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A PARAMETRIC STUDY OF PLANFORM AND AEROELASTIC EFFECTS ON AERODYNAMIC CENTER, α- AND q- STABILITY DERIVATIVES

APPENDIX D

PROCEDURES USED TO DETERMINE THE MASS DISTRIBUTION FOR IDEALIZED LOW ASPECT RATIO TWO SPAR FIGHTER WINGS

by

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1. INTRODUCTION

The purpose of this appendix is to describe the method used in preparing the mass matrices for the parametric study of Reference 1. Although it is feasible to develop generalized procedures for finding approximate mass distributions of arbitrary airplanes this has not been done under this grant. Instead only the procedures used to establish the mass matrices characteristic for the fighter type wings studied in Reference 1 are given.

A description of the procedure used to find the mass associated with a specific aerodynamic panel is given in Section 2. Section 3 gives some examples of the application of the procedure given in Section 2.

2. PROCEDURE USED TO FIND WING MASS DISTRIBUTIONS

Figures 1, 2, and 3 present wing mass distributions in slugs/ft (kgm/m). These mass distributions apply to all wings of the parametric study of Reference 1.

To determine the mass assigned to each aerodynamic panel it is necessary to know the spanwise and chordwise mass distributions of each wing. For purposes of this study it was assumed that the wing mass can be broken down into the following components:

1. Wing structural mass distribution
2. Wing control surface (including the associated hydraulics) mass distribution
3. Wing fuel mass distribution

Figures 1, 2, and 3 present typical wing mass distributions in slugs/ft (kgm/m) for these cateogries.

The mass distribution shown in these figures were taken from unpublished weights data for representative fighter aircraft. These data were presented in ratio $\left(\frac{\text{Component Weight}}{\text{Total A/C Gross Weight}}\right)$ form. The area under each curve in Figures 1, 2, and 3 represents the total component mass. For each mass component a distribution along the chord was also developed. Results are shown in Figure 4. A detailed explanation of the shapes of these mass distributions will be given next.

In Figure 1, the total wing structural mass was first assumed to vary in a parabolic manner along the half span similar to the wing bending moment due to a uniformly distributed loading. This parabolic curve (not shown in Fig. 1) would show the wing structural mass more concentrated toward the centerline of the planform than as shown in Figure 1. This parabolic curve was then modified empirically with the following guidelines: (1) the wing is to carry fuel out to the wing tip and (2) in the case of variable sweep planforms, the wing pivot is located outboard of the planform centerline. Both guidelines require added structural integrity outboard of the root section. Using these guidelines and requiring that the total area under the distribution curve equals 77.2 slugs (1130 kgm), the empirical distribution curve of Figure 2 was determined. The value of 77.2 slugs for structural mass of the half wing was arrived at using the unpublished weight ratio mentioned before.

Figure 2 was developed by assuming that the controls and hydraulics were evenly distributed along the half span and located only behind the rear spar.

The mass distribution of Figure 3 was developed by assuming that the wing has a constant thickness ratio. Thus the thickness varies as a straight line from root to tip and the fuel distribution was also assumed to vary in the same manner.

The chordwise mass distributions shown in Figure 4 were developed in the following manner. Figure 4a was generated by assuming that each one of the two spars represented 30% of the wing structural mass. The remaining 40% of the wing structuralmass was distributed uniformly over the entire chord giving a value of 0.4 units over the entire 100% chord (since 0.4 units x 100% = 40%). The two spars were arbitrarily positioned at 20% and 70% chord in all the wings of the parametric study of Reference 1, and their masses were considered to be concentrated in the ranges from 19% to 21% chord and from 69% to 71% chord. Thus in order for each spar to represent 30% of the structural mass, the wing structural mass due to the spar over its 2% chord range must be 15 units (since 2% x 15 units = 30%). This is added to the 0.4 units uniform distribution giving a final value of 15.4 units at the spars. Note that the total area under the curve in Figure 4a is equal to 100%, or the total structural mass. The control surface mass in Figure 4b is assumed to be evenly distributed between the rear spar and the trailing edge, giving a value of 3.33 units over 30% of the chord to

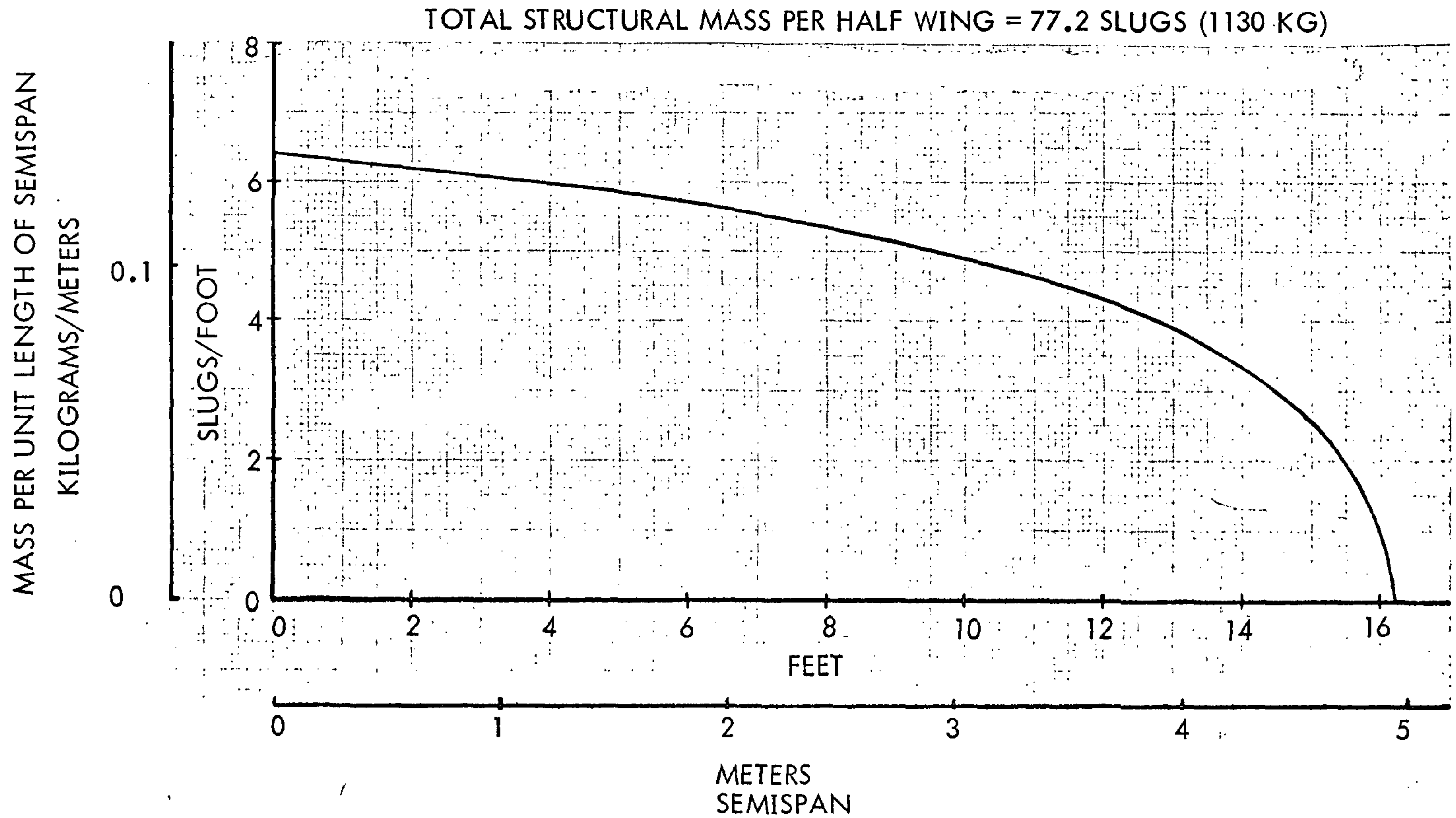

Figure 1   Spanwise Distribution of Structural Wing Mass

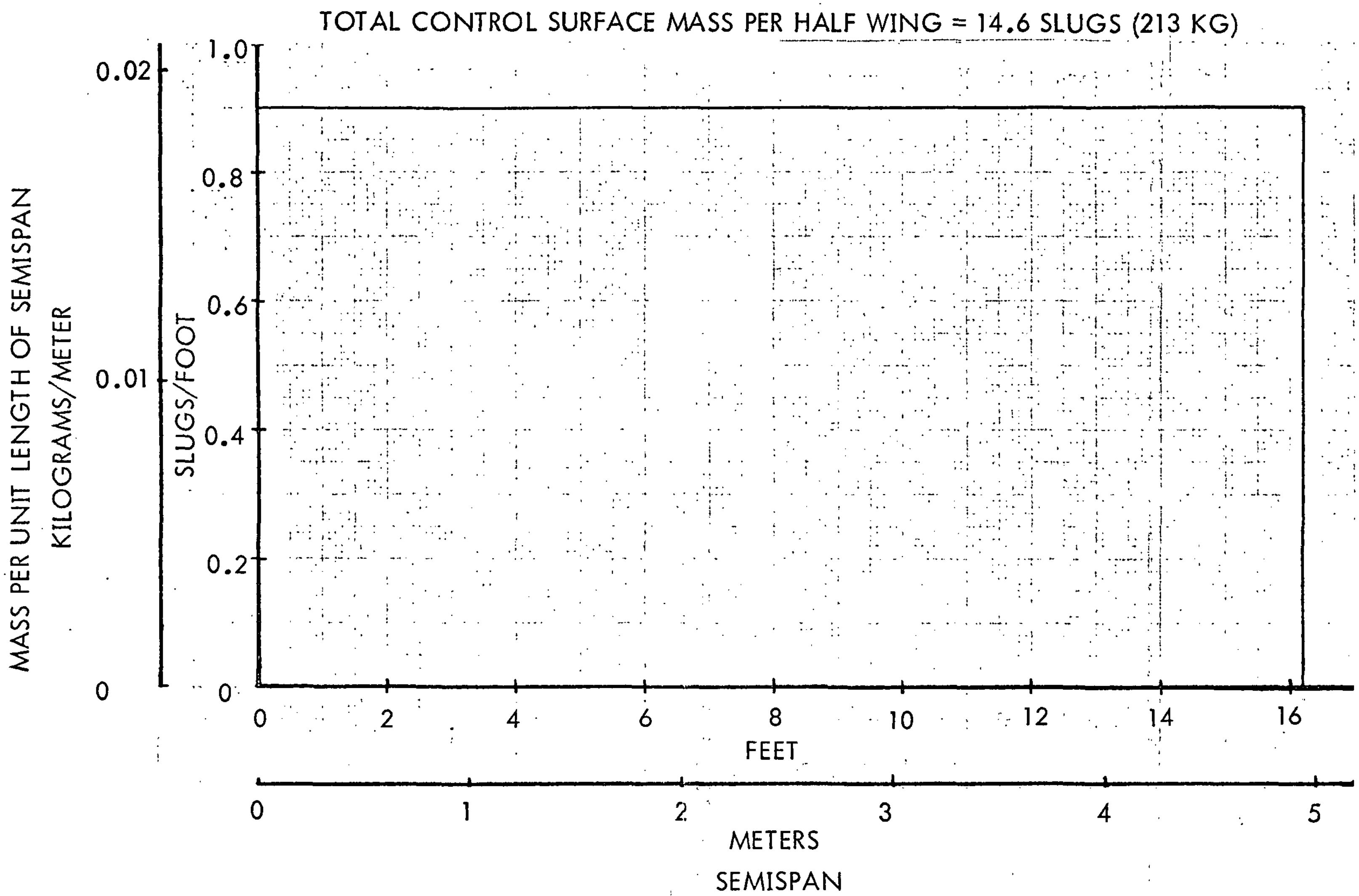

Figure 2 Spanwise Distribution of Control Surface Mass (Including Hydraulics)

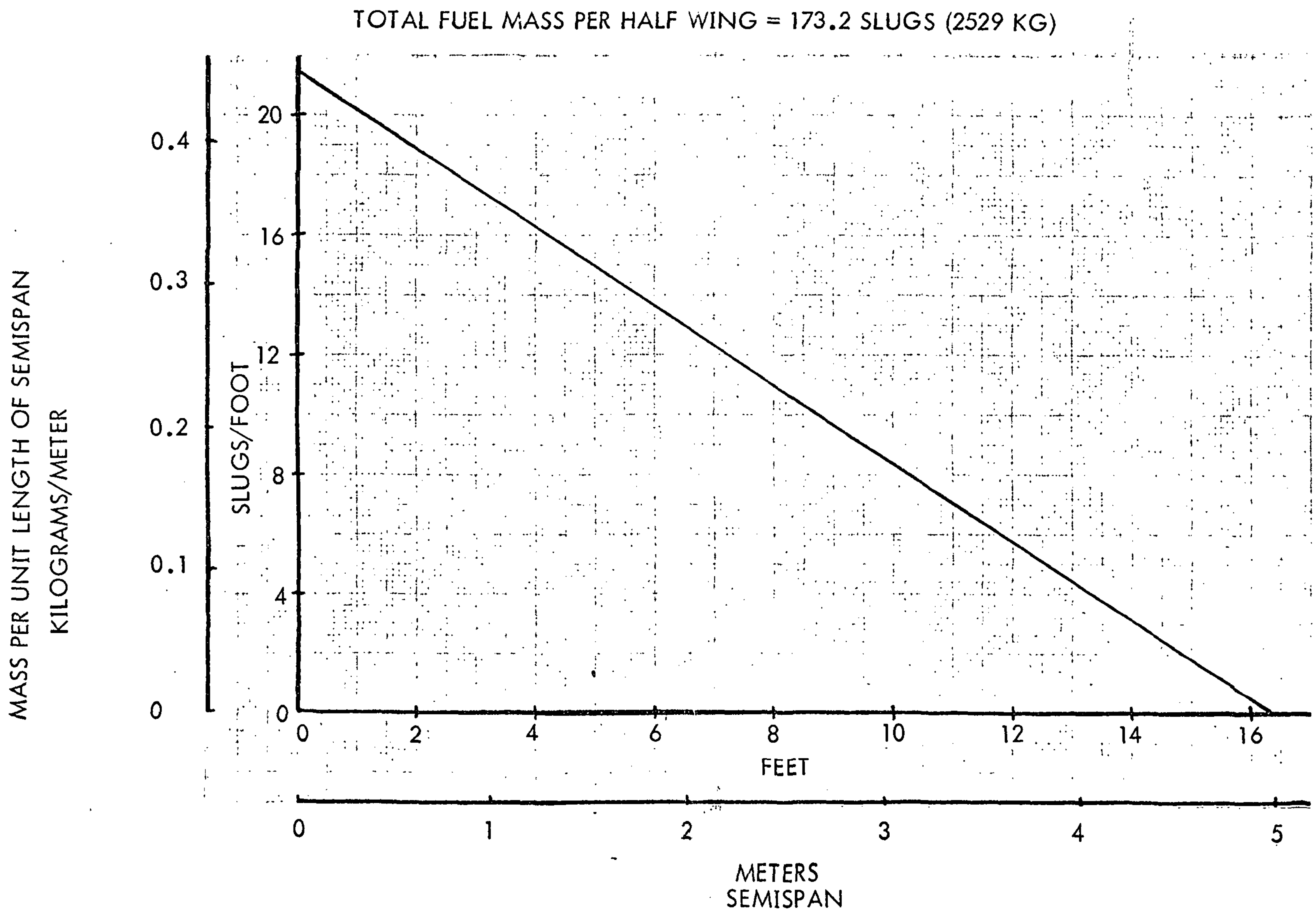

Figure 3 Spanwise Distribution of Fuel Mass

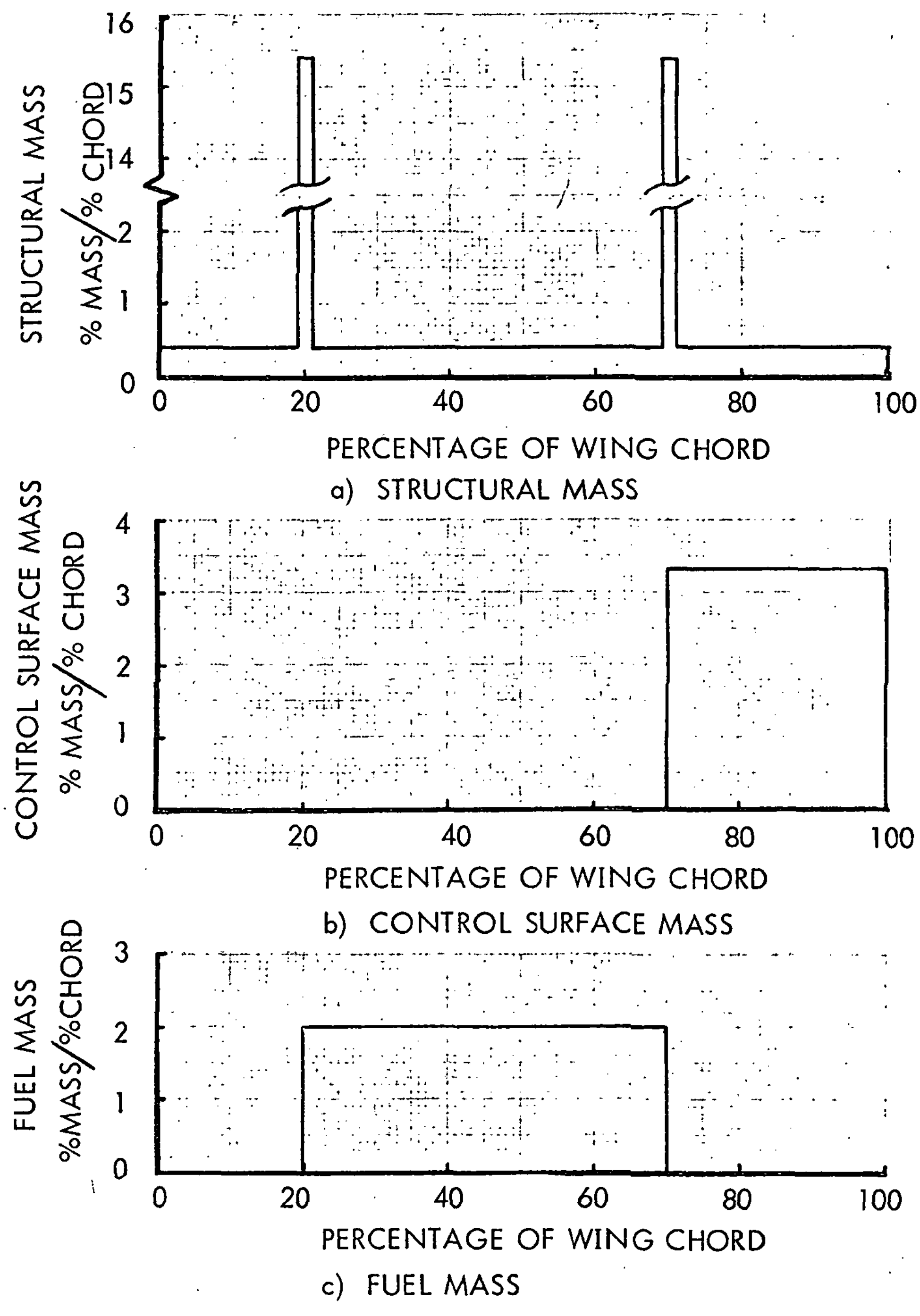

Figure 4 Chordwise Distribution of Component Masses at Each Spanwise Station

account for 100% of the control surface mass. The chordwise fuel mass distribution in Figure 4c was assumed to be uniformly distributed between the spars. A value of 2 units over the 50% chord range between the two spars accounts for 100% of the fuel mass.

It was also assumed that the mass plots of Figures 1 through 4 apply to both fixed sweep and variable sweep wings.

The actual assignment of a mass to a wing panel is based on the area of that panel, its spanwise distance from the root chord and also its chordwise distance from the wing leading edge.

For a horizontal tail, the procedure is quite similar to that used for the wing. First it is necessary to establish the total tail weight. This is done using ratioed data on comparable fighter aircraft. Second, the spanwise and chordwise distributions are established using philosophies similar to those used in the case of the wing. Third, the panel mass is found from knowledge of its location on the planform.

For a fuselage, it is necessary to use a significant amount of judgement because of the effects of payload, systems, crew provisions, wing and tail tie-in etc.

When existing airplanes (as opposed to parametric airplanes) are used, it is of course possible to establish the actual mass distribution on the basis of hard facts rather than guesstimates.

Section 3 describes examples of how specific panel weights were established for the parametric study of Reference 1.

3. EXAMPLE OF MASS CALCULATION FOR SPECIFIC PANELS

To illustrate the use of the procedures discussed in Section 2, the following examples of the determination of the masses of some panels on the aircraft configuration shown in Figure 5 are now given.

First, consider panel 12 on the example configuration of Figure 5. The mass of this panel can be considered to be made up of fuselage mass and a wing mass since this is a configuration in which the fuselage and the wing are located in the same plane. Using the fuselage mass distribution postulated from a typical fighter airplane in Figure 6, the following procedure is used to find the fuselage masses.

Step 1) The line midway between the configuration's center line and the line representing the outboard side of the fuselage is located. This line is found to be 17.5 inches or 1.45 ft (.445 m) from the centerline.

Step 2) The leading edge point of this line is found to be at fuselage station 382.5 in (9.37 m).

Step 3) The trailing edge point of this line is found to be at fuselage station 417.5 in (10.59 m).

Step 4) Integrating the curve in Figure 6 between these limits gives a mass of 108.60 slugs (1586 kgm).

The following procedure is used to find the wing mass of panel 12.

Step 1) The width, inboard and outboard y-coordinates of the column of containing the desired panel is determined, and then multiplied by the ratio of the semi-spans to fit Figures 1, 2, and 3. For panels 10-16:

$$\text{ratioed width} = (2.917 \text{ ft}) \left(\frac{16.2\text{ft}}{19.375 \text{ ft}} \right) = 2.439 \text{ ft } (.742 \text{ m})$$

ratioed inboard y-coordinate = 0 ft (0 m)

ratioed outboard y-coordinate = 2.439 ft (.742 m)

Step 2) The curves in Figures 1, 2, and 3 are integrated across the chordwise column of panels to give the structural, control surface and fuel masses of the column.

From Figure 1 the wing structural mass distribution ranges from 6.41 slugs/ft (inboard) to 6.13 slugs/ft (outboard). Integrating this gives 15.29 slugs (223.2 kgm) for panels 10 through 16.

From Figure 2 the wing control surface mass for panels 10 through 16 is 2.19 slugs (32.04 kgm).

From Figure 3 the wing fuel mass for panels 10 through 16 is 48.29 slugs (705.0 kgm).

Step 3) The chordwise mass distributions of Figure 4 are now used to find the masses of each panel in the spanwise column of panels. The plots of Figure 4 show the percentage of the mass to be assigned to the different panels.

The wing planform has been divided by eight equally spaced constant percentage chordwise lines, and panel 12 lies between 28.6% chord and 42.9% chord. Integrating the area between these lines in Figure 4a gives a structural mass of

$$\frac{(42.9 - 28.6)}{100} (.4) (15.29) = 0.875 \text{ slugs } (12.81 \text{ kgm})$$

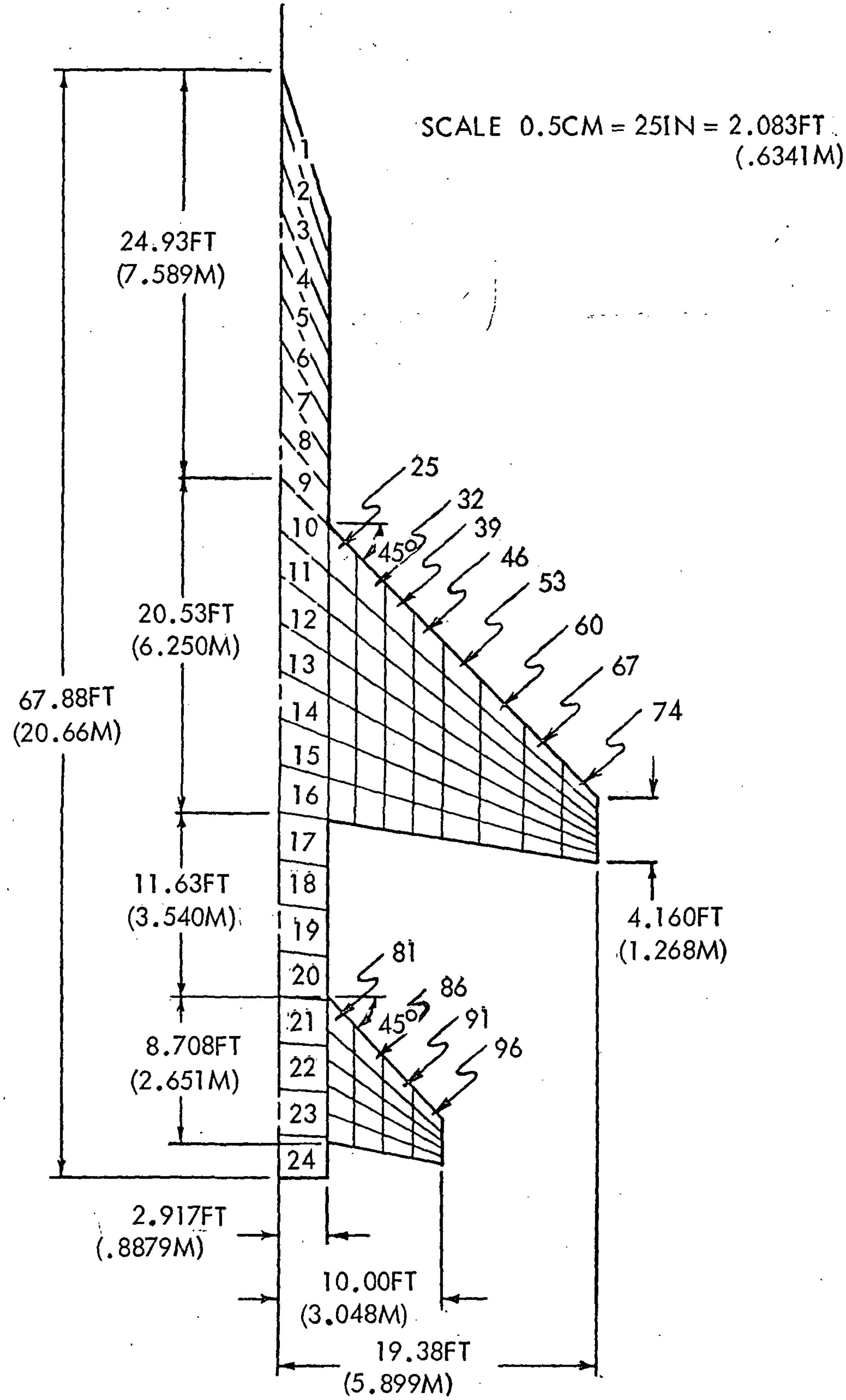

Figure 5 Example of a Complete Wing-Body-Tail Configuration

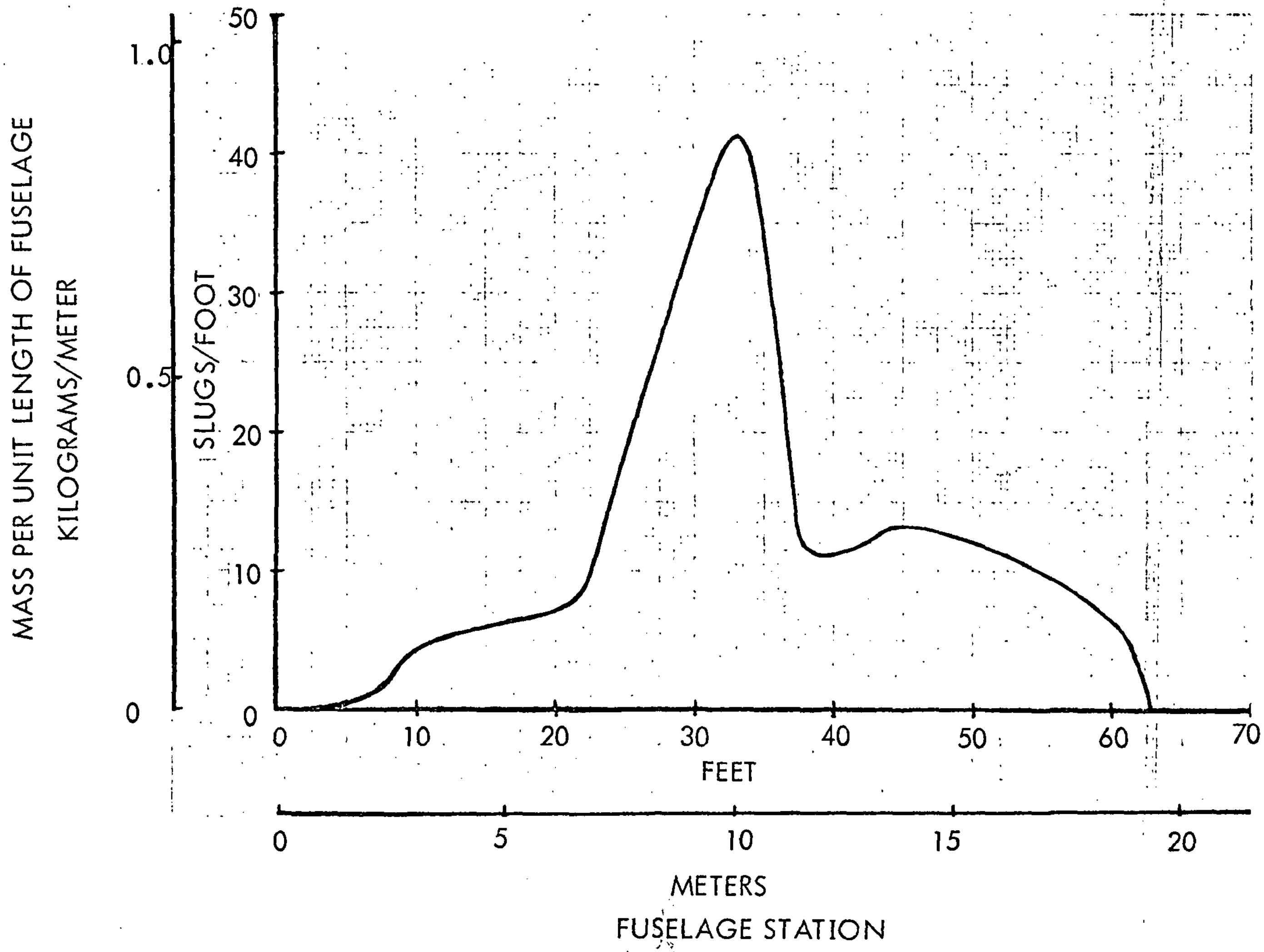

Figure 6 Fuselage Distribution for the Configuration of Figure 5

From Figure 4b the control surface mass will be:

$$\frac{(42.9 - 28.6)}{100} \; (0) \; (2.19) = 0 \text{ slugs (0kgm)}$$

From Figure 4c the fuel mass will be:

$$\frac{(42.9 - 28.6)}{100} \; (2) \; (48.29) = 13.81 \text{ slugs (202.33 kgm)}$$

The total wing mass for panel 12 is therefore:

$.875 + 13.81 = 14.69$ slugs (215.2 kgm)

The total mass of the panel is the sum of this and the fuselage mass obtained earlier. This is given by:

$108.6 + 14.69 = 123.3$ slugs (1806 kgm)

As a second example, consider panel number 90 on the horizontal tail. The procedure followed for the wing is followed using Figures 1, 2, and 4.

Step 1) The percentage width of the spanwise column containing panel 90 is given by:

$$\text{Percentage width} = \tfrac{1}{4} \left(\frac{10.0 \text{ ft} - 2.917 \text{ ft}}{10.0 \text{ ft}}\right) = 17.7\%$$

Step 2) This represents 1.77 ft (.539 m) since the semispan is 10ft.

Step 3) For Figures 1 and 2, the ratioed width of the column of panels is:

$$(1.77) \left(\frac{16.2}{10}\right) = 2.87 \text{ ft } (.873 \text{ m})$$

The ratioed inboard and outboard y-coordinates for panels 86 through 90 are:

$$\text{inboard: } (2.917 + 1.77) \left(\frac{16.2}{10}\right) = 7.59 \text{ ft } (2.31 \text{ m})$$

$$\text{outboard: } (2.917 + 3.54) \left(\frac{16.2}{10}\right) = 10.46 \text{ ft } (3.19 \text{ m})$$

Step 4) Since the area of the horizontal tail is one-third that of the wing, the structural mass and control surface masses are also one-third. Therefore, the structural mass for panels 86 through 90 is given below by reading the values of 5.39 slugs/ft and 4.78 slugs/ft at 7.59 ft and 10.46 ft respectively from Figure 1, and using the trapezoidal rule to integrate (including the factor 1/3).

$$(\tfrac{1}{2}) \; (5.39 + 4.78) \; (1/3) \; (2.87) = 4.862 \text{ slugs (71.17 kgm)}$$

The total control surface mass is given by integrating Figure 2 between 7.59 ft and 10.46 ft. (note that this curve is a constant .90 slugs/ft)

$(.90) \; (1/3) \; (2.87) = 0.860$ slugs (12.6 kgm)

Step 5) Since there are six constant percentage chordwise lines, panel 90 lies between the 80% and 100% chord lines. Integrating this area in Figure 4a, the structural mass is:

$$\frac{(100 - 80)}{100} \; (.4) \; (4.862) = .389 \text{ slugs (5.70 kgm)}$$

From Figure 4b, the control surface mass is:

$$\frac{(100 - 80)}{100} (3.33) (.860) = .573 \text{ slugs } (8.39 \text{ kgm})$$

The total mass of panel 90 is therefore:

$$.389 + .573 = .962 \text{ slugs } (14.09 \text{ kgm})$$

4. REFERENCES

1. Roskam, J., and Lan, C.; A Parametric Study of Planform and Aeroelastic Effects on Aerodynamic Center, α - and q- Stability Derivatives; NASA CR-2117; Summary Report, Prepared under NASA Grant NGR 17-002-071 by the Flight Research Laboratory of the Department of Aerospace Engineering of The University of Kansas, October, 1972.