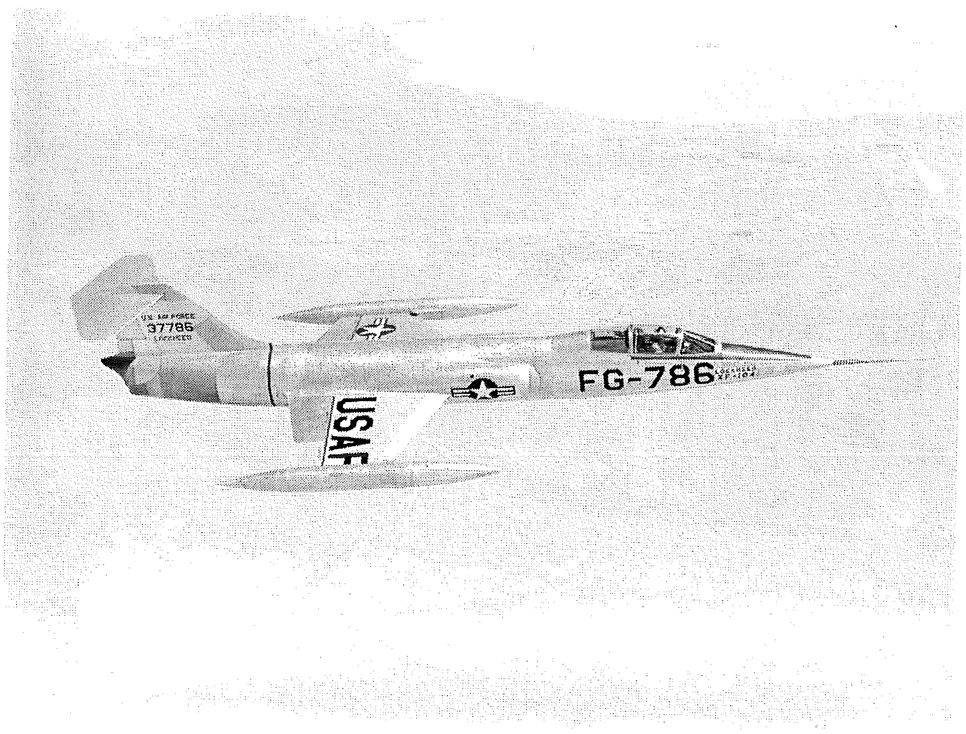
The SURE Project



Lecture – 10/10

STARFIGHTER UTILIZATION RELIABILITY EFFORT

LECTURE 10

A

RECOMMENDED METHOD

FOR

PILOTING

AERODYNAMICALLY CONTROLLED

FIXED WING

VEHICLES

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FOREWORD

I guess it's standard procedure that if you survive a lengthy flying career, you look back and wonder, "What did I do right?"- especially if it's a lengthy flying career in fighter aircraft. In the front of Lockheed Report CA/ME/2301, I wrote the SURE motto, "Knowledge + Experience + Luck = Mission Effectiveness with Flight Safety". In writing the nine previous SURE Lectures, I attempted to pass onto you all the knowledge that I had gained from test flying the Zip for over 17 years. With this 10th and final SURE Lecture, I want to pass onto you my basic concepts of Aircraft handling that I have learned from my experiences during a 26 year career in fighter aviation. To my knowledge, a formalized presentation, such as this Lecture, has not been presented on the decision process for flying aerodynamically controlled fixed wing vehicles. To fill that void, I have once again taken pen in hand and cranked up the thinking helmet. It has been said that learning from experience is the school of hard knocks, but when the chips are down, I can assure you that nothing stands by you so strong and firm as experience. If you want to learn from my experiences, Ace, and not your own hard knocks, I suggest that you read and study this SURE Lecture.

Definitions; Symbols; Aircraft Control Concepts

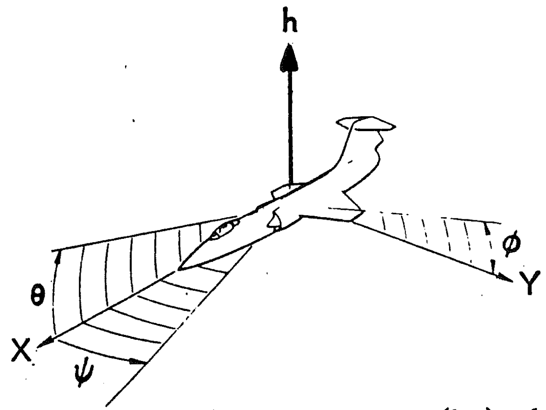
We shall utilize the basic flight control indications of Airspeed, Attitude, and Altitude in this Lecture. Their definitions and symbols are:

1. Airspeed: The speed that the aircraft is traveling relative to its surrounding airmass. For our purposes, we will consider only V_i or indicated airspeed. During the takeoff roll and the post touchdown rollout, this can be considered as the groundspeed of the aircraft.

2. Attitude: The attitude of the aircraft in pitch, bank and yaw, i.e.,
   a. Pitch Angle (θ): Position of the nose of the aircraft (degrees up or down) relative to the horizon.
   b. Bank Angle (ϕ): Position of the wings of the aircraft (degrees up or down) relative to the horizon.
   c. Yaw Angle (ψ): Position of the nose of the aircraft (degrees right or left) relative to an initial heading on the horizon.

A look at our drawing shows the pictorial display of θ, ϕ and ψ.

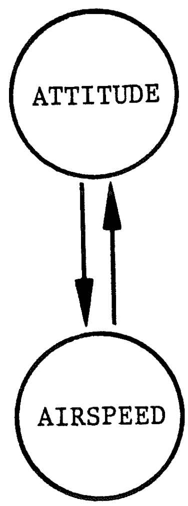
Three-dimensional Coordinate System



3. Altitude: The pressure altitude (h_p) above sea level.

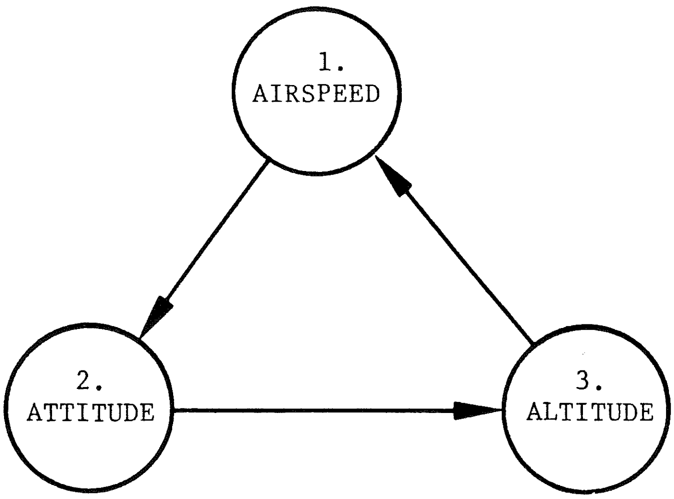
There are two distinct realms of aircraft control, i.e., "on the ground"" and "in the sky".

Excluding the taxiing phase, aircraft control "on the ground" consists of the takeoff roll to liftoff and the post touchdown rollout to aircraft stop. During these "on the ground" phases, aircraft control is based on the following concept:



The control decision process is guided by the inputs of attitude and airspeed as shown. The attitude (ψ, aircraft heading and θ) is primary with Airspeed (V_i) correlated but secondary. This Double A control method is a continuous loop decision process utilized for "on the ground" control.

For "in the sky", aircraft control is based on the following concept:



The Airspeed - Attitude - Altitude concept, or Triple A method of piloting is a continuous loop decision process that operates in a triangular pattern as shown. This continuous loop decision process is utilized for <u>all</u> phases of "in the sky" control in the following manner:

1. Airspeed - The primary, driving indicator.
2. Attitude - A correlated indication but secondary to airspeed.
3. Altitude - The third correlated indicator that finalizes the control decision.

By continuously assimilating the Triple A indications, the pilot's control decisions result in smooth, precise piloting of the aircraft.

Now, let's go through a flight profile and examine the use of our control concepts.

I. AIRCRAFT CONTROL- ON THE GROUND

A. Takeoff Roll to Liftoff:

1. Description: The aircraft accelerates along a controlled groundroll path down the runway until nose rotation speed is attained and then the aircraft rotates nose up. When the aircraft's combination of Attitude (θ) and groundspeed (V_i) generates enough lift, the aircraft flies off the runway.

2. Pilot Tasks: At the start of the takeoff roll, the pilot uses aircraft controls to maintain the proper groundroll path (ψ, yaw angle attitude). While maintaining the proper groundroll path, the pilot ascertains that the aircraft is accelerating normally. Following the aircraft acceleration check (dV_i/dt), the pilot then rotates the aircraft nose up at the proper rotation speed (V_i). By sensing the aircraft's acceleration (dV_i/dt), the pilot's control inputs for nose up movement results in the correct liftoff attitude (ψ and θ) being achieved simultaneously with the correct liftoff speed (V_i).

3. Conclusion: Up to the rotation point, aircraft attitude (ψ , heading) is paramount with groundspeed

(V_i) correlated but secondary. Then, aircraft attitude (ψ and θ) are blended with liftoff speed (V_i) to achieve flight.

II. AIRCRAFT CONTROL - IN THE SKY

A. Liftoff:

1. Description: At the instant of entering the realm of flight, the aircraft responds to all aerodynamic forces and aircraft control inputs around the aircraft's aerodynamic center of gravity (C. G.). This is the distinct shifting point from Double A "on the ground" to the "in the sky" Triple A control method.

2. Pilot Tasks: At liftoff, the pilot raises the landing gear. As the aircraft accelerates, the pilot monitors the airspeed (V_i) while maintaining the proper aircraft attitude (θ, ϕ and ψ). At the correct airspeed (V_i), the pilot raises the flaps (if used). When climb airspeed (V_i) is attained, the pilot adjusts the attitude (θ) to initiate the climb phase.

3. Conclusion: Immediately upon becoming airborne, the

Triple A continuous closed loop decision process takes effect.

B. Climb Out:

1. Description: The aircraft climbs on a schedule for maximum climb efficiency until reaching its cruise altitude.

2. Pilot Tasks: With climb power, the pilot maintains scheduled airspeed (V_i) by varying the pitch attitude (θ) until reaching the cruise altitude (h_p).

3. Conclusion: The airspeed (V_i), attitude (θ, ϕ, and ψ) and altitude (h_p) are monitored and the airspeed (V_i) and attitude (θ) are adjusted during the climb-out in order to follow the required climb schedule.

C. Acrobatics:

1. Description: The aircraft departs from a straight and level flight path and proceeds to create two-dimensional and three-dimensional contours in the sky. The contours are defined by tracing the flight path of the aircraft. The contour is completed when the aircraft returns to a straight and level flight path.

2. Pilot Tasks: Prior to starting on any acrobatic contour, the pilot must be positive of the following:

(a) Airspeed (V_i): The aircraft must have the exact initial airspeed in order to fly the correct contour. Too fast an airspeed and the contour will become stretched. Too slow an airspeed and the aircraft may not complete the planned contour and will probably depart on an unplanned contour.

(b) Attitude (θ, ϕ, ψ): The aircraft should be flying so that $\theta = 0^o$, $\phi = 0^o$ and $\psi = 0^o$. Only by starting from this initial flight attitude can the entire acrobatic contour be realized.

(c) Altitude (h_p): The aircraft should have adequate initial altitude to take into account any section of the acrobatic contour that will be below the initial altitude of the aircraft. During acrobatics where the initial aircraft altitude and the local terrain altitude are approximately equal, the pilot must ensure that adequate altitude clearance exists for the acrobatic contour.

After initiating the maneuver, the pilot checks the aircraft's airspeed (V_i), attitude (θ, ϕ, ψ) and altitude (h_p) at critical points during the acrobatic contour.

3. Conclusion: The Triple A control method will fly you safely throughout all acrobatic contours.

D. Instrument Flight:

1. Description: The aircraft is flown solely by reference to cockpit instrumentation.

2. Pilot Tasks: The pilot flies the aircraft without the use of a horizon or a view of the local terrain. Therefore, the pilot relies solely on his cockpit instruments for climb, cruise, letdown, approach and landing.

3. Conclusion: The Triple A control method yields positive basic control of the aircraft during instrument flying. By assuring yourself of the basic control of the aircraft, you are in total command of the situation. Therefore, you are in the best position to control the other required phases of instrument flight i.e., departure clearance, route clearance, approach clearance and landing clearance.

E. Weapons Delivery:

Air-to-Ground

1. Description: The aircraft flies along a pre-calculated flight path and at a certain point, the weapon is fired, launched or released.

2. Pilot Tasks: The pilot flies the aircraft along the weapons delivery flight path and at an exact airspeed (V_i) attitude (θ, ϕ, ψ) and altitude (h_p) above

the target, the pilot fires, launches or releases the weapon. For unguided, ballistic weapons, i.e., iron bombs, the more exact the point of release, the closer to the target will be the impact point.

3. Conclusion: Airspeed (V_i), attitude (θ, ϕ, ψ) and altitude (h_p) are the paramount indicators that you must monitor and adjust during air-to-ground weapons delivery.

<u>Air-to-Air</u>

1. Description: The aircraft is maneuvered until it is in a lethal firing or launch position and then the weapon is fired or launched.

2. Pilot Tasks: The pilot maneuvers the aircraft while closing on the target until the target is within launch or firing range of the weapon. Once these conditions are met, the pilot sights for the weapon (if required) and then fires or launches the weapon. It should be noted that launch and firing envelopes for missiles are bounded by airspeed, altitude, acceleration parameters and seeker head look angles.

3. Conclusion: In the dynamic realm of Air Combat Maneuvering (ACM), the aircraft's airspeed (V_i), attitude (θ, ϕ, ψ) and altitude (h_p) are directly dictated by the positioning of the target. The aircraft's airspeed capability is used for overtake of the target. The aircraft's maneuverability is used to attain an attack attitude on the target. The aircraft's altitude vis-a-vis

the target's altitude is the determinate factor in the type of attack maneuver to be flown.

F. Letdown:

1. Description: The aircraft descends on an approved, published flight path at recommended airspeeds and crosses designated geographical points at specified altitudes until the aircraft intersects the final approach path.

2. Pilot Tasks: The pilot flies the aircraft at Letdown airspeeds (V_i) while maintaining the proper attitude (θ, ϕ, ψ) so that the flight path and the altitude (h_p) are correct at the checkpoints.

3. Conclusion: The airspeed (V_i), attitude (θ, ϕ, ψ) and altitude (h_p) are your guiding indicators during the letdown.

G. Approach:

1. Description: The aircraft flies down a fixed glide path until it reaches the flare point above the end of the runway

2. Pilot Tasks: The pilot flies the aircraft at a constant airspeed (V_i) while adjusting the attitude (θ, ϕ, ψ) and maintaining a constant loss of altitude (dh_p/dt) along the fixed glide path to the flare point.

3. Conclusion: Since the fixed glide path tolerates only a small amount of deviation which decreases the closer the aircraft approaches to the flare point, the Triple A control method will fly you down the glide path smoothly and with the minimum amount of deviation.

H. Landing (Flare/Touchdown):

1. Description: At the flare point, the aircraft flares and smoothly loses its lift so that the aircraft touches down gently on the runway.

2. Pilot Tasks: The pilot flies the aircraft so that its airspeed (V_i) decreases toward the stall speed while flaring the aircraft to a nose up attitude (θ). At the same time, the pilot maintains the runway heading (ψ, yaw angle attitude) while simultaneously the aircraft altitude (h_p) gently lowers until the main landing gear wheels touch the runway.

3. Conclusion: The landing is the most exacting maneuver you have to fly. You must match an exact airspeed (V_i) with an exact attitude (θ, ϕ, ψ) at an exact altitude (h_p) while positioning the aircraft to a precise point in space; the touchdown point on the runway. For grease jobs, Ace - use Triple A!

III. AIRCRAFT CONTROL - ON THE GROUND

A. Post Touchdown Rollout:

1. Description: After the main landing gear wheels settle onto the runway, the nosegear of the aircraft comes down onto the runway and the aircraft decelerates along a controlled groundroll path to a stop. At the moment that the main landing gear wheels settle

onto the runway the shift is made from "in the sky" control method to "on the ground".

2. Pilot Tasks: As the main landing gear wheels contact the runway, the pilot uses aircraft controls to maintain the proper groundroll path (ψ, yaw angle attitude). While maintaining the proper groundroll path, the pilot slows the groundspeed (V_i) until the aircraft is stopped.

3. Conclusion: Attitude (ψ, yaw angle) keeps the aircraft on the runway while decelerating (dV_i/dt) to a stop.

IV. UTILIZATION OF DOUBLE A AND TRIPLE A

A. Standardized Instruction: I am aware that the word standardization is anathema to some pilots. But in this case, I believe the benefits would be immediate and enduring. If all future student pilots were taught the principles of control decision for "on the ground" and "in the sky", the advantages would be:

- Instructor's workload would be simplified.
- Instructor would have standardized base for judging the student pilot's progress.
- Instructor assignment change would have minimum impact upon student pilot's progress.
- Student pilot would receive training in pilot skills that would be applicable throughout his entire flying career.

The Double A and Triple A standardization could encompass:

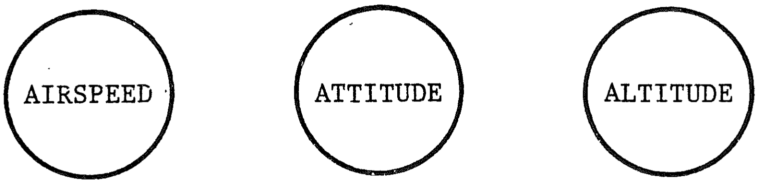
- Classroom presentations
- Study aids
- Handout materials

- Simulator work
- Flight briefings
- In-flight instructions
- Debriefings

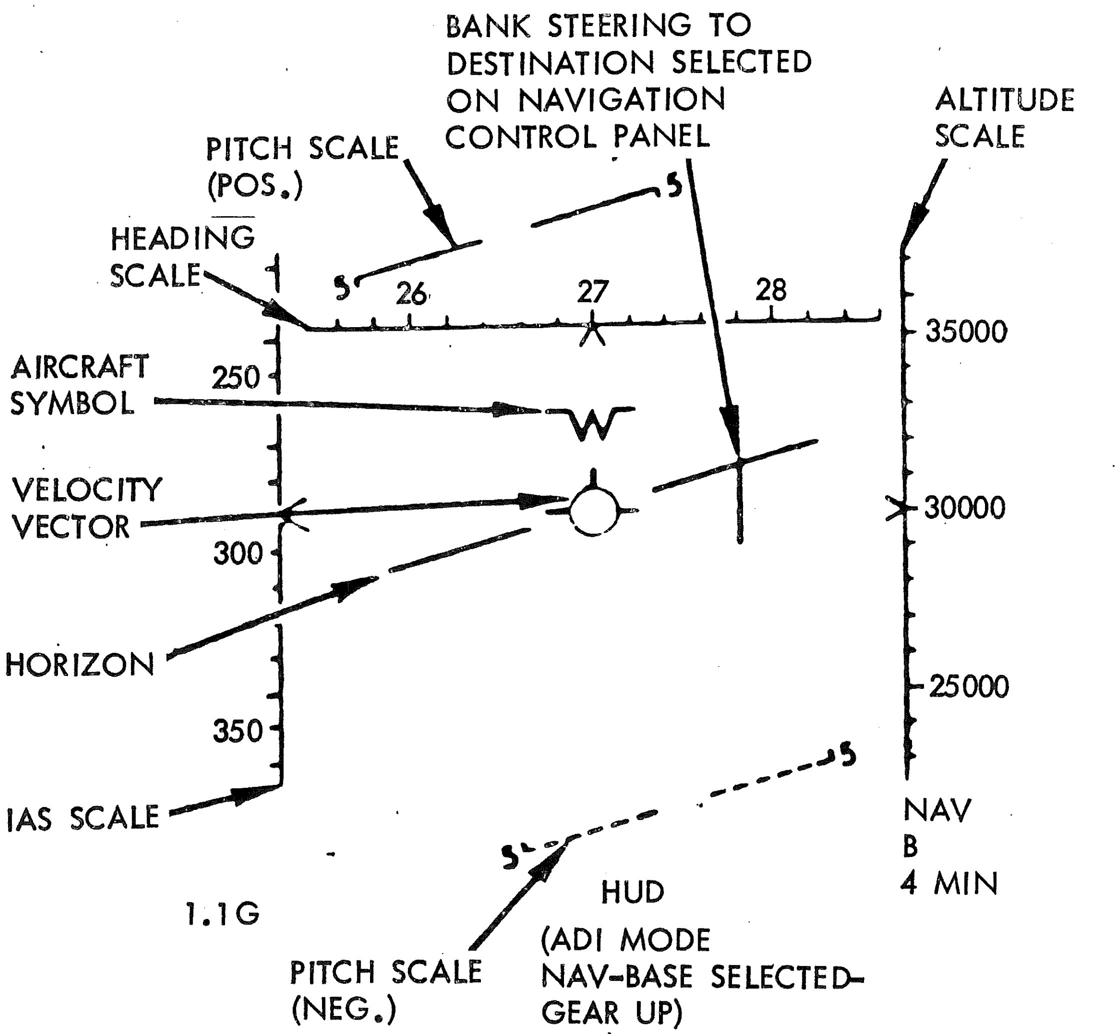
B. Standardized Instrumentation: In conjunction with the standardized instruction of the Double A and Triple A control method is the desirability of matching instrumentation. An inspection of late model USAF fighter aircraft, i.e., the F-15A and F-16A reveals the following:

Basic Cockpit Instrumentation

F-15A/F-16A

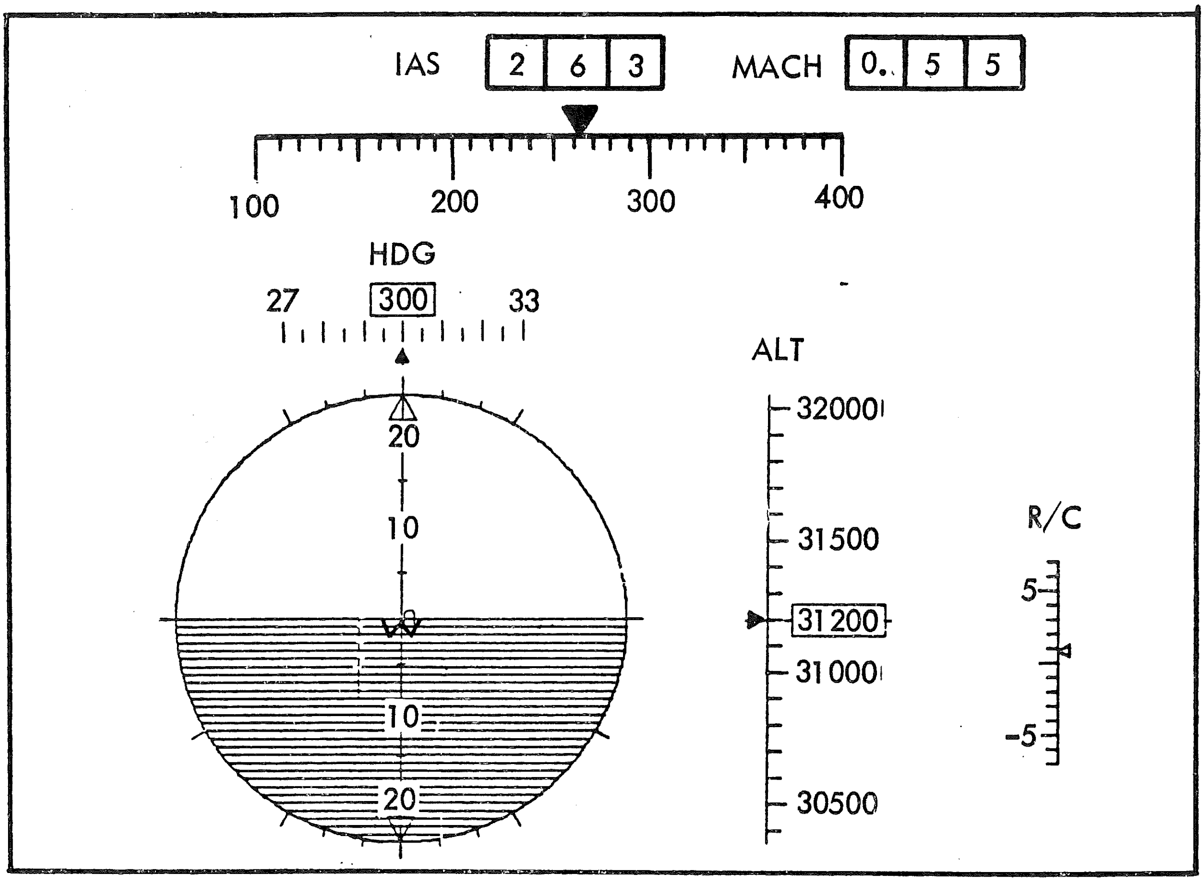


Here we find the Double A and Triple A instrumentation grouped together. An even better grouping can be found on the Head Up Display (HUD) of the F-15A.



This grouping satisfies the Double A and Triple A control method very well.

Since Cathode Ray Tube (CRT) displays are the wave of the future, I would like to see future aircraft with this instrumentation grouping.



This grouping would ideally satisfy the Double A and Triple A control method instrumentation requirements.

V. DOUBLE A AND TRIPLE A ADVANTAGES/RESULTS

If the "on the ground" and "in the sky" continuous loop decision control process and the appropriate instrumentation were to become Standardized throughout the aerospace profession, I believe the following advantages would accrue:

- A standardized, consistency of instruction could be schieved.
- The student pilot could more quickly master the skills of flight.
- The cockpit position where the pilot looks to perceive critical flight data would be more centralized and localized.
- The interpretation of basic flight instrumentation would become more simplified.

These advantages would cause the following results to occur:

- An increased safety in aircraft operations
- A corresponding decrease in aviation accidents