Group 3: High-Angle-of-Attack Criteria

Present at this working session were a dozen people, half of whom were from the DoD. The constitution of the group led to little controversy; the numbness of the participants led not so much to consensus as to individual ideas and statements of fact. Therefore the proceedings which follow should only be taken as individual ideas that were raised or commentary on problems.

The first point made was that wind tunnel aerodynamic data needs to be more accurate at high angles of attack (AOA). This would help identify problems in the simulation stage of development. Problems were encountered with this imprecision in the F-16 development.

Probably the most significant part of the session was learning some facts about the F-16 from Mr. Bailey of General Dynamics. A summary of his comments is provided here. The flight control system (FCS) of the F-16 is quad-redundant, fail-safe, fail-operational, analog fly-by-wire. It limits AOA in symmetric flight to 25.5 degrees. At AOA above 29 degrees (in the range where departures and spins can occur), the pilot is taken out of the control loop and anti-spin controls are driven by yaw rate. At negative AOA, the rudder was found to be effective; therefore the yaw damper was considered to be enough augmentation and AOA limiting unnecessary. Angle-of-attack sensors are triple redundant; the FCS selects the middle value. True AOA (in degrees) is displayed in the cockpit. Sideslip is measured but used only in the fire control system. It is realized that any AOA limits can be defeated by a maneuver such as a vertical zoom. Nevertheless,

AOA limiting is relied upon to prevent F-16 loss of control. The extent of its flight demonstration program is still being debated.

The stability and control requirement that was found to be critical in terms of FCS design modifications is unique to that airplane: at load factors of from zero to 0.8 n_L, down to 100 knots airspeed and up to limit AOA, freedom from any departure tendency or undesirable oscillation must be demonstrated in 360-degree rolls. The difficulty encountered with this was the tendency of the basic airplane to pitch up due to inertial coupling at high roll rates. At maximum roll rates the elevator would saturate, allowing the aircraft to depart. Since the test pilots insisted on the validity of this requirement, protests against it were overruled. Although finding a fix was feared extremely difficult if not impossible, one was found. It involves limiting the commandable roll rate to 80% of maximum available at these critical high-AOA conditions. Maximum sideslip generated in this maneuver now amounts to only seven degrees.

Mr. Choo of Northrop was proud of the fact that the F-5 has such good airframe stability that at high AOA they simply turn off the stability augmentation system.

Ken Johnson of ASD (a major contributor to this session) summarized experience with the A-10 stall/spin test program. Departure recovery was emphasized, he said, but still all areas of the stall/spin regime were tested. MIL-S-83691 worked well for them in this respect. Bowman's (NASA Langley) control block served well for spin entry. Johnson commented that there is a lot of data on tape at Edwards if someone were interested in asking the SPO for it.

Don Johnston described STI's upcoming (December 1978) simulation being sponsored by AFFDL and NADC at MACAIR. Some of the maneuvers that will be performed involve closed-loop tasks (such as maintaining pitch attitude) at stall; some cases of instability have been found with stable aircraft when a pilot attempts closed-loop control; coupling of lateral-directional motion with longitudinal is involved. He then described the rating scale that STI has developed for use when the Cooper-Harper scale would yield a ten. STI will be conducting a high-AOA survey of government and industry shortly under AFFDL contract.

The balance of this session report will consist of ideas or comments raised at different points in the discussion.

a. Mr. Jenny of McDonnell suggested adding a requirement to consider departures from abrupt pushovers to large negative AOA.

b. Any airplane can be made to depart by simply running out of airspeed.

c. A required limit on allowable sideslip angle was discussed, but was countered by the need for fuselage aiming. This is a new development; its value at very high AOA has yet to be demonstrated in flight.

d. There is no stated requirement for transient turning ability except in terms of limit load factor and roll performance in response to stick or wheel commands. These can be limited by elevator or rudder power.

e. The technique of unloading g's before rolling was discussed . In any case it seems unsafe to rely on a pilot's doing this for departure prevention.

f. On proposed paragraph 3.4.11 <u>Control Margin</u>, we agreed on the difficulty of stating a requirement of sufficient impact and generality without being unduly restrictive or impossible to meet literally. Tailoring to individual procurements was suggested, but concrete suggestions for solution did not emerge.

g. Why not include simple requirements such as positive C_{n_β}DYNAMIC (does not include nonlinear or FCS effects) or control authority (directional: enough rudder power to counter a given sideslip; longitudinal: enough elevator power to cancel a given pitch rate) within an aircraft's AOA envelope? These have a place as design criteria but we are required to write specifications in terms of performance rather than descriptive parameters.

h. Why not have a minimum approach speed requirement? Traditionally, this has been left to the aerodynamic performance specification. But stall margin is a valid flying qualities parameter in terms of speed regulation, maneuvering, and gust tolerance. The AMST flying qualities specification contains such considerations.

i. Departure must be prevented; during the approach and landing it does no good to specify recoverability.

j. Based on his F-15 and F-16 experience, Skip Hickey of ASD would like a general requirement for 360-degree fighter roll capability at load factors up to at least 3g.

k. A high-AOA capability is beneficial for quick decelerations

in an air combat maneuver. Good examples are the F-14 and T-38/F-5.

We hope to gather many more ideas such as these to evaluate

for the MIL-PRIME-Standard.

ROBERT J. WOODCOCK   ROBERT B. CROMBIE,1LT, USAF
Moderator   Recorder

Attendance

High-Angle-of-Attack Criteria Session

R.J. Woodcock, AFFDL/FGC, Moderator
C.C. Bailey, General Dynamics/Ft. Worth
D.K. Bowser, AFFDL/FGC
L.W. Brown, NASA/Langley
D.K. Choo, Northrop Aircraft
J.T. Clay, Beech Aircraft
G.K. Hellmann, AFFDL/FGC
R.B. Jenny, McDonnell Douglas/St. Louis
K.L. Johnson, ASD/ENFTC
D.E. Johnston, Systems Technology, Inc.
J.M. Stifel, NADC
R.B. Crombie, AFFDL/FGC, Recorder

REMARKS
R.J. Woodcock, AFFDL/FGC

A. FLIGHT TEST

Available flight test time never has been sufficient for specific demonstration of compliance with every requirement of the flying qualities specification. Further, the trend is to increased cost and increased emphasis on operational-type flying at the expense of demonstrating specification compliance. Thus we must rely increasingly on analysis and simulation, plus flight test techniques such as Twisdale's SIFT. Section 4 of 8785B provides for callout, for each procurement, of the means for demonstrating compliance at each stage of development: analysis, simulation, test.

B. CONTROL MARGIN

I would like to share with you an example from a few years back of the need to assure adequate control authority in an unstable vehicle. After losing a number of aircraft through failure to recover from inverted flight, Mervyn O'Gorman, then head of the Royal Aircraft establishment, led an investigation. Their conclusion is apparent in these two figures. Note the date: January 1919. Relaxed static stability is not a new concept.

C. TURN COORDINATION

The stability-axis side-force equation is

$$n_y = \frac{Y}{mg} = \frac{1}{g} Ur - \cos \theta \, \sin \phi$$

or

$$r = \frac{g}{V_R \cos \beta} (\cos \theta \, \sin \phi + n_y)$$

In near-level flight, for tolerable β we have $\cos \theta$ and $\cos \beta$ approximately 1. Thus it is apparent that $n_y = 0$ and $r = g \sin \phi / V_R$ are entirely equivalent definitions of turn coordination. But, as pointed out yesterday, $\beta = 0$ can be a significantly different thing at low speed.

Also, since in a steady turn about a vertical axis

$$r = \dot{\psi} \cos \theta \, \cos \phi$$

we have

$$\dot{\psi} = \frac{g}{V_R \cos \beta} (\tan \phi + \frac{n_y}{\cos \theta \, \cos \phi})$$

showing two different concepts of turning. Wings-level skidding

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was used before the Wright brothers invented bank-to-turn, and it's once again being considered as an application of direct force control.

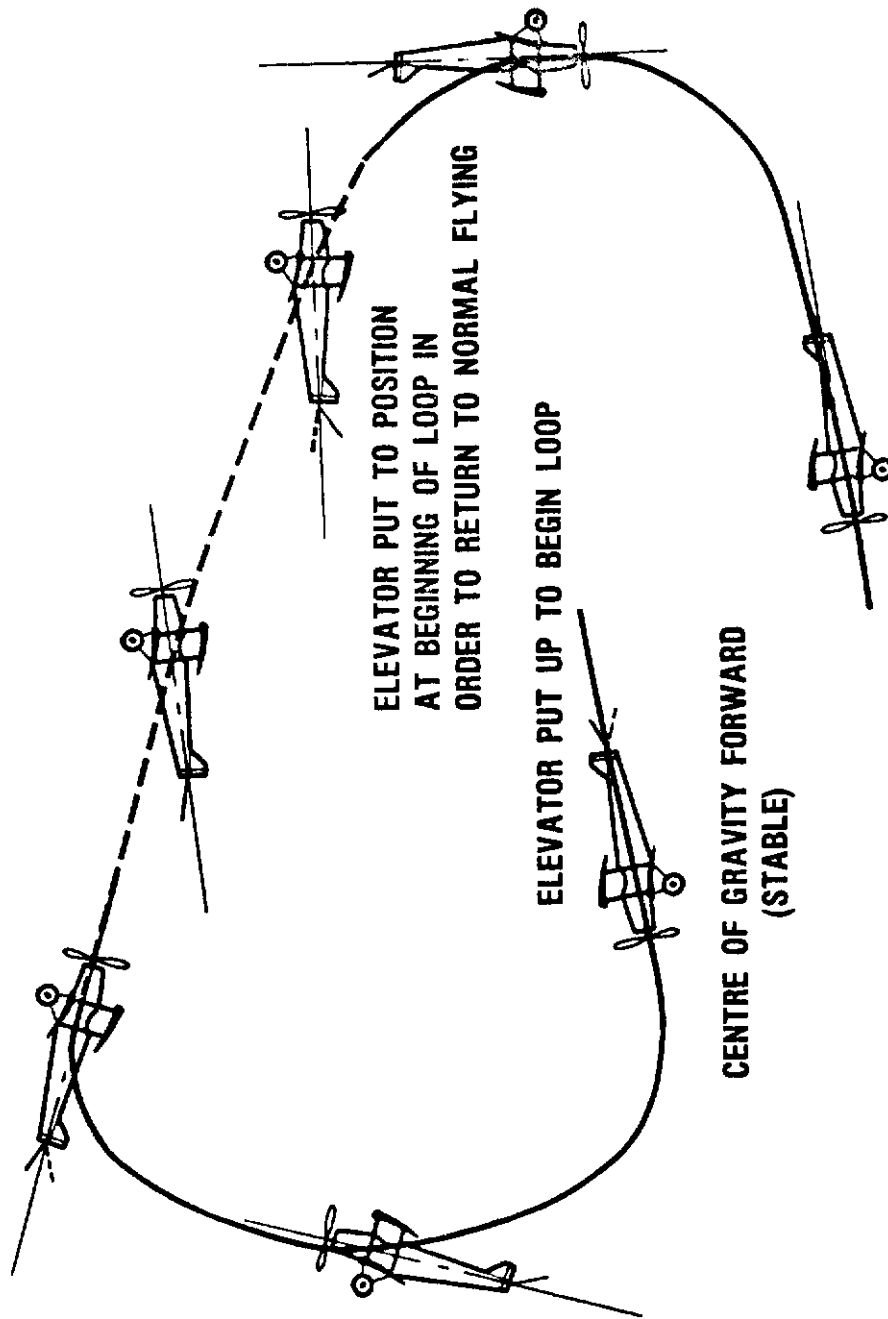D. THE CALSPAN DUTCH ROLL RECOMMENDATIONS

I must confess to being one of those who are confused - as Chick Chalk said yesterday can easily happen - by the graphs and charts in the back of AFFDL TR 72-41. After trying my best to sort out the applicable data points, I fail to see that the Calspan proposal fits the data any better than the present requirements do.

Now, there may be some merit in accuracy and clarity of interpretation of the proposed changes, but we still lack a totally satisfactory requirement on lateral-directional dynamics. I'd like to solicit comments and recommendations on whether or not to adopt these changes.

STABLE AEROPLANE

ELEVATOR PUT BACK TO ORIGINAL PLACE
TO GET UPSIDE DOWN FLYING

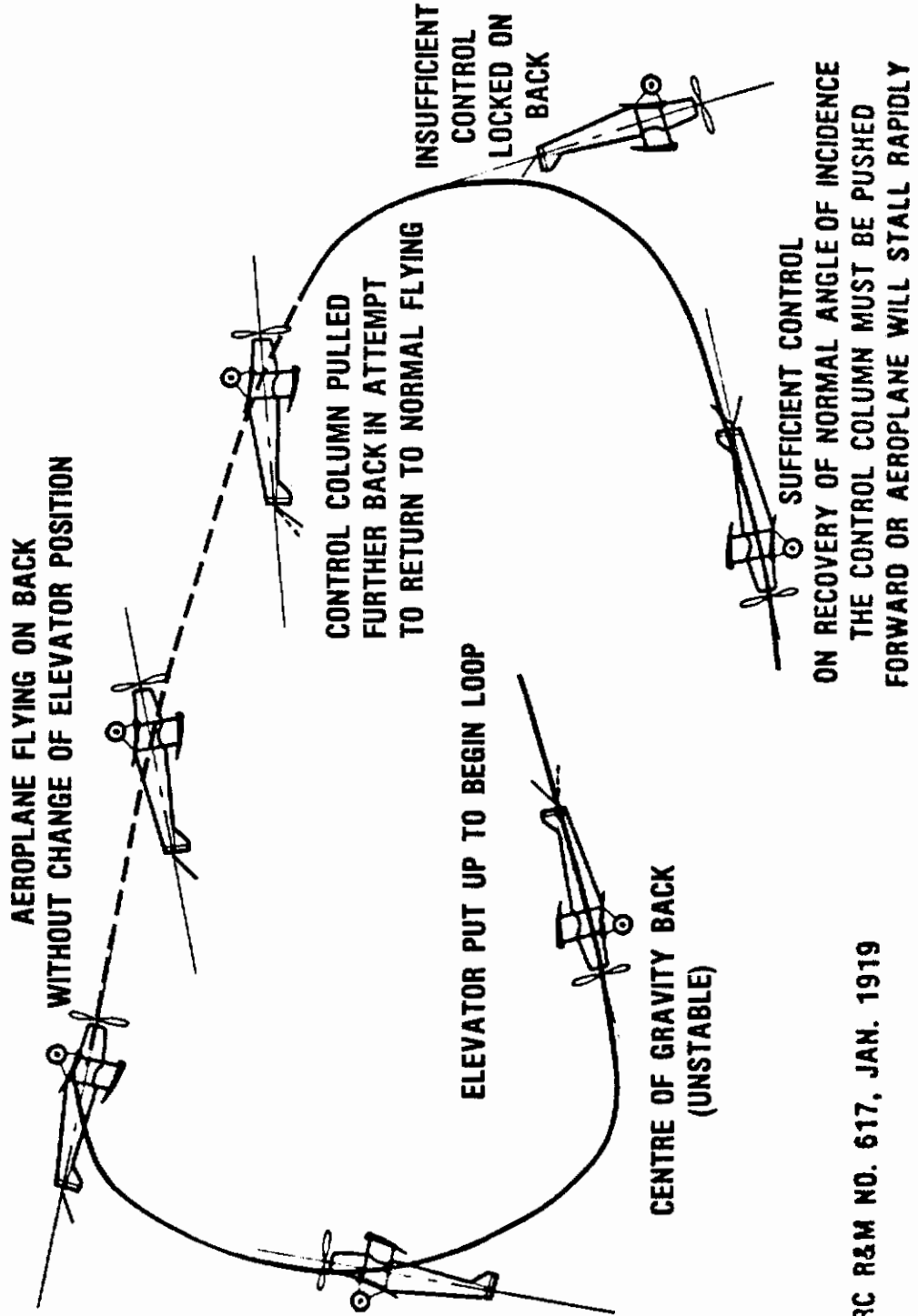ELEVATOR PUT TO POSITION
AT BEGINNING OF LOOP IN
ORDER TO RETURN TO NORMAL FLYING

ELEVATOR PUT UP TO BEGIN LOOP

CENTRE OF GRAVITY FORWARD
(STABLE)

RECOVERY COMPLETE

ARC R&M NO. 617, JAN. 1919

FGG 8-8-2.

UNSTABLE AEROPLANE

INSUFFICIENT CONTROL LOCKED ON BACK

CONTROL COLUMN PULLED FURTHER BACK IN ATTEMPT TO RETURN TO NORMAL FLYING

SUFFICIENT CONTROL

ON RECOVERY OF NORMAL ANGLE OF INCIDENCE THE CONTROL COLUMN MUST BE PUSHED FORWARD OR AEROPLANE WILL STALL RAPIDLY

AEROPLANE FLYING ON BACK WITHOUT CHANGE OF ELEVATOR POSITION

ELEVATOR PUT UP TO BEGIN LOOP

CENTRE OF GRAVITY BACK (UNSTABLE)

. ARC R&M NO. 617, JAN. 1919