL FUTURE APPLICATIONS

F-22

F-18 E/F

JAST

PRESENT FIGHTER A/C

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The goal of the Fourth High Alpha Conference, held at the NASA Dryden Flight Research Center on July 12–14, 1994, was to focus on the flight validation of high angle-of-attack technologies and provide an in-depth review of the latest high angle-of-attack activities. Areas that were covered include, high angle-of-attack aerodynamics, propulsion and inlet dynamics, thrust vectoring, control laws and handling qualities, tactical utility, and forebody controls.

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