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# F-18 High Alpha Research Vehicle (HARV) Parameter Identification Flight Test Maneuvers for Optimal Input Design Validation and Lateral Control Effectiveness

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## Abstract

Flight test maneuvers are specified for the F-18 High Alpha Research Vehicle (HARV). The maneuvers were designed for open loop parameter identification purposes, specifically for optimal input design validation at 5 degrees angle of attack, identification of individual strake effectiveness at 40 and 50 degrees angle of attack, and study of lateral dynamics and lateral control effectiveness at 40 and 50 degrees angle of attack. Each maneuver is to be realized by applying square wave inputs to specific control effectors using the On-Board Excitation System (OBES). Maneuver descriptions and complete specifications of the time / amplitude points defining each input are included, along with plots of the input time histories.

# Nomenclature

| | |
|---|---|
| ANSER | Actuated Nose Strakes for Enhanced Rolling |
| $h$ | altitude, feet |
| OBES | On-Board Excitation System |
| TV | thrust vectoring |
| $t$ | time, seconds |
| $V$ | airspeed, feet/second |
| $\alpha$ | angle of attack, degrees |
| $\delta_{a_r}$ | right aileron deflection in degrees, positive for trailing edge down |
| $\delta_{a_l}$ | left aileron deflection in degrees, positive for trailing edge down |
| $\delta_a$ | differential aileron deflection in degrees = $\left(\delta_{a_r} - \delta_{a_l}\right)/2$ |
| $\delta_{r_r}$ | right rudder deflection in degrees, positive for trailing edge left |
| $\delta_{r_l}$ | left rudder deflection in degrees, positive for trailing edge left |
| $\delta_r$ | symmetric rudder deflection in degrees = $\left(\delta_{r_r} + \delta_{r_l}\right)/2$ |
| $\delta_{s_r}$ | right stabilator deflection in degrees, positive for trailing edge down |
| $\delta_{s_l}$ | left stabilator deflection in degrees, positive for trailing edge down |
| $\delta_s$ | symmetric stabilator deflection in degrees = $\left(\delta_{s_r} + \delta_{s_l}\right)/2$ |
| $\delta_{str_r}$ | right strake deflection in degrees, positive for outward deflection into the airstream |
| $\delta_{str_l}$ | left strake deflection in degrees, positive for outward deflection into the airstream |
| $\delta_{sstr}$ | symmetric strake deflection in degrees = $\left(\delta_{str_r} + \delta_{str_l}\right)/2$ |
| $\delta_{dstr}$ | differential strake deflection in degrees = $\delta_{str_r} - \delta_{str_l}$ |
| $\delta_{rtv}$ | roll thrust vectoring in degrees, positive for thrust vectoring to produce negative roll rate |
| $\delta_{ytv}$ | yaw thrust vectoring in degrees, positive for thrust vectoring to produce negative yaw rate |

subscripts

| | |
|---|---|
| $o$ | nominal or trim value |

# I. Introduction

The F-18 High Alpha Research Vehicle (HARV) is a highly instrumented research aircraft used in the NASA High Alpha Technology Program[1]. Objectives for this program include investigating advanced flight testing techniques and determining the effectiveness of novel control effectors for maneuvering flight at high angles of attack.

In this work, the technique described in references [2] and [3] was used to design flight test maneuvers consisting of optimal open loop square wave inputs. These square wave inputs are to be applied directly to the relevant control effectors by the On-Board Excitation System (OBES)[4]. The optimal input design technique uses dynamic programming to compute globally optimal square wave inputs for model parameter estimation experiments, based on *a priori* dynamic models. Linear *a priori* dynamic models were obtained from an F-18 HARV nonlinear simulation[5] using central finite differences. The maneuvers were designed specifically to collect flight data with maximum information content for dynamic modeling purposes.

Specific objectives addressed by the maneuvers specified in this document are:

1. Study the efficacy of optimal square wave inputs implemented by the On-Board Excitation System (OBES) for aircraft parameter identification, including comparison with standard 3-2-1-1 input forms. Comparison of piloted optimal square wave inputs with piloted doublet inputs has been documented in reference [6].

2. Determine individual strake effectiveness at 40 and 50 degrees angle of attack for comparison with wind tunnel data and results from alternative flight test methods.

3. Study aircraft lateral dynamic response, differential strake effectiveness, and yaw / roll thrust vectoring effectiveness at 40 and 50 degrees angle of attack.

4. Update and verify existing aerodynamic models.

The purpose of this report is to document the specifications for the maneuvers designed to achieve the above objectives.

## II. Maneuver Descriptions

There are thirteen (13) optimal square wave input maneuvers described in this report. The maneuvers can be divided into three groups:

1. Five (5) maneuvers for optimal input design validation using the OBES system.
2. Two (2) maneuvers for investigating individual strake effectiveness at 40 and 50 degrees angle of attack using the OBES system.
3. Six (6) maneuvers for studying lateral dynamic response and control effectiveness at 40 and 50 degrees angle of attack using the OBES system.

All maneuvers are to be flown using the Actuated Nose Strakes for Enhanced Rolling (ANSER) control law in thrust vectoring (TV) mode[7,8]. Control definitions and sign conventions are given above in the **Nomenclature** section. Detailed descriptions of the maneuvers in each group appear below, with numbering corresponding to that given above.

**1.** This group of five maneuvers is for studying the optimal input design technique. Initial flight condition is trim angle of attack 5 degrees and approximately 25,000 feet altitude, with the ANSER control law in TV mode. This initial flight condition applies for all five maneuvers.

The first two maneuvers involve deflection of the symmetric stabilator for studying optimal input design and for longitudinal model updates and verification. The first input is a standard 3-2-1-1 input, which will be compared to the second input, an optimal square wave, in terms of efficacy for longitudinal dynamic response flight testing. It is therefore important that these two maneuvers be run in sequence on the same flight to minimize extraneous influences on the comparison. Input specifications for the symmetric stabilator 3-2-1-1 input are given in Table 1, and the optimal symmetric stabilator specifications are given in Table 2. Figures 1 and 2 show time histories for the 3-2-1-1 and optimal inputs, respectively. Both inputs included a rate limit of 40 degrees/second for the symmetric stabilator.

The next three maneuvers involve deflection of the rudder and aileron for studying optimal multiple input design and for lateral model updates and verification. The first input is a standard 3-2-1-1 input, which will be compared to the next two inputs, a sequential optimal square wave and a simultaneous optimal square wave, in terms of efficacy for lateral dynamic response flight testing. It is therefore important that these three maneuvers be run in sequence on the same flight to minimize extraneous influences on the comparison. Input specifications for the rudder / aileron 3-2-1-1 input are given in Table 3, specifications for the sequential rudder / aileron optimal input are given in Table 4, and the specifications for the simultaneous rudder / aileron optimal input are given in Table 5. Figures 3, 4, and 5 show time histories for the 3-2-1-1, sequential optimal, and simultaneous optimal inputs, respectively. All inputs included a rate limits of 75 degrees/second for rudder and 100 degrees/second for aileron.

Each of the five maneuvers in this group is to be flown two (2) times, for a total of ten (10) runs. Each run should be preceded by at least two seconds of steady trimmed flight, and followed by at least two seconds of free response before the pilot takes action to control the aircraft. The duration of each maneuver is 20 seconds. Estimated flight time for this set of maneuvers (including repeats) is approximately 15 minutes.

**2.** This group of two maneuvers is for studying the effectiveness of individual strake deflections at high angles of attack, independent of the scheduled symmetric strake deployment associated with the ANSER control law.

For the first maneuver, initial flight condition is trim angle of attack 40 degrees and approximately 25,000 feet altitude, with the ANSER control law in TV mode. This maneuver involves independent deflection of the left and right strakes for studying individual strake effectiveness. Input specifications for the left / right strake optimal square wave input are given in Table 6. Figure 6 shows time histories for the optimal strake inputs. The inputs included a rate limit of 100 degrees/second for both left and right strakes.

For the second maneuver, initial flight condition is trim angle of attack 50 degrees and approximately 25,000 feet altitude, with the ANSER control law in TV mode. This maneuver involves independent deflection of the left and right strakes for studying individual strake effectiveness. Input specifications for the left / right strake optimal square wave input are given in Table 7. Figure 7 shows time histories for the optimal strake inputs. The inputs included a rate limit of 100 degrees/second for both left and right strakes

Both maneuvers in this group are to be flown two (2) times, for a total of four (4) runs. Each run should be preceded by at least two seconds of steady trimmed flight, and followed by at least two seconds of free response before the pilot takes action to control the aircraft. The duration of each maneuver is 24 seconds. Estimated flight time for this set of maneuvers (including repeats) is approximately 10 minutes.

**3.** This group of six maneuvers is for studying lateral dynamics and control effectiveness at high angle of attack. There are three different types of maneuver in this group. A maneuver of each type was designed for two initial flight conditions:

a.) Trim angle of attack 40 degrees and approximately 25,000 feet altitude, with the ANSER control law in TV mode.

b.) Trim angle of attack 50 degrees and approximately 25,000 feet altitude, with the ANSER control law in TV mode.

A description of each maneuver type and the corresponding input specifications for the two flight conditions listed above are given next.

The first maneuver type involves simultaneous deflection of the rudder and aileron for studying lateral dynamic response and for model updates and verification. Input specifications for the rudder / aileron optimal square wave inputs are given in Table 8 for 40 degrees angle of attack, and in Table 11 for 50 degrees angle of attack. Figures 8 and 11 show time histories of the optimal inputs for 40 degrees angle of attack and 50 degrees angle of attack, respectively. All inputs included rate limits of 82 degrees/second for rudder and 100 degrees/second for aileron.

The second maneuver type involves simultaneous deflection of the yaw thrust vectoring and differential strake for studying yaw thrust vectoring effectiveness and differential strake effectiveness, and for model updates and verification. A symmetric strake deflection must be applied slowly before the start of this maneuver. The symmetric strake deflection $\delta_{sstr}$ is computed as:

$$\delta_{sstr} = (\alpha_o - 30) \text{ degrees} \qquad \text{for } \alpha_o > 30 \text{ degrees}$$

or,

$$\delta_{sstr} = 10 \text{ degrees for } \alpha_o = 40 \text{ degrees}$$

$$\delta_{sstr} = 20 \text{ degrees for } \alpha_o = 50 \text{ degrees}$$

Input specifications for the yaw thrust vectoring / differential strake optimal square wave inputs are given in Table 9 for 40 degrees angle of attack, and in Table 12 for 50 degrees angle of attack. Individual strake deflections are non-negative and are computed by combining the symmetric strake deflection $\delta_{sstr}$ with the differential strake deflections $\delta_{dstr}$ from Tables 9 and 12, using the following logic:

if (abs( $\delta_{dstr}$ ) ≤ 2.0*( $\delta_{sstr}$ )) then

$$\delta_{str_l} = \delta_{sstr} - 0.5*(\delta_{dstr})$$

$$\delta_{str_r} = \delta_{sstr} + 0.5*(\delta_{dstr})$$

else

if ( $\delta_{dstr}$ > 0.0) then

$$\delta_{str_l} = 0.0$$

$$\delta_{str_r} = \delta_{dstr}$$

else

$$\delta_{str_l} = -\delta_{dstr}$$

$\delta_{str_r} = 0.0$

end if

end if

Figures 9 and 12 show time histories of the optimal inputs for 40 degrees angle of attack and 50 degrees angle of attack, respectively. All inputs included rate limits of 100 degrees/second for yaw thrust vectoring and 180 degrees/second for differential strake.

The third maneuver type involves sequential deflection of the rudder, aileron, yaw thrust vectoring, differential strake, and roll thrust vectoring for studying control effectiveness and optimal input design, and for model updates and verification. A symmetric strake deflection must be applied slowly before the start of this maneuver. The symmetric strake deflection $\delta_{sstr}$ is computed as:

$$\delta_{sstr} = (\alpha_o - 30) \text{ degrees} \qquad \text{for } \alpha_o > 30 \text{ degrees}$$

or,

$$\delta_{sstr} = 10 \text{ degrees for } \alpha_o = 40 \text{ degrees}$$

$$\delta_{sstr} = 20 \text{ degrees for } \alpha_o = 50 \text{ degrees}$$

Input specifications for the rudder / aileron / yaw thrust vectoring / differential strake / roll thrust vectoring optimal square wave inputs are given in Table 10 for 40 degrees angle of attack, and in Table 13 for 50 degrees angle of attack. Individual strake deflections are computed exactly as described above for the second maneuver type in this set. Figures 10 and 13 show time histories of the optimal inputs for 40 degrees angle of attack and 50 degrees angle of attack, respectively. All inputs included rate limits of 82 degrees/second for rudder, 100 degrees/second for aileron, 100 degrees/second for yaw thrust vectoring, 180 degrees/second for differential strake, and 100 degrees/second for roll thrust vectoring.

Each of the six maneuvers in this group is to be flown two (2) times, for a total of twelve (12) runs. Each run should be preceded by at least two seconds of steady trimmed flight, and followed by at least two seconds of free response before the pilot takes action to control the aircraft. The duration of the rudder / aileron maneuvers and the yaw thrust vectoring / differential strake maneuvers is 15 seconds. The duration of the sequential rudder / aileron / yaw thrust vectoring / differential strake / roll thrust vectoring maneuvers is 21 seconds. Estimated flight time for this set of maneuvers (including repeats) is approximately 20 minutes.

## III. Acknowledgments

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## IV. References

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# V. Input Specification Tables

## 5 α 3-2-1-1 LONGITUDINAL STABILATOR MANEUVER

Initial Conditions

$\alpha_o = 5°$

$V_o$ = 370 knots

$h_o$ = 25,000 feet

$|\text{OBES } \delta_s|_{\max}$ = 3.0 degrees

**Table 1**

(Figure 1)

OBES stabilator

| Time (seconds) | OBES $\delta_s$ (degrees) |
|---|---|
| 0 | 0 |
| 0.025 | 3 |
| 3.000 | 3 |
| 3.050 | -3 |
| 5.000 | -3 |
| 5.050 | 3 |
| 6.000 | 3 |
| 6.050 | -3 |
| 7.000 | -3 |
| 7.025 | 0 |
| 12.000 | 0 |
| 12.025 | -3 |
| 15.000 | -3 |
| 15.050 | 3 |
| 17.000 | 3 |
| 17.050 | -3 |
| 18.000 | -3 |
| 18.050 | 3 |
| 19.000 | 3 |
| 19.025 | 0 |
| 24.000 | 0 |

## 5 α OPTIMAL LONGITUDINAL STABILATOR MANEUVER

Initial Conditions

$\alpha_o = 5°$

$V_o$ = 370 knots

$h_o$ = 25,000 feet

$|\text{ OBES } \delta_s|_{max}$ = 4.0 degrees

**Table 2**

(Figure 2)

OBES stabilator

| Time (seconds) | OBES $\delta_s$ (degrees) |
|---|---|
| 0 | 0 |
| 0.100 | 4 |
| 2.500 | 4 |
| 2.700 | -4 |
| 3.000 | -4 |
| 3.200 | 4 |
| 3.500 | 4 |
| 3.700 | -4 |
| 6.000 | -4 |
| 6.200 | 4 |
| 6.500 | 4 |
| 6.700 | -4 |
| 7.000 | -4 |
| 7.200 | 4 |
| 9.750 | 4 |
| 9.950 | -4 |
| 10.250 | -4 |
| 10.450 | 4 |
| 10.750 | 4 |
| 10.950 | -4 |
| 13.250 | -4 |
| 13.450 | 4 |

(cont.)

**Table 2** (cont.)

(Figure 2)

OBES stabilator

| Time (seconds) | OBES $\delta_s$ (degrees) |
|---|---|
| 13.750 | 4 |
| 13.950 | -4 |
| 14.250 | -4 |
| 14.450 | 4 |
| 17.000 | 4 |
| 17.200 | -4 |
| 17.500 | -4 |
| 17.700 | 4 |
| 18.000 | 4 |
| 18.200 | -4 |
| 20.000 | -4 |
| 20.200 | 4 |
| 20.500 | 4 |
| 20.700 | -4 |
| 21.000 | -4 |
| 21.200 | 4 |
| 22.250 | 4 |
| 22.450 | -4 |
| 22.750 | -4 |
| 22.950 | 4 |
| 23.250 | 4 |
| 23.450 | -4 |
| 23.750 | -4 |
| 23.850 | 0 |
| 24.000 | 0 |

## 5 $\alpha$ 3-2-1-1 LATERAL RUDDER / AILERON MANEUVER

Initial Conditions

$\alpha_o = 5°$

$V_o$ = 370 knots

$h_o$ = 25,000 feet

$|\text{OBES } \delta_r|_{max}$ = 4.0 degrees

$|\text{OBES } \delta_a|_{max}$ = 2.5 degrees

**Table 3**

(Figure 3)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 0 | 0 |
| 0.050 | 4 |
| 2.675 | 4 |
| 2.775 | -4 |
| 4.475 | -4 |
| 4.575 | 4 |
| 5.375 | 4 |
| 5.475 | -4 |
| 6.275 | -4 |
| 6.325 | 0 |
| 20.000 | 0 |

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 0 | 0 |
| 10.000 | 0 |
| 10.025 | -2.5 |
| 12.675 | -2.5 |
| 12.725 | 2.5 |
| 14.475 | 2.5 |
| 14.525 | -2.5 |
| 15.375 | -2.5 |
| 15.425 | 2.5 |
| 16.275 | 2.5 |
| 16.300 | 0 |
| 20.000 | 0 |

**5 α SEQUENTIAL OPTIMAL LATERAL RUDDER / AILERON MANEUVER**

Initial Conditions

$\alpha_o = 5°$

$V_o$ = 370 knots

$h_o$ = 25,000 feet

| OBES $\delta_r |_{max}$ = 4.0 degrees

| OBES $\delta_a |_{max}$ = 2.5 degrees

**Table 4**

(Figure 4)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 0 | 0 |
| 0.075 | 4 |
| 0.900 | 4 |
| 0.975 | 0 |
| 1.125 | 0 |
| 1.200 | 4 |
| 1.575 | 4 |
| 1.650 | 0 |
| 2.025 | 0 |
| 2.100 | 4 |
| 2.475 | 4 |
| 2.550 | 0 |
| 2.700 | 0 |
| 2.775 | 4 |
| 3.600 | 4 |
| 3.675 | 0 |
| 3.825 | 0 |
| 3.900 | 4 |
| 4.050 | 4 |
| 4.175 | -4 |
| 6.075 | -4 |

(cont.)

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 0 | 0 |
| 10.125 | 0 |
| 10.150 | -2.5 |
| 11.925 | -2.5 |
| 11.975 | 2.5 |
| 13.050 | 2.5 |
| 13.100 | -2.5 |
| 14.400 | -2.5 |
| 14.450 | 2.5 |
| 18.000 | 2.5 |
| 18.025 | 0 |
| 18.450 | 0 |
| 18.475 | -2.5 |
| 19.800 | -2.5 |
| 19.825 | 0 |
| 20.000 | 0 |

**Table 4** (cont.)

(Figure 4)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 6.200 | 4 |
| 7.200 | 4 |
| 7.325 | -4 |
| 7.425 | -4 |
| 7.500 | 0 |
| 7.650 | 0 |
| 7.725 | -4 |
| 7.875 | -4 |
| 7.950 | 0 |
| 8.100 | 0 |
| 8.175 | 4 |
| 8.775 | 4 |
| 8.900 | -4 |
| 10.125 | -4 |
| 10.200 | 0 |
| 20.000 | 0 |

## 5 $\alpha$ OPTIMAL LATERAL RUDDER / AILERON MANEUVER

<u>Initial Conditions</u>

$\alpha_o = 5°$

$V_o$ = 370 knots

$h_o$ = 25,000 feet

$|$ OBES $\delta_r |_{max}$ = 4.0 degrees

$|$ OBES $\delta_a |_{max}$ = 2.5 degrees

**Table 5**

(Figure 5)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 0 | 0 |
| 0.075 | -4 |
| 0.225 | -4 |
| 0.300 | 0 |
| 0.450 | 0 |
| 0.525 | -4 |
| 1.350 | -4 |
| 1.475 | 4 |
| 1.800 | 4 |
| 1.875 | 0 |
| 2.025 | 0 |
| 2.100 | 4 |
| 2.250 | 4 |
| 2.375 | -4 |
| 2.700 | -4 |
| 2.825 | 4 |
| 2.925 | 4 |
| 3.050 | -4 |
| 4.500 | -4 |
| 4.625 | 4 |
| 4.725 | 4 |

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 0 | 0 |
| 0.025 | 2.5 |
| 1.125 | 2.5 |
| 1.175 | -2.5 |
| 1.350 | -2.5 |
| 1.400 | 2.5 |
| 1.800 | 2.5 |
| 1.850 | -2.5 |
| 2.475 | -2.5 |
| 2.525 | 2.5 |
| 3.150 | 2.5 |
| 3.200 | -2.5 |
| 5.175 | -2.5 |
| 5.200 | 0 |
| 5.400 | 0 |
| 5.425 | 2.5 |
| 9.225 | 2.5 |
| 9.250 | 0 |
| 9.450 | 0 |
| 9.475 | -2.5 |
| 11.250 | -2.5 |

(cont.)

**Table 5** (cont.)

(Figure 5)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 4.800 | 0 |
| 4.950 | 0 |
| 5.025 | 4 |
| 6.075 | 4 |
| 6.200 | -4 |
| 6.300 | -4 |
| 6.375 | 0 |
| 6.525 | 0 |
| 6.600 | -4 |
| 6.975 | -4 |
| 7.050 | 0 |
| 7.200 | 0 |
| 7.275 | 4 |
| 7.875 | 4 |
| 8.000 | -4 |
| 8.775 | -4 |
| 8.850 | 0 |
| 9.000 | 0 |
| 9.075 | 4 |
| 9.900 | 4 |
| 10.025 | -4 |
| 11.475 | -4 |
| 11.550 | 0 |
| 11.700 | 0 |
| 11.775 | 4 |
| 12.150 | 4 |
| 12.225 | 0 |
| 12.375 | 0 |
| 12.450 | 4 |
| 12.600 | 4 |
| 12.725 | -4 |
| 12.825 | -4 |

(cont.)

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 11.300 | 2.5 |
| 11.925 | 2.5 |
| 11.975 | -2.5 |
| 13.725 | -2.5 |
| 13.775 | 2.5 |
| 14.625 | 2.5 |
| 14.650 | 0 |
| 14.850 | 0 |
| 14.875 | -2.5 |
| 15.750 | -2.5 |
| 15.800 | 2.5 |
| 17.775 | 2.5 |
| 17.825 | -2.5 |
| 18.675 | -2.5 |
| 18.725 | 2.5 |
| 19.800 | 2.5 |
| 19.825 | 0 |
| 20.000 | 0 |

**Table 5** (cont.)

(Figure 5)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 12.950 | 4 |
| 13.050 | 4 |
| 13.175 | -4 |
| 14.400 | -4 |
| 14.525 | 4 |
| 14.850 | 4 |
| 14.925 | 0 |
| 15.075 | 0 |
| 15.150 | 4 |
| 16.200 | 4 |
| 16.325 | -4 |
| 16.650 | -4 |
| 16.775 | 4 |
| 16.875 | 4 |
| 17.000 | -4 |
| 17.325 | -4 |
| 17.400 | 0 |
| 17.775 | 0 |
| 17.850 | 4 |
| 18.000 | 4 |
| 18.125 | -4 |
| 18.225 | -4 |
| 18.350 | 4 |
| 19.350 | 4 |
| 19.475 | -4 |
| 19.575 | -4 |
| 19.700 | 4 |
| 19.800 | 4 |
| 19.875 | 0 |
| 20.000 | 0 |

## 40 α OPTIMAL STRAKE MANEUVER

Initial Conditions
$\alpha_o = 40°$
$V_o$ = 155 knots
$h_o$ = 25,000 feet

| OBES $\delta_{str_l}$ $|_{max}$ = 30.0 degrees

| OBES $\delta_{str_r}$ $|_{max}$ = 30.0 degrees

## Table 6

(Figure 6)

OBES left strake

| Time (seconds) | OBES $\delta_{str_l}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.900 | 0 |
| 1.200 | 30 |
| 1.500 | 0 |
| 3.000 | 0 |
| 3.300 | 30 |
| 3.600 | 30 |
| 3.900 | 0 |
| 5.700 | 0 |
| 6.000 | 30 |
| 6.300 | 0 |
| 7.800 | 0 |
| 8.100 | 30 |
| 8.400 | 0 |
| 9.000 | 0 |
| 9.300 | 30 |
| 9.900 | 30 |
| 10.200 | 0 |
| 11.700 | 0 |
| 12.000 | 30 |
| 12.300 | 30 |
| 12.600 | 0 |
| 13.800 | 0 |

OBES right strake

| Time (seconds) | OBES $\delta_{str_r}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.300 | 30 |
| 0.600 | 30 |
| 0.900 | 0 |
| 4.800 | 0 |
| 5.100 | 30 |
| 5.400 | 30 |
| 5.700 | 0 |
| 6.600 | 0 |
| 6.900 | 30 |
| 7.500 | 30 |
| 7.800 | 0 |
| 10.500 | 0 |
| 10.800 | 30 |
| 11.400 | 30 |
| 11.700 | 0 |
| 12.900 | 0 |
| 13.200 | 30 |
| 13.500 | 30 |
| 13.800 | 0 |
| 15.000 | 0 |
| 15.300 | 30 |
| 16.200 | 30 |

(cont.)

**Table 6** (cont.)

(Figure 6)

OBES left strake

| Time (seconds) | OBES $\delta_{str_l}$ (degrees) |
|---|---|
| 14.100 | 30 |
| 14.400 | 30 |
| 14.700 | 0 |
| 16.500 | 0 |
| 16.800 | 30 |
| 17.700 | 30 |
| 18.000 | 0 |
| 19.200 | 0 |
| 19.500 | 30 |
| 19.800 | 30 |
| 20.100 | 0 |
| 21.300 | 0 |
| 21.600 | 30 |
| 21.900 | 0 |
| 22.200 | 0 |
| 22.500 | 30 |
| 22.800 | 30 |
| 23.100 | 0 |
| 24.000 | 0 |

OBES right strake

| Time (seconds) | OBES $\delta_{str_r}$ (degrees) |
|---|---|
| 16.500 | 0 |
| 18.300 | 0 |
| 18.600 | 30 |
| 18.900 | 30 |
| 19.200 | 0 |
| 20.400 | 0 |
| 20.700 | 30 |
| 21.000 | 30 |
| 21.300 | 0 |
| 24.000 | 0 |

**50 α OPTIMAL STRAKE MANEUVER**

Initial Conditions

$\alpha_o = 50°$

$V_o = 155$ knots

$h_o = 25{,}000$ feet

$|\text{OBES } \delta_{str_l}|_{max} = 40.0$ degrees

$|\text{OBES } \delta_{str_r}|_{max} = 40.0$ degrees

## Table 7

(Figure 7)

OBES left strake

| Time (seconds) | OBES $\delta_{str_l}$ (degrees) |
|---|---|
| 0 | 0 |
| 1.200 | 0 |
| 1.600 | 40 |
| 2.000 | 0 |
| 4.000 | 0 |
| 4.400 | 40 |
| 5.200 | 40 |
| 5.600 | 0 |
| 7.200 | 0 |
| 7.600 | 40 |
| 8.400 | 40 |
| 8.800 | 0 |
| 10.400 | 0 |
| 10.800 | 40 |
| 11.200 | 40 |
| 11.600 | 0 |
| 14.400 | 0 |
| 14.800 | 40 |
| 15.200 | 0 |
| 17.200 | 0 |
| 17.600 | 40 |
| 18.000 | 0 |
| 18.400 | 0 |

OBES right strake

| Time (seconds) | OBES $\delta_{str_r}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.400 | 40 |
| 0.800 | 40 |
| 1.200 | 0 |
| 2.800 | 0 |
| 3.200 | 40 |
| 3.600 | 40 |
| 4.000 | 0 |
| 6.000 | 0 |
| 6.400 | 40 |
| 6.800 | 40 |
| 7.200 | 0 |
| 9.200 | 0 |
| 9.600 | 40 |
| 10.000 | 40 |
| 10.400 | 0 |
| 12.800 | 0 |
| 13.200 | 40 |
| 14.000 | 40 |
| 14.400 | 0 |
| 16.000 | 0 |
| 16.400 | 40 |
| 16.800 | 40 |

(cont.)

**Table 7** (cont.)

(Figure 7)

OBES left strake

| Time (seconds) | OBES $\delta_{str_l}$ (degrees) |
|---|---|
| 18.800 | 40 |
| 19.200 | 40 |
| 19.600 | 0 |
| 22.800 | 0 |
| 23.200 | 40 |
| 23.600 | 40 |
| 24.000 | 0 |

OBES right strake

| Time (seconds) | OBES $\delta_{str_r}$ (degrees) |
|---|---|
| 17.200 | 0 |
| 24.000 | 0 |

**40 $\alpha$ OPTIMAL LATERAL RUDDER / AILERON MANEUVER**

Initial Conditions

$\alpha_o = 40°$

$V_o$ = 155 knots

$h_o$ = 25,000 feet

| OBES $\delta_r$ $|_{max}$ = 18.0 degrees

| OBES $\delta_a$ $|_{max}$ = 20.0 degrees

## Table 8

(Figure 8)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 0 | 0 |
| 0.2000 | 18 |
| 0.5000 | 18 |
| 0.7000 | 0 |
| 1.0000 | 0 |
| 1.2000 | -18 |
| 1.5000 | -18 |
| 1.7000 | 0 |
| 2.0000 | 0 |
| 2.2000 | -18 |
| 2.5000 | -18 |
| 2.7000 | 0 |
| 3.0000 | 0 |
| 3.2000 | 18 |
| 3.5000 | 18 |
| 3.7000 | 0 |
| 4.0000 | 0 |
| 4.2000 | -18 |
| 4.5000 | -18 |
| 4.8750 | 18 |
| 5.0000 | 18 |

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 0 | 0 |
| 0.2500 | 20 |
| 0.5000 | 20 |
| 0.7500 | 0 |
| 1.0000 | 0 |
| 1.2500 | -20 |
| 3.5000 | -20 |
| 4.0000 | 20 |
| 4.5000 | 20 |
| 5.0000 | -20 |
| 6.5000 | -20 |
| 7.0000 | 20 |
| 8.5000 | 20 |
| 8.7500 | 0 |
| 9.0000 | 0 |
| 9.2500 | 20 |
| 10.0000 | 20 |
| 10.2500 | 0 |
| 10.5000 | 0 |
| 10.7500 | 20 |
| 12.5000 | 20 |

(cont.)

**Table 8** (cont.)

(Figure 8)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 5.3750 | -18 |
| 5.5000 | -18 |
| 5.8750 | 18 |
| 6.5000 | 18 |
| 6.7000 | 0 |
| 7.0000 | 0 |
| 7.2000 | -18 |
| 8.0000 | -18 |
| 8.2000 | 0 |
| 8.5000 | 0 |
| 8.7000 | 18 |
| 9.0000 | 18 |
| 9.2000 | 0 |
| 9.5000 | 0 |
| 9.7000 | 18 |
| 10.5000 | 18 |
| 10.8750 | -18 |
| 11.5000 | -18 |
| 11.7000 | 0 |
| 13.0000 | 0 |
| 13.2000 | 18 |
| 13.5000 | 18 |
| 13.8750 | -18 |
| 14.5000 | -18 |
| 14.7000 | 0 |
| 15.0000 | 0 |

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 12.7500 | 0 |
| 13.0000 | 0 |
| 13.2500 | -20 |
| 14.0000 | -20 |
| 14.5000 | 20 |
| 14.5500 | 20 |
| 14.7500 | 0 |
| 15.0000 | 0 |

**40 α OPTIMAL LATERAL YAW TV / DIFFERENTIAL STRAKE MANEUVER**

Initial Conditions
$\alpha_o = 40°$
$V_o$ = 155 knots
$h_o$ = 25,000 feet

| OBES $\delta_{ytv}$ $|_{max}$ = 6.0 degrees | OBES $\delta_{dstr}$ $|_{max}$ = 20.0 degrees

**Table 9**
(Figure 9)

OBES yaw thrust vectoring

| Time (seconds) | OBES $\delta_{ytv}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.0750 | 6 |
| 0.4500 | 6 |
| 0.5750 | -6 |
| 0.7500 | -6 |
| 0.8750 | 6 |
| 1.0500 | 6 |
| 1.1750 | -6 |
| 2.2500 | -6 |
| 2.3750 | 6 |
| 2.8500 | 6 |
| 2.9250 | 0 |
| 3.1500 | 0 |
| 3.2250 | 6 |
| 4.2000 | 6 |
| 4.3250 | -6 |
| 5.2500 | -6 |
| 5.3250 | 0 |
| 5.7000 | 0 |
| 5.7750 | 6 |
| 6.4500 | 6 |
| 6.5250 | 0 |
| 6.7500 | 0 |

OBES differential strake

| Time (seconds) | OBES $\delta_{dstr}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.1250 | -20 |
| 0.3000 | -20 |
| 0.4250 | 0 |
| 0.9000 | 0 |
| 1.0250 | 20 |
| 1.2000 | 20 |
| 1.4250 | -20 |
| 1.8000 | -20 |
| 2.0250 | 20 |
| 2.7000 | 20 |
| 2.9250 | -20 |
| 3.0000 | -20 |
| 3.2250 | 20 |
| 3.4500 | 20 |
| 3.5750 | 0 |
| 3.7500 | 0 |
| 3.8750 | 20 |
| 4.5000 | 20 |
| 4.7250 | -20 |
| 5.8500 | -20 |
| 5.9750 | 0 |
| 6.3000 | 0 |

(cont.)

**Table 9** (cont.)

(Figure 9)

OBES yaw thrust vectoring

| Time (seconds) | OBES $\delta_{ytv}$ (degrees) |
|---|---|
| 6.8250 | 6 |
| 7.0500 | 6 |
| 7.1750 | -6 |
| 8.2500 | -6 |
| 8.3250 | 0 |
| 8.5500 | 0 |
| 8.6250 | 6 |
| 9.1500 | 6 |
| 9.2250 | 0 |
| 9.9000 | 0 |
| 9.9750 | -6 |
| 10.8000 | -6 |
| 10.8750 | 0 |
| 11.1000 | 0 |
| 11.1750 | -6 |
| 11.4000 | -6 |
| 11.5250 | 6 |
| 11.7000 | 6 |
| 11.8250 | -6 |
| 12.0000 | -6 |
| 12.1250 | 6 |
| 13.0500 | 6 |
| 13.1250 | 0 |
| 13.3500 | 0 |
| 13.4250 | 6 |
| 14.7000 | 6 |
| 14.7750 | 0 |
| 15.0000 | 0 |

OBES differential strake

| Time (seconds) | OBES $\delta_{dstr}$ (degrees) |
|---|---|
| 6.4250 | -20 |
| 6.6000 | -20 |
| 6.8250 | 20 |
| 8.1000 | 20 |
| 8.2250 | 0 |
| 8.4000 | 0 |
| 8.5250 | -20 |
| 9.6000 | -20 |
| 9.7250 | 0 |
| 9.9000 | 0 |
| 10.0250 | -20 |
| 10.3500 | -20 |
| 10.5750 | 20 |
| 10.8000 | 20 |
| 10.9250 | 0 |
| 11.1000 | 0 |
| 11.2250 | -20 |
| 11.5500 | -20 |
| 11.7750 | 20 |
| 12.0000 | 20 |
| 12.1250 | 0 |
| 12.6000 | 0 |
| 12.7250 | 20 |
| 13.6500 | 20 |
| 13.7750 | 0 |
| 13.9500 | 0 |
| 14.0750 | 20 |
| 14.2500 | 20 |
| 14.4750 | -20 |
| 14.7000 | -20 |
| 14.8250 | 0 |
| 15.0000 | 0 |

## 40 $\alpha$ OPTIMAL LATERAL SEQUENTIAL MANEUVER

Initial Conditions

$\alpha_o = 40°$

$V_o$ = 155 knots

$h_o$ = 25,000 feet

| OBES $\delta_r$ $|_{max}$ = 19.0 degrees

| OBES $\delta_a$ $|_{max}$ = 18.0 degrees

| OBES $\delta_{ytv}$ $|_{max}$ = 6.0 degrees

| OBES $\delta_{dstr}$ $|_{max}$ = 20.0 degrees

| OBES $\delta_{rtv}$ $|_{max}$ = 10.0 degrees

## Table 10

(Figure 10)

| OBES rudder | | OBES aileron | | OBES yaw TV | | OBES diff. strake | | OBES roll TV | |
|---|---|---|---|---|---|---|---|---|---|
| Time (sec) | OBES $\delta_r$ (deg) | Time (sec) | OBES $\delta_a$ (deg) | Time (sec) | OBES $\delta_{ytv}$ (deg) | Time (sec) | OBES $\delta_{dstr}$ (deg) | Time (sec) | OBES $\delta_{rtv}$ (deg) |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.250 | 19 | 4.000 | 0 | 8.000 | 0 | 12.000 | 0 | 16.000 | 0 |
| 0.500 | 19 | 4.200 | 18 | 8.075 | 6 | 12.125 | 20 | 16.100 | -10 |
| 0.750 | 0 | 4.500 | 18 | 9.500 | 6 | 12.500 | 20 | 17.000 | -10 |
| 1.000 | 0 | 4.875 | -18 | 9.625 | -6 | 12.725 | -20 | 17.100 | 0 |
| 1.250 | 19 | 5.000 | -18 | 11.000 | -6 | 13.500 | -20 | 17.500 | 0 |
| 1.500 | 19 | 5.375 | 18 | 11.075 | 0 | 13.625 | 0 | 17.600 | 10 |
| 1.975 | -19 | 5.500 | 18 | 11.500 | 0 | 14.000 | 0 | 18.000 | 10 |
| 2.000 | -19 | 5.875 | -18 | 11.575 | 6 | 14.125 | 20 | 18.100 | 0 |
| 2.475 | 19 | 6.000 | -18 | 12.000 | 6 | 15.000 | 20 | 18.500 | 0 |
| 2.500 | 19 | 6.200 | 0 | 12.075 | 0 | 15.225 | -20 | 18.600 | 10 |
| 2.975 | -19 | 6.500 | 0 | 21.000 | 0 | 15.500 | -20 | 19.500 | 10 |
| 3.000 | -19 | 6.700 | -18 | | | 15.625 | 0 | 19.700 | -10 |
| 3.250 | 0 | 7.000 | -18 | | | 21.000 | 0 | 20.000 | -10 |
| 3.500 | 0 | 7.375 | 18 | | | | | 20.100 | 0 |
| 3.750 | 19 | 8.000 | 18 | | | | | 21.000 | 0 |
| 4.000 | 19 | 8.200 | 0 | | | | | | |
| 4.250 | 0 | 21.000 | 0 | | | | | | |
| 21.000 | 0 | | | | | | | | |

**50 α OPTIMAL LATERAL RUDDER / AILERON MANEUVER**

Initial Conditions
$\alpha_o = 50°$
$V_o$ = 155 knots
$h_o$ = 25,000 feet

| OBES $\delta_r$ $|_{max}$ = 20.0 degrees

| OBES $\delta_a$ $|_{max}$ = 20.0 degrees

**Table 11**

(Figure 11)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 0 | 0 |
| 0.250 | -20 |
| 0.500 | -20 |
| 1.000 | 20 |
| 2.000 | 20 |
| 2.250 | 0 |
| 3.000 | 0 |
| 3.250 | -20 |
| 4.000 | -20 |
| 4.500 | 20 |
| 5.000 | 20 |
| 5.250 | 0 |
| 5.500 | 0 |
| 5.750 | -20 |
| 6.000 | -20 |
| 6.250 | 0 |
| 7.000 | 0 |
| 7.250 | -20 |
| 7.500 | -20 |
| 7.750 | 0 |
| 8.500 | 0 |

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 0 | 0 |
| 0.200 | -20 |
| 0.500 | -20 |
| 0.700 | 0 |
| 1.000 | 0 |
| 1.200 | 20 |
| 1.500 | 20 |
| 1.700 | 0 |
| 2.000 | 0 |
| 2.200 | -20 |
| 2.500 | -20 |
| 2.700 | 0 |
| 3.000 | 0 |
| 3.200 | 20 |
| 4.000 | 20 |
| 4.200 | 0 |
| 4.500 | 0 |
| 4.700 | -20 |
| 5.000 | -20 |
| 5.400 | 20 |
| 6.500 | 20 |

(cont.)

**Table 11** (cont.)

(Figure 11)

OBES rudder

| Time (seconds) | OBES $\delta_r$ (degrees) |
|---|---|
| 8.750 | 20 |
| 9.500 | 20 |
| 9.750 | 0 |
| 10.000 | 0 |
| 10.250 | 20 |
| 10.500 | 20 |
| 10.750 | 0 |
| 13.000 | 0 |
| 13.250 | -20 |
| 13.500 | -20 |
| 13.750 | 0 |
| 15.000 | 0 |

OBES aileron

| Time (seconds) | OBES $\delta_a$ (degrees) |
|---|---|
| 6.900 | -20 |
| 7.500 | -20 |
| 7.700 | 0 |
| 8.000 | 0 |
| 8.200 | 20 |
| 8.500 | 20 |
| 8.900 | -20 |
| 9.000 | -20 |
| 9.200 | 0 |
| 9.500 | 0 |
| 9.700 | -20 |
| 10.500 | -20 |
| 10.700 | 0 |
| 11.000 | 0 |
| 11.200 | -20 |
| 11.500 | -20 |
| 11.900 | 20 |
| 12.000 | 20 |
| 12.200 | 0 |
| 12.500 | 0 |
| 12.700 | -20 |
| 13.000 | -20 |
| 13.200 | 0 |
| 13.500 | 0 |
| 13.700 | -20 |
| 14.000 | -20 |
| 14.400 | 20 |
| 14.500 | 20 |
| 14.700 | 0 |
| 15.000 | 0 |

## 50 $\alpha$ OPTIMAL LATERAL YAW TV / DIFFERENTIAL STRAKE MANEUVER

Initial Conditions

$\alpha_o = 50°$

$V_o$ = 155 knots

$h_o$ = 25,000 feet

| OBES $\delta_{ytv}$ $|_{max}$ = 5.0 degrees

| OBES $\delta_{dstr}$ $|_{max}$ = 15.0 degrees

**Table 12**

(Figure 12)

OBES yaw thrust vectoring

| Time (seconds) | OBES $\delta_{ytv}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.050 | 5 |
| 0.800 | 5 |
| 0.850 | 0 |
| 1.000 | 0 |
| 1.050 | -5 |
| 1.200 | -5 |
| 1.250 | 0 |
| 1.400 | 0 |
| 1.450 | -5 |
| 1.800 | -5 |
| 1.900 | 5 |
| 2.000 | 5 |
| 2.050 | 0 |
| 2.400 | 0 |
| 2.450 | 5 |
| 2.600 | 5 |
| 2.700 | -5 |
| 2.800 | -5 |
| 2.850 | 0 |
| 3.000 | 0 |
| 3.050 | -5 |
| 3.600 | -5 |
| 3.700 | 5 |

OBES differential strake

| Time (seconds) | OBES $\delta_{dstr}$ (degrees) |
|---|---|
| 0 | 0 |
| 0.100 | 15 |
| 0.800 | 15 |
| 0.975 | -15 |
| 2.000 | -15 |
| 2.175 | 15 |
| 2.200 | 15 |
| 2.375 | -15 |
| 2.600 | -15 |
| 2.775 | 15 |
| 3.400 | 15 |
| 3.575 | -15 |
| 4.800 | -15 |
| 4.975 | 15 |
| 5.600 | 15 |
| 5.775 | -15 |
| 5.800 | -15 |
| 5.900 | 0 |
| 6.000 | 0 |
| 6.100 | -15 |
| 6.200 | -15 |
| 6.300 | 0 |
| 6.400 | 0 |
| 6.500 | -15 |

(cont.)

**Table 12** (cont.)

(Figure 12)

OBES yaw thrust vectoring

| Time (seconds) | OBES $\delta_{ytv}$ (degrees) |
|---|---|
| 4.200 | 5 |
| 4.250 | 0 |
| 4.400 | 0 |
| 4.450 | -5 |
| 6.000 | -5 |
| 6.100 | 5 |
| 8.200 | 5 |
| 8.300 | -5 |
| 8.800 | -5 |
| 8.850 | 0 |
| 9.000 | 0 |
| 9.050 | -5 |
| 9.200 | -5 |
| 9.300 | 5 |
| 10.800 | 5 |
| 10.900 | -5 |
| 11.200 | -5 |
| 11.250 | 0 |
| 11.600 | 0 |
| 11.650 | -5 |
| 11.800 | -5 |
| 11.850 | 0 |
| 12.000 | 0 |
| 12.050 | -5 |
| 12.200 | -5 |
| 12.300 | 5 |
| 12.400 | 5 |
| 12.500 | -5 |
| 12.600 | -5 |
| 12.700 | 5 |
| 14.800 | 5 |
| 14.850 | 0 |
| 15.000 | 0 |

OBES differential strake

| Time (seconds) | OBES $\delta_{dstr}$ (degrees) |
|---|---|
| 6.800 | -15 |
| 6.975 | 15 |
| 7.200 | 15 |
| 7.375 | -15 |
| 9.200 | -15 |
| 9.300 | 0 |
| 9.400 | 0 |
| 9.500 | -15 |
| 10.200 | -15 |
| 10.375 | 15 |
| 10.800 | 15 |
| 10.900 | 0 |
| 11.200 | 0 |
| 11.300 | 15 |
| 12.000 | 15 |
| 12.175 | -15 |
| 13.600 | -15 |
| 13.775 | 15 |
| 14.800 | 15 |
| 14.900 | 0 |
| 15.000 | 0 |

**50 α OPTIMAL LATERAL SEQUENTIAL MANEUVER**

Initial Conditions
$\alpha_o = 50°$
$V_o = 155$ knots
$h_o = 25{,}000$ feet

| OBES $\delta_r$ $|_{max}$ = 19.0 degrees | OBES $\delta_a$ $|_{max}$ = 20.0 degrees
| OBES $\delta_{ytv}$ $|_{max}$ = 5.0 degrees | OBES $\delta_{dstr}$ $|_{max}$ = 20.0 degrees
| OBES $\delta_{rtv}$ $|_{max}$ = 10.0 degrees

## Table 13
(Figure 13)

| OBES rudder | | OBES aileron | | OBES yaw TV | | OBES diff. strake | | OBES roll TV | |
|---|---|---|---|---|---|---|---|---|---|
| Time (sec) | OBES $\delta_r$ (deg) | Time (sec) | OBES $\delta_a$ (deg) | Time (sec) | OBES $\delta_{ytv}$ (deg) | Time (sec) | OBES $\delta_{dstr}$ (deg) | Time (sec) | OBES $\delta_{rtv}$ (deg) |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.250 | -19 | 4.000 | 0 | 8.000 | 0 | 12.000 | 0 | 16.000 | 0 |
| 2.500 | -19 | 4.200 | 20 | 8.050 | 5 | 12.125 | -20 | 16.100 | 10 |
| 2.975 | 19 | 4.500 | 20 | 9.500 | 5 | 14.000 | -20 | 17.000 | 10 |
| 3.000 | 19 | 4.900 | -20 | 9.600 | -5 | 14.225 | 20 | 17.200 | -10 |
| 3.250 | 0 | 5.500 | -20 | 10.500 | -5 | 16.000 | 20 | 18.000 | -10 |
| 3.500 | 0 | 5.900 | 20 | 10.600 | 5 | 16.125 | 0 | 18.100 | 0 |
| 3.750 | -19 | 6.500 | 20 | 11.000 | 5 | 21.000 | 0 | 18.500 | 0 |
| 4.000 | -19 | 6.900 | -20 | 11.050 | 0 | | | 18.600 | 10 |
| 4.250 | 0 | 7.500 | -20 | 11.500 | 0 | | | 20.000 | 10 |
| 21.000 | 0 | 7.900 | 20 | 11.550 | 5 | | | 20.100 | 0 |
| | | 8.000 | 20 | 12.000 | 5 | | | 21.000 | 0 |
| | | 8.200 | 0 | 12.050 | 0 | | | | |
| | | 21.000 | 0 | 21.000 | 0 | | | | |

# VI. Control Time Histories

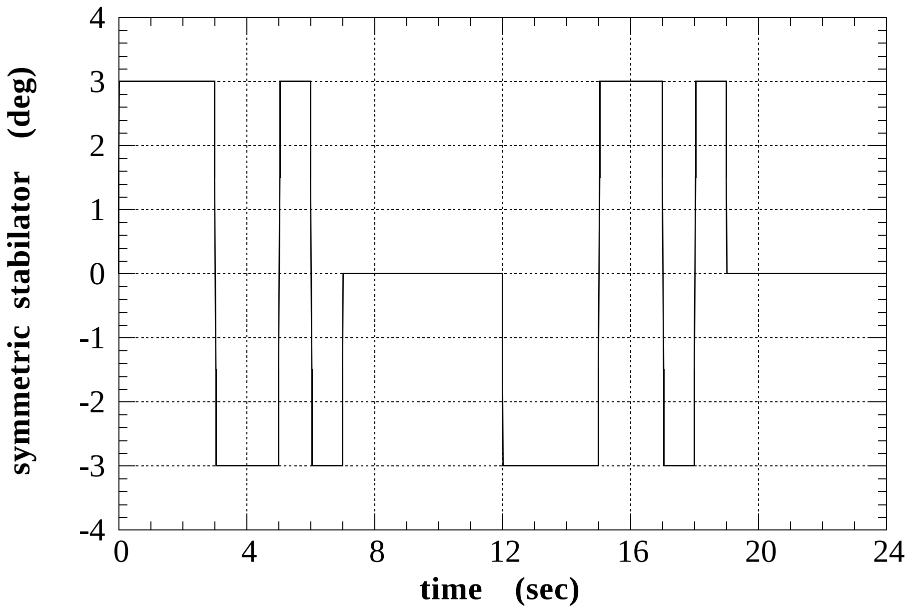



**Figure 1** F-18 HARV 3-2-1-1 Longitudinal Stabilator Input, $\alpha = 5$ degrees

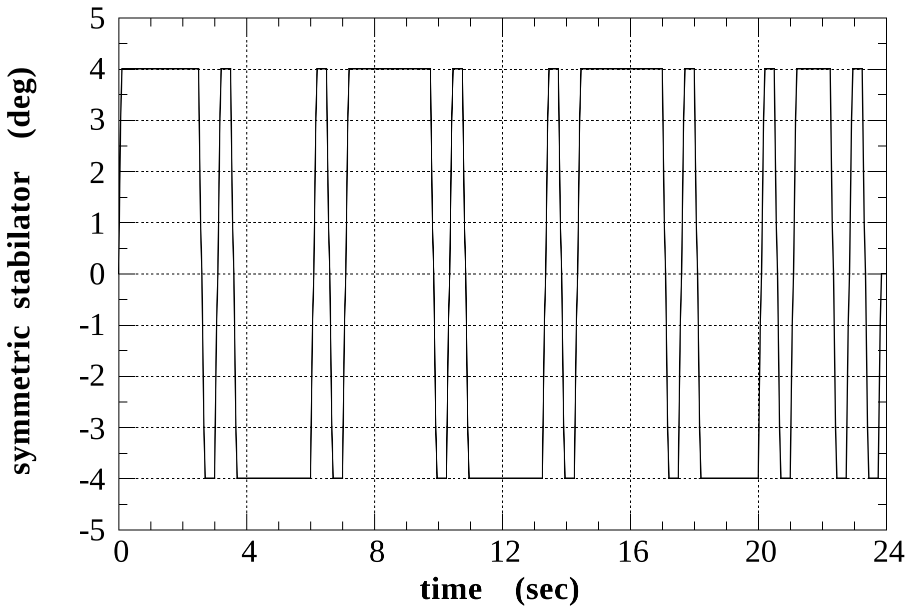



**Figure 2** F-18 HARV Optimal Longitudinal Stabilator Input, $\alpha = 5$ degrees

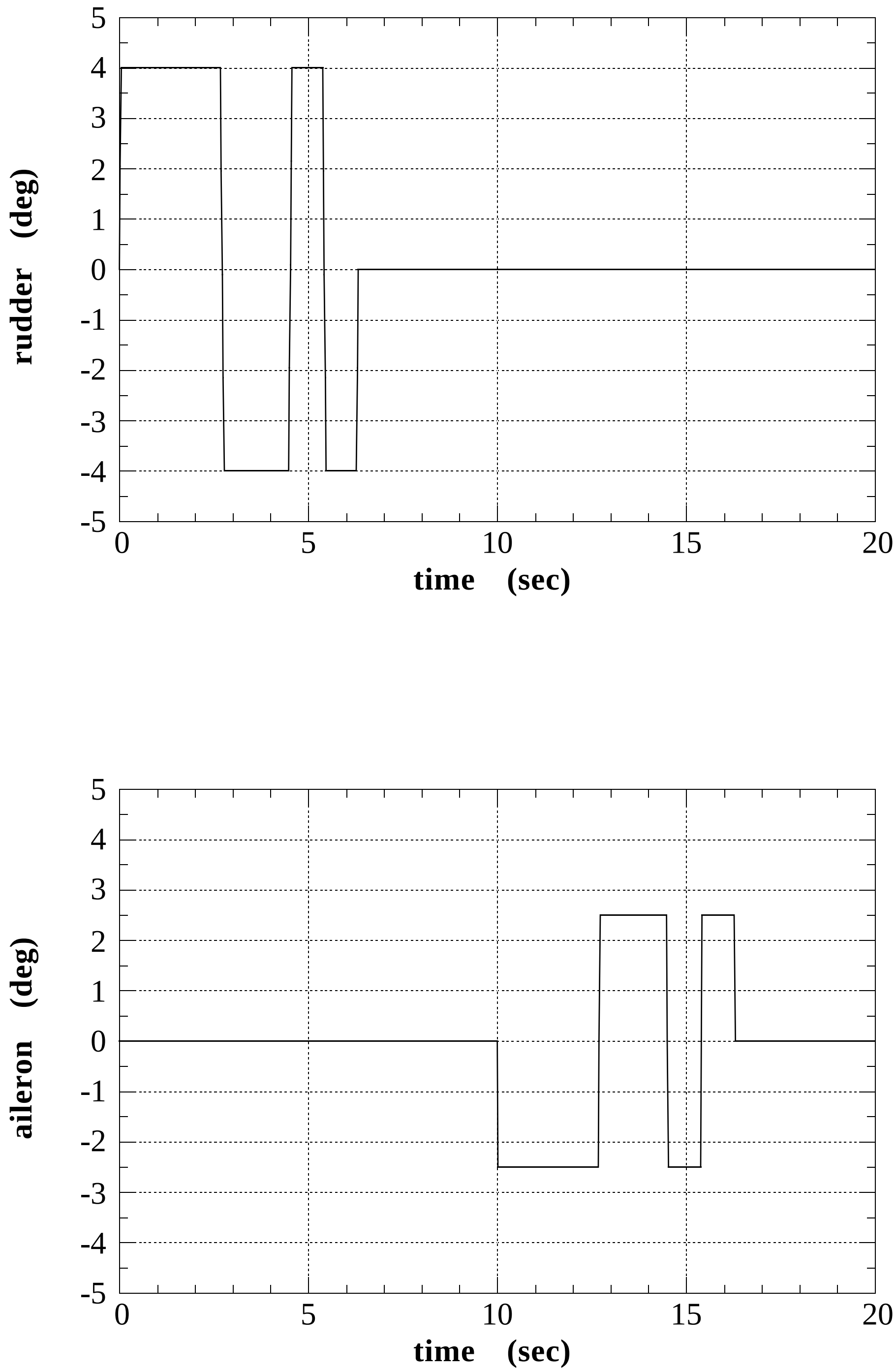



**Figure 3** F-18 HARV 3-2-1-1 Lateral Rudder/Aileron Inputs, $\alpha = 5$ degrees

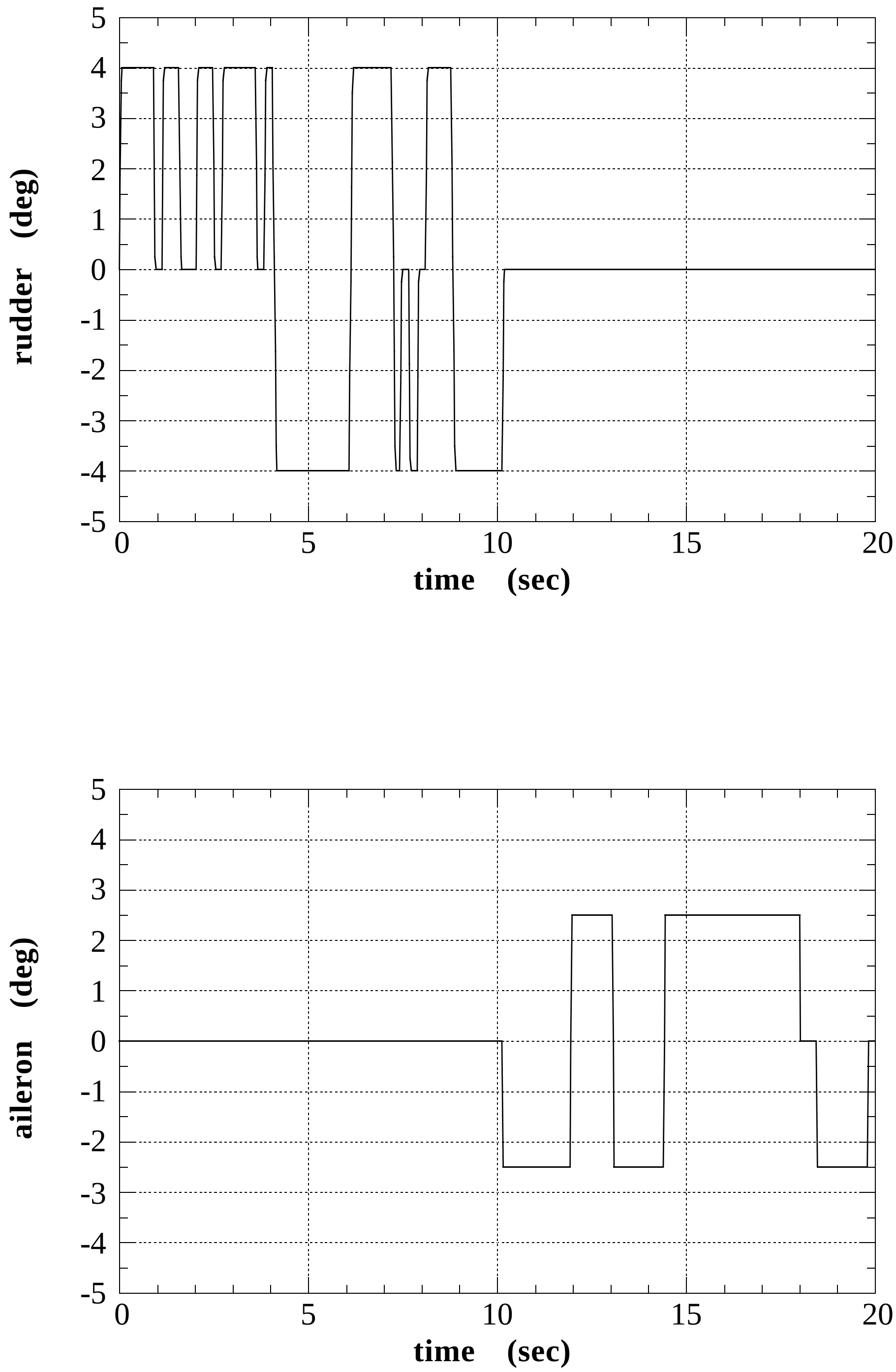



**Figure 4** F-18 HARV Sequential Optimal Lateral Rudder/Aileron Inputs, $\alpha = 5$ degrees

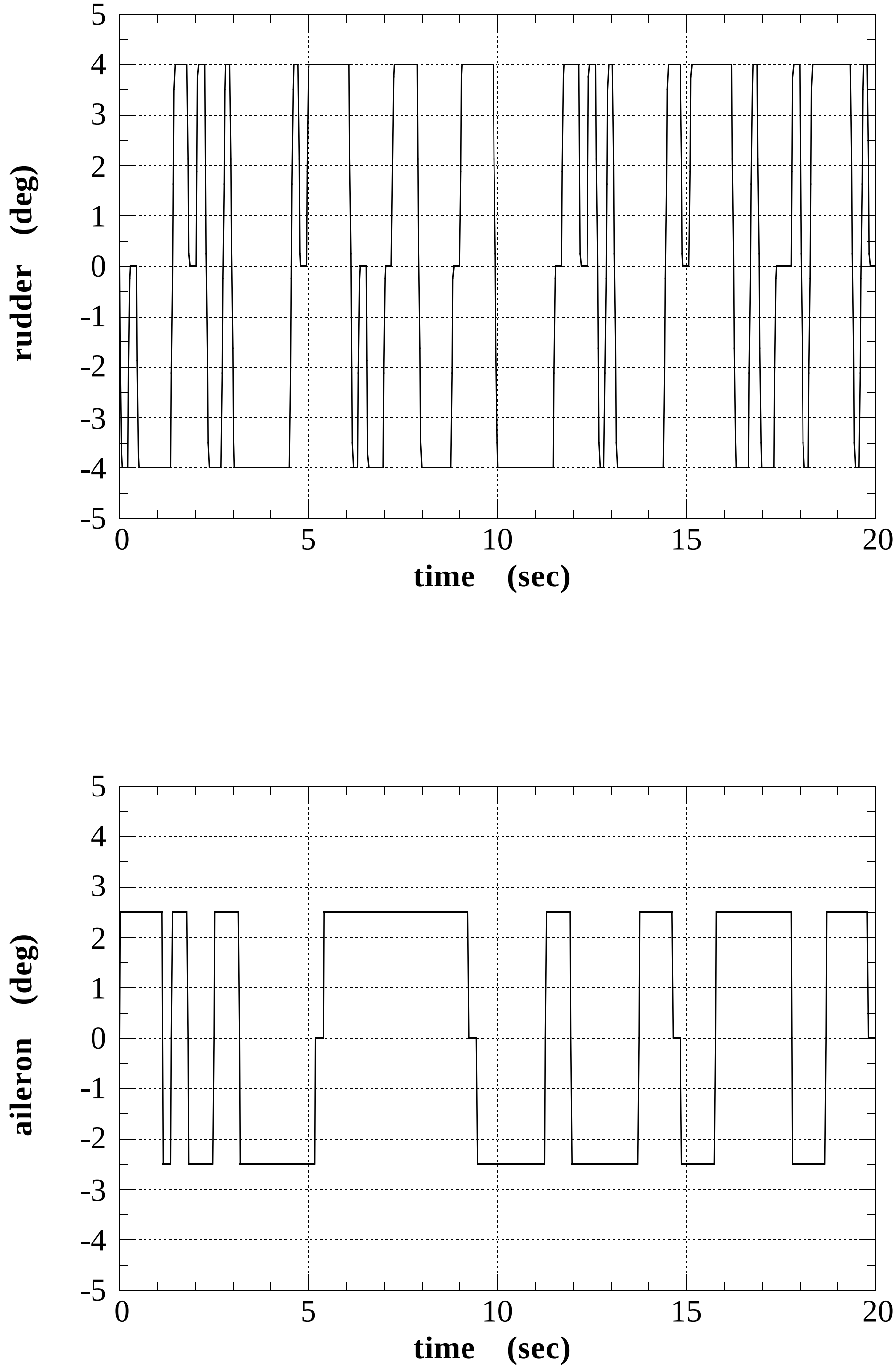
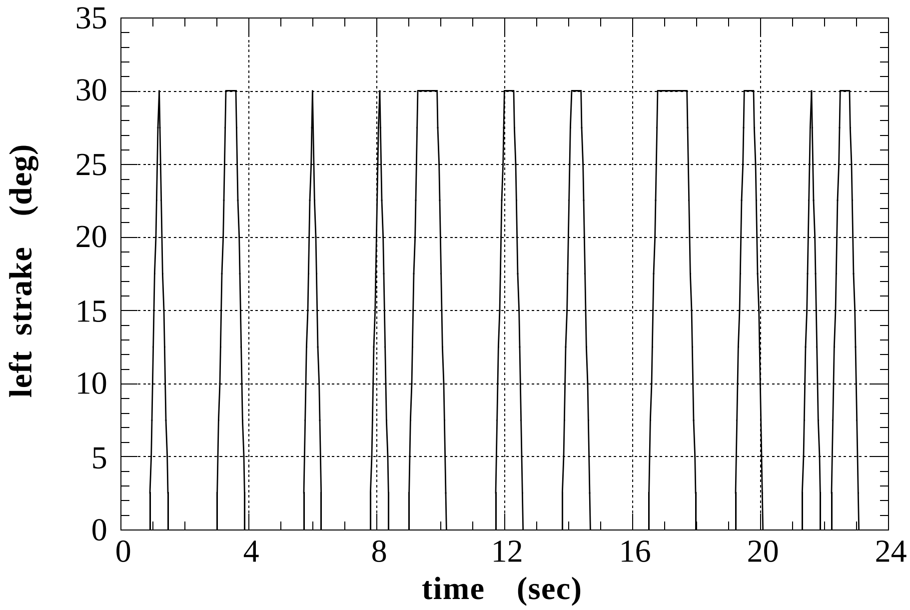



**Figure 5** F-18 HARV Optimal Lateral Rudder/Aileron Inputs, $\alpha = 5$ degrees



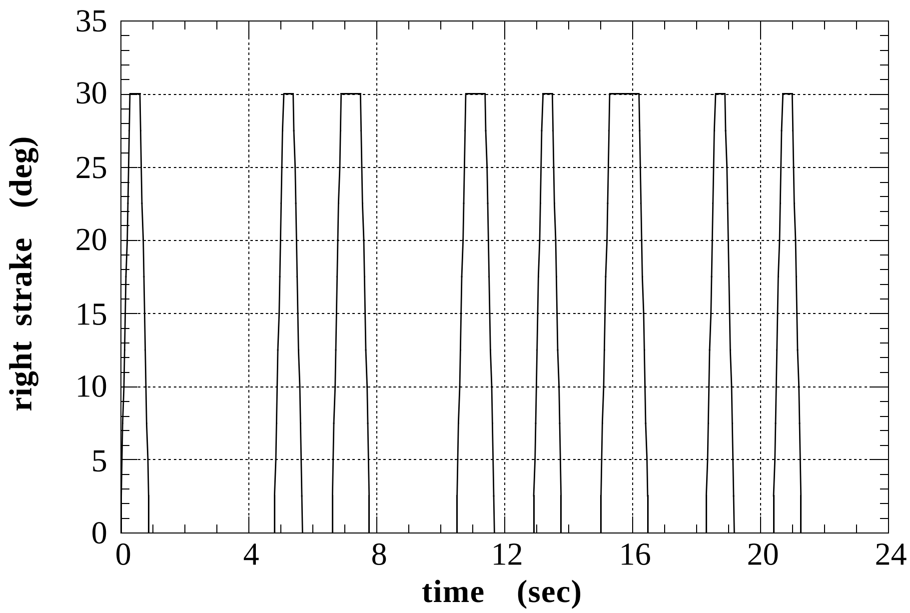




**Figure 6** F-18 HARV Optimal Lateral Left/Right Strake Inputs, $\alpha$ = 40 degrees

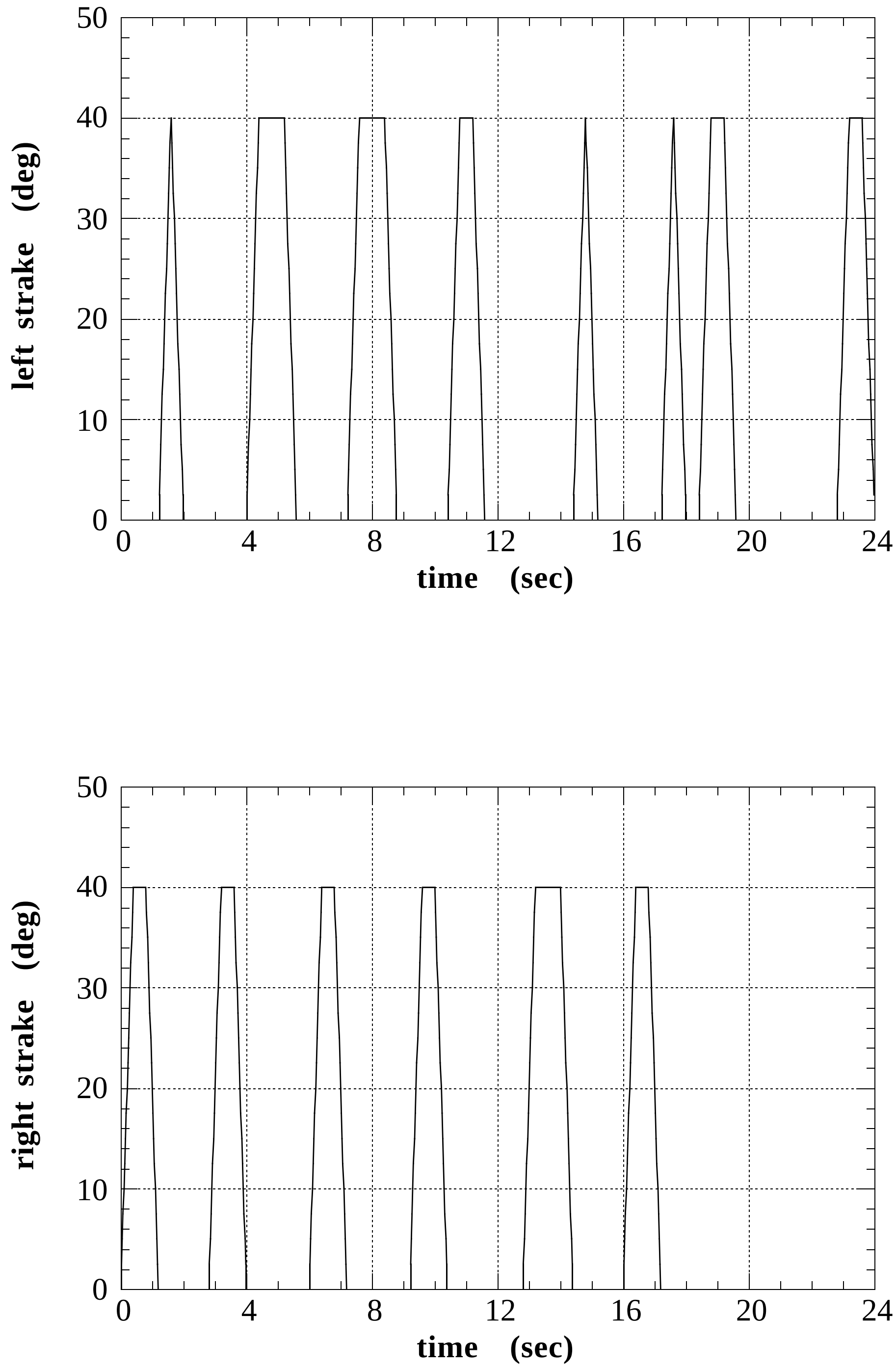
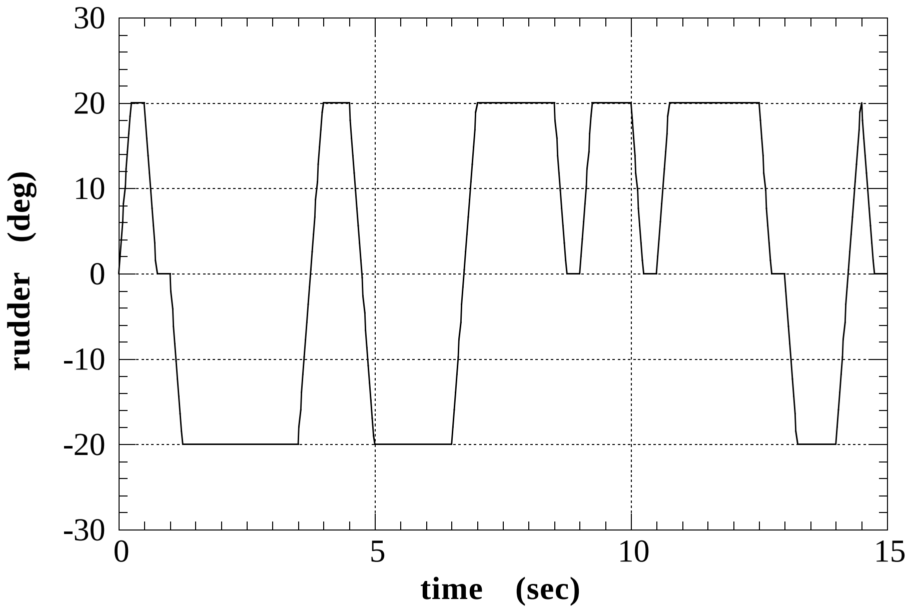
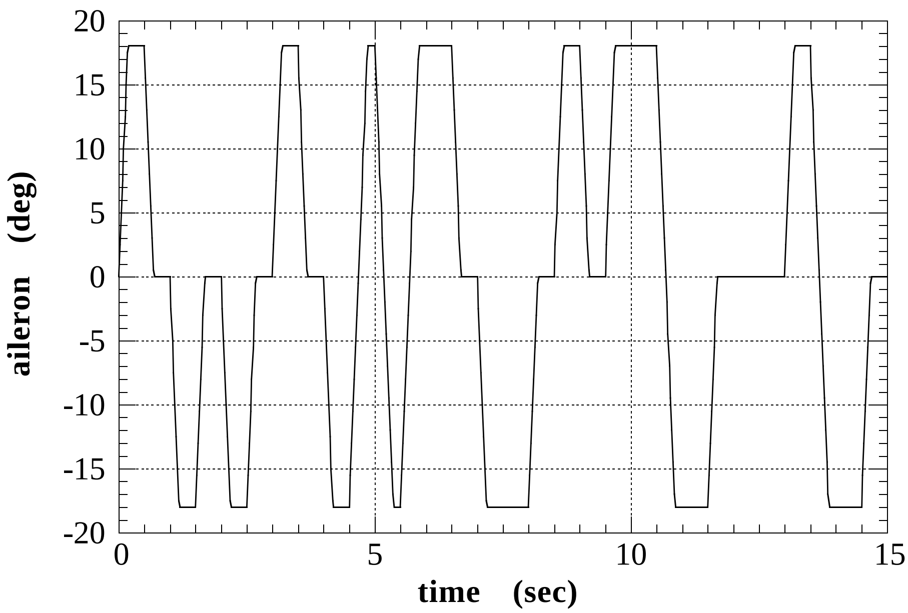



**Figure 7** F-18 HARV Optimal Lateral Left/Right Strake Inputs, $\alpha = 50$ degrees




**<u>Figure 8</u>** F-18 HARV Optimal Lateral Rudder/Aileron Inputs, $\alpha = 40$ degrees

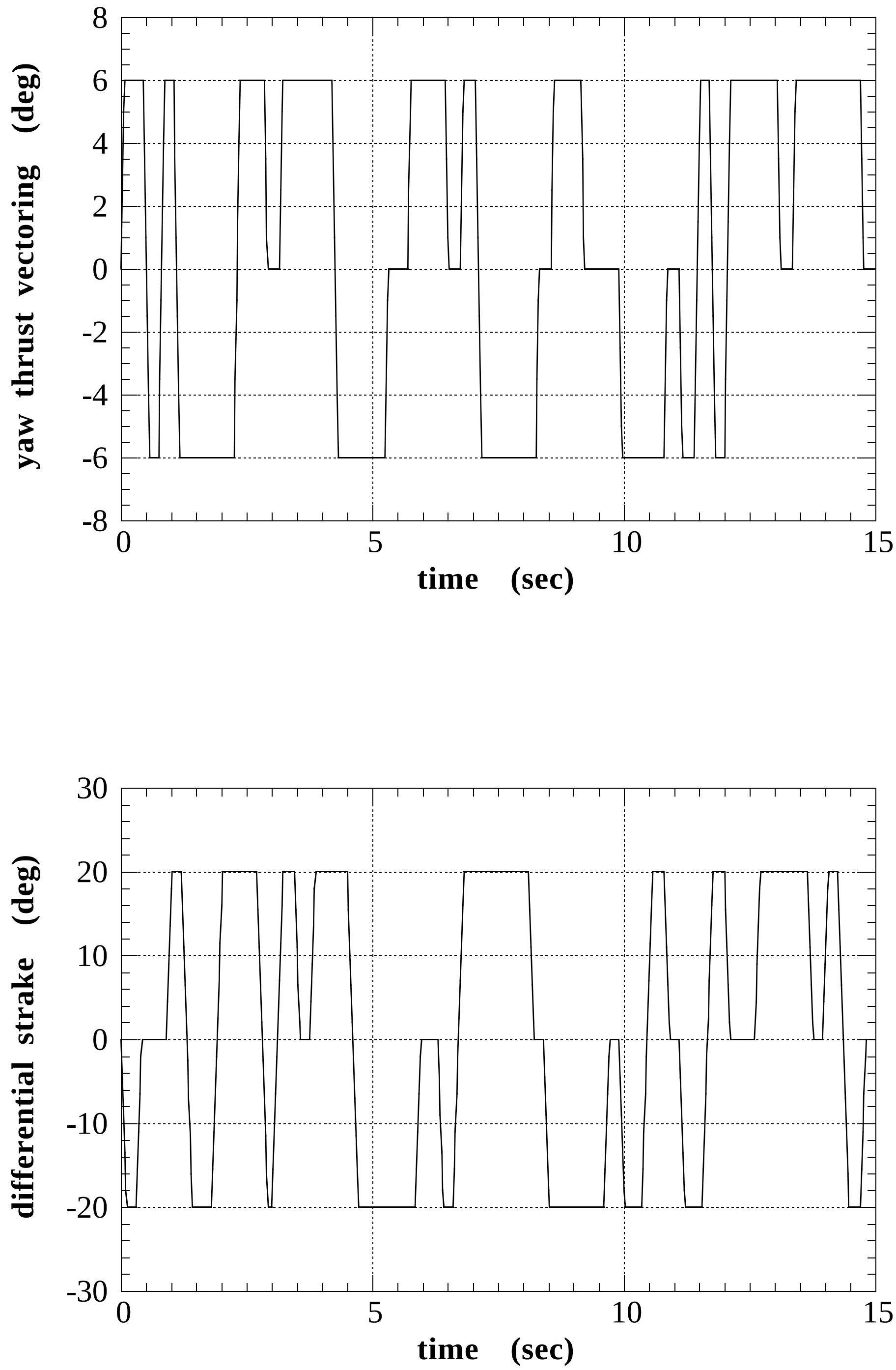



**Figure 9** F-18 HARV Optimal Lateral Yaw TV/Differential Strake Inputs, $\alpha$ = 40 degrees

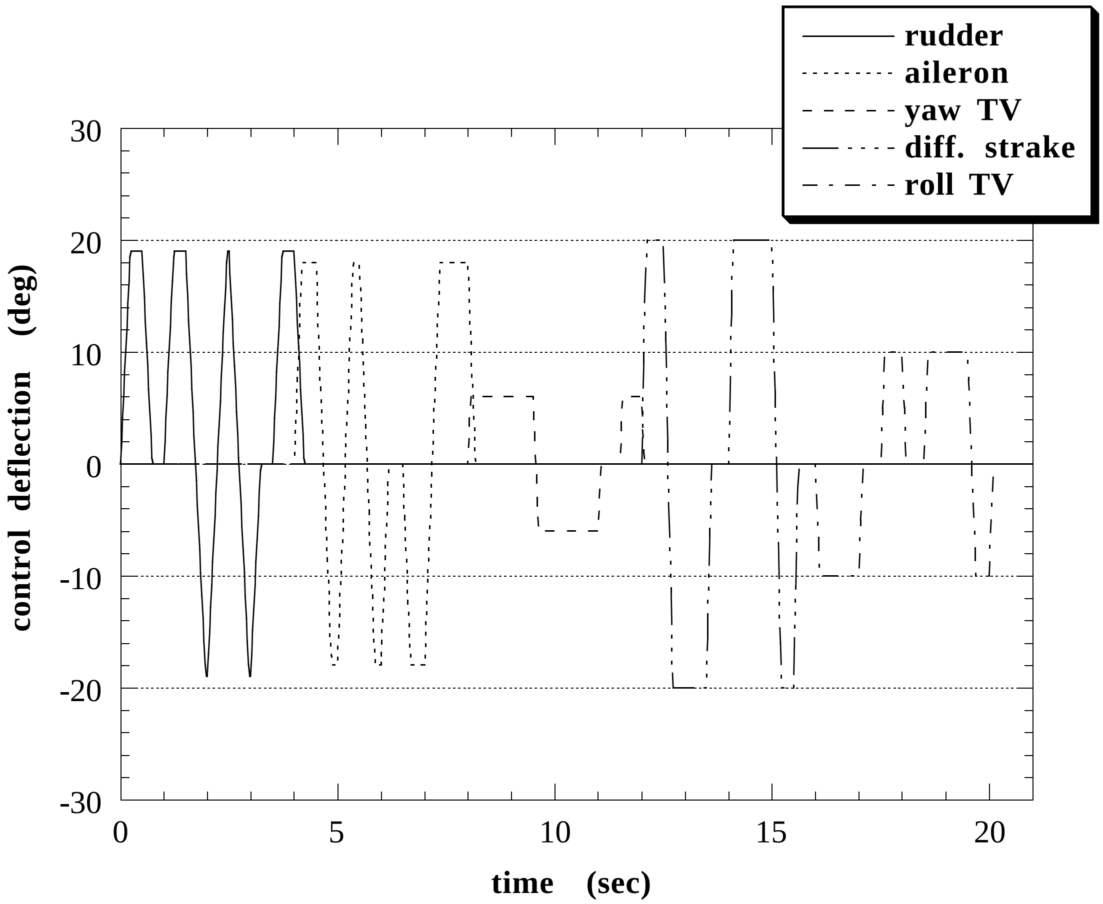



**Figure 10** F-18 HARV Optimal Lateral Rudder/Aileron/Yaw TV/Differential Strake/Roll TV Inputs, $\alpha = 40$ degrees

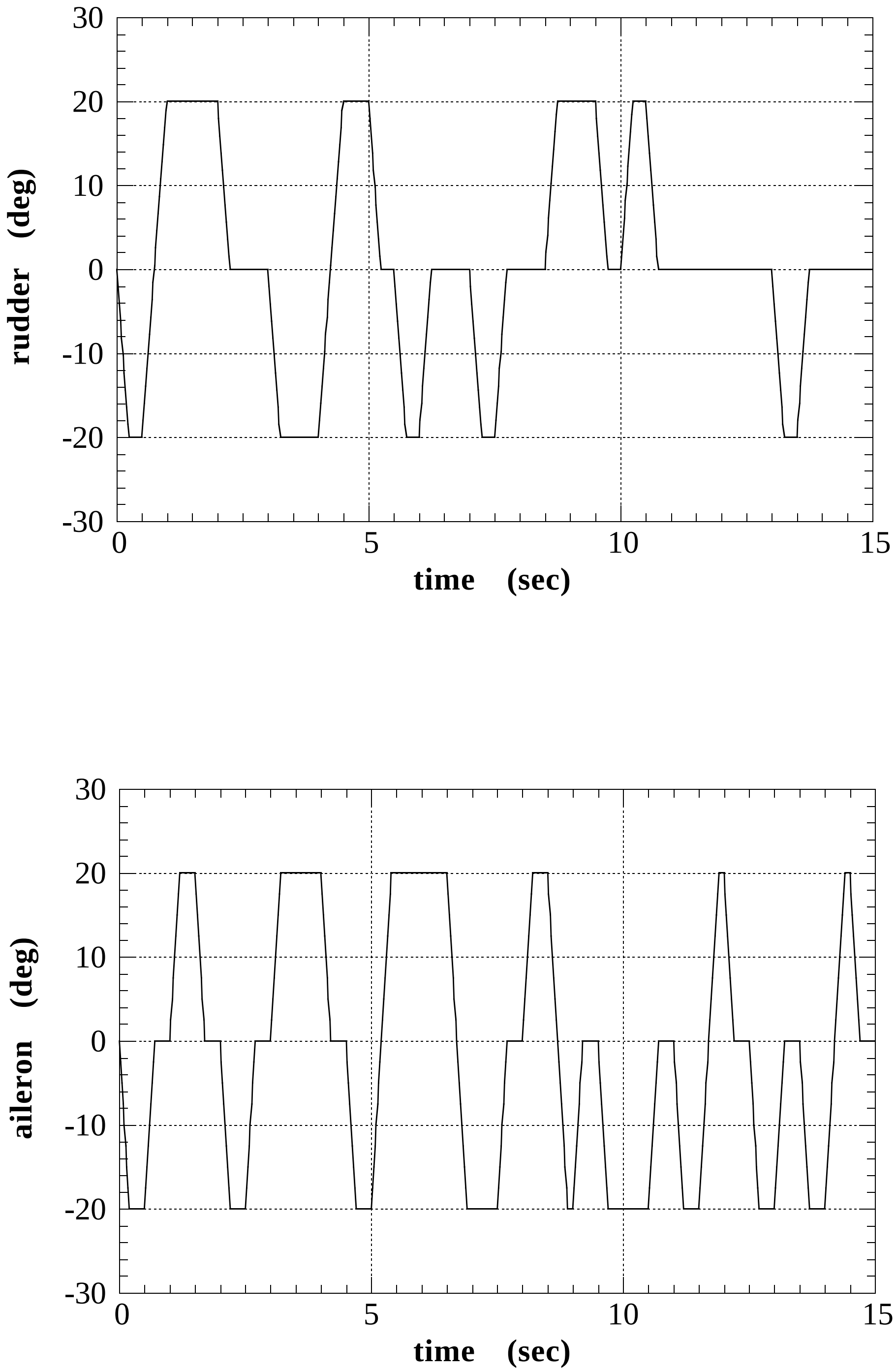
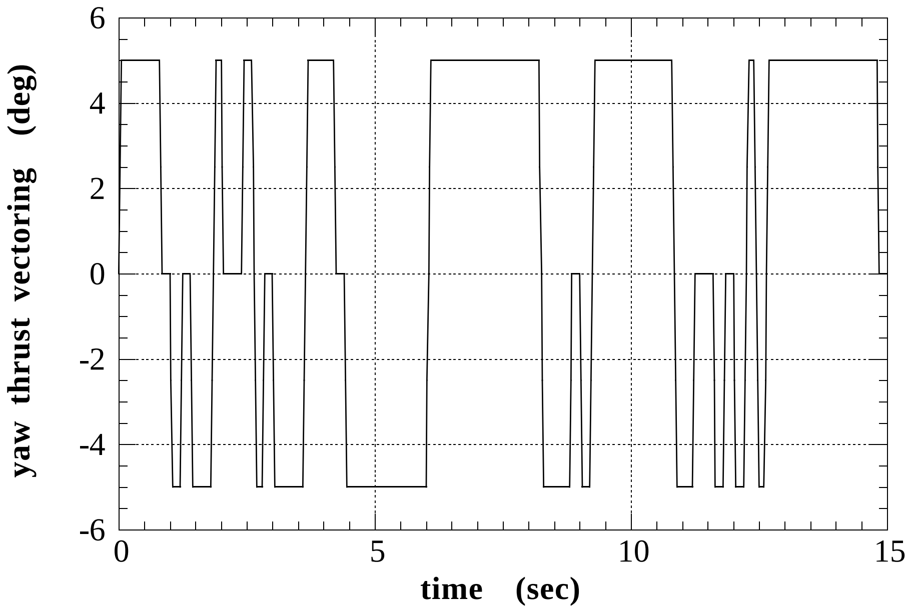



**Figure 11** F-18 HARV Optimal Lateral Rudder/Aileron Inputs, $\alpha = 50$ degrees



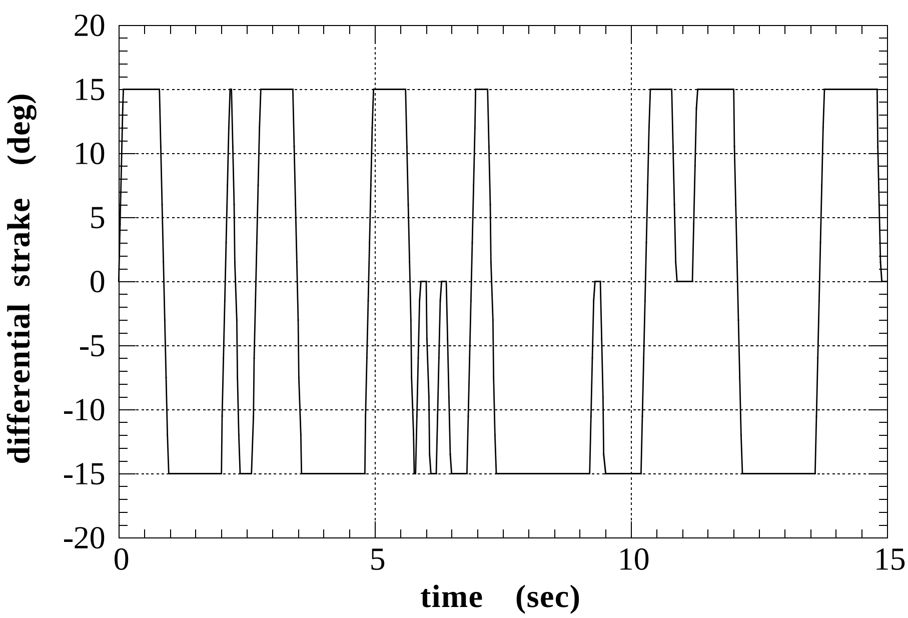




**Figure 12** F-18 HARV Optimal Lateral Yaw TV/Differential Strake Inputs, $\alpha = 50$ degrees

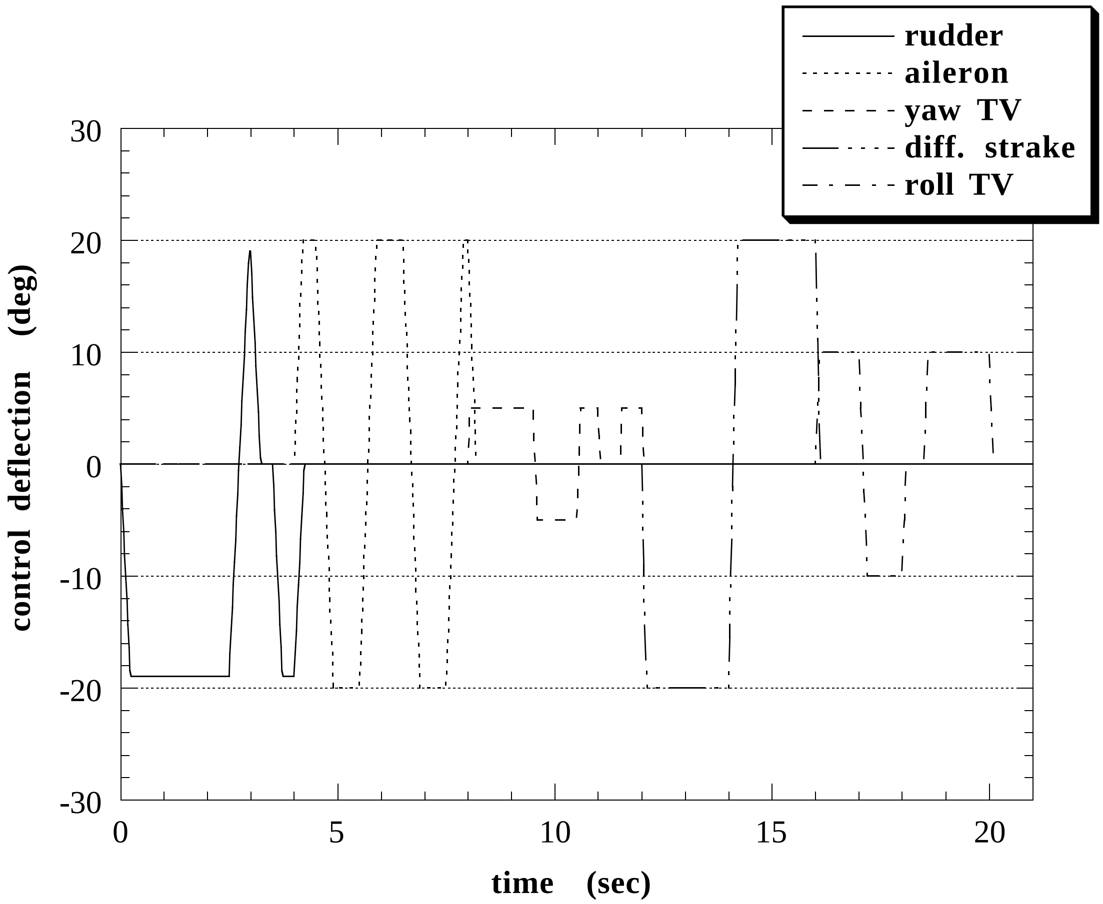



**Figure 13** F-18 HARV Optimal Lateral Rudder/Aileron/Yaw TV/Differential Strake/Roll TV Inputs, $\alpha = 50$ degrees