Looking at the missile shot geometry in Figure 14 of an X-31A using PST and equipped with a generic high-AoA missile, one can detect forward quarter missile hits possible since the X-31A can shoot before the opponent breaks the minimum range boundary.

The X-31A can choose to allow the fight to expand and employ the missile, or press for a gun kill as described before.

8.4 Post Stall Maneuvers

The flight regime beyond stall houses several unique types of maneuvers of which two will be described here. Not being limited to the maximum aerodynamic lift during heading changes as in conventional flight (see Equation 8) PST maneuvers are characterized by extremely small turn radii.

Substituting the load factor in Equation (3) by

$$n_z = \frac{L}{mg} \tag{7}$$

yields with the lift coefficient C_L an expression for the minimum turn radius r_{min}:

$$r_{\min} = \frac{V^2}{g} \cdot \frac{1}{\sqrt{\left(\frac{C_{L_{\max}} \frac{\rho}{2} V^2 S}{mg} \right)^2 - 1}} \tag{8}$$

A considerable contribution by the thrust vector to balance the weight, i.e. an increase of the denominator, allows for smaller turn radii.

The clinical 'Herbst Maneuver' and a maneuver resembling a 'funnel' or a 'fire pole' belong to the typical PST maneuvers.

8.4.1 'Herbst Maneuver'

The 'Herbst Maneuver' is a very tight 180° heading change [3]. It is depicted in Figure 15.

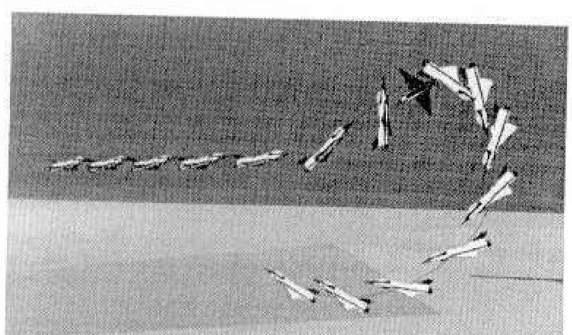

Figure 15: Herbst Maneuver

The 'Herbst Maneuver' is characterized by the following phases: The X-31A enters the maneuver at high speed. A rapid deceleration while increasing angle of attack exceeds the conventional aerodynamics limit (stall) reaching an angle of attack of 70°. In this PST flight condition the X-31A performs a velocity vector roll, i.e. a coordinated body axis roll and yaw maneuver. With this 'coning' motion a new flight direction, i.e. a heading change, is achieved. Unloading and decreasing the angle of attack the X-31A terminates the 'Herbst Maneuver' in an accelerating fashion.

8.4.2 'Fire Pole'

A PST maneuver with an even greater impact on tactical utility is shown in Figure 16.

Closing in onto the adversary both aircraft try to establish a gun tracking solution. While the adversary's turn radius (refer Equation 8) is limited by its maximum possible load factor, i.e. maximum lift, the X-31A can exploit its PST capabilities. The adversary aircraft (solid aircraft in Figure 16) bleeds off speed to achieve smaller turn radii and to establish a gun tracking solution. Having reached its minimum turn radius, the adversary aircraft is restrained to circling

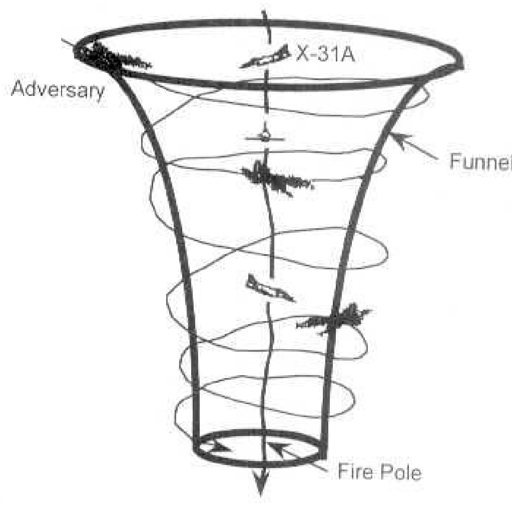

Figure 16: 'Fire Pole'

at this turn radius. Thus its flight path describes the surface of a 'funnel' with a cylindrical lower part. The X-31A however slides down a 'fire pole'. With its extremely tight turn radii and its aircraft reference line decoupled from its flight path, the X-31A can permanently threaten the adversary. The X-31A's motion along is referred to as 'Helicopter Gun Attack' maneuver since the X-31A can turn its nose and thus its gun aiming line like a helicopter.

9. CONCLUSIONS

As no aircraft before the X-31A has demonstrated post stall capabilities up to 70° angle of attack. The X-31A using post stall technologies including a thrust vectoring system was significantly superior in CIC to various state of the art fighter aircraft. Improvement in CIC effectiveness was not only a mere few percent but changed by almost an order of magnitude.

Even though the X-31A was a low cost demonstrator and thus aerodynamically anything but optimized, it was perfectly suitable to evaluate the tactical utility of aircraft with post stall capabilities. The delta-canard configured single engine X-31A has flown a total of 580 flight during its flight test program. The joint efforts of the International Test Organization as it united various international partners from Germany and the USA including the two main industry contractors Daimler-Benz Aerospace AG and Rockwell International enabled a timely and cost-efficient experimental program.