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PRELIMINARY SIZING AND PERFORMANCE OF AIRCRAFT

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SUMMARY

A procedure that allows preliminary assessment of the effects of component size changes on the characteristics and performance capability of aircraft has been developed into a computer program. Applications can be made to subsonic, supersonic, and hypersonic aircraft using JP, liquid-hydrogen, or liquid-methane fuel. Jet engines as well as propeller systems can be treated. Basically, the program requires an input baseline aircraft on which component sizing changes are made; new aerodynamic, propulsion, and weight characteristics are then determined and a mission profile, including a reserve fuel segment, is computed to find the new aircraft's range capability. One of the output options provided by the program is the basis for preparing aircraft sizing "thumbprints" which pinpoint the wing and engine size for best performance.

INTRODUCTION

A computer program for aircraft sizing is a useful tool for preliminary aircraft system studies. The method must account for the interactions between aircraft geometry, aerodynamics, propulsion, and weights while providing rapid, low-cost evaluations of design options. Important advantages offered by this capability include the realistic assessment of technological advances and the identification of promising areas that justify further studies in greater depth.

A program that satisfies these requirements has been developed for use in the Aeronautical Systems Office at the NASA Langley Research Center. An earlier version was reported in reference 1. Briefly, the method performs sizing operations on a baseline aircraft and then a mission analysis to determine the effects of sizing on range. In the few instances where comparisons are possible, results of the method are in close agreement with similar ones in industry (refs. 2 and 3).

This paper contains a description of the processes used in the program, some applications of the program to subsonic, supersonic, and hypersonic aircraft, and definitions of input and output. For identification purposes, the program is called ASP, (A)ircraft (S)izing (P)erformance program.

SYMBOLS

BF	Breguet factor, $V(L/D)/SFC/(1 - V^2/gR_e)$
C	centigrade
C_D	drag coefficient
$C_{D,BL}$	engine bleed drag coefficient
C_{D_0}	zero-lift drag coefficient
C_L	lift coefficient

D	drag
$D_{MAX,F}$	maximum diameter of fuselage
$F_{N,F}$	fuselage fineness ratio
g	gravitational acceleration
H	altitude
L	lift
L/D	lift-drag ratio
$(L/D)_{MAX}$	maximum lift-drag ratio
L_F	length of fuselage
M	Mach number
P/W	shaft horsepower-to-gross weight ratio
R	range
R_e	radius of earth
SFC	specific fuel consumption
t	time
T	thrust
T/W	thrust-to-gross weight ratio
V	velocity
V_{AP}	approach velocity
V_{LO}	lift-off velocity
V_{rotate}	velocity at start of rotation during takeoff
W	weight
W_F	fuel weight
W_G	gross weight
W/S	wing loading, gross weight/reference area
α	angle of attack
θ	flight path angle
δ_F	flap deflection

Subscripts

AP	approach
BL	baseline aircraft or bleed drag
F	fuel
LO	lift off
MAX	maximum
SL	sea level

A dot over a symbol denotes its time derivative.

PRELIMINARY CONSIDERATIONS

The computer program described herein cannot be used to design an aircraft concept. Instead, the program performs operations on a baseline aircraft which has already been designed in sufficient detail to provide the required inputs. Within the program, this baseline aircraft is sized according to optional input values such as wing loading, engine thrust, number of passengers, and gross weight. After sizing, the aerodynamic, propulsion, and weight characteristics of the aircraft are determined; then a mission profile with reserve fuel segments is computed to find the range of the aircraft.

Some of the output provided by the program include:

1. Range for given gross weight and number of passengers
2. Gross weight for given range and number of passengers
3. Number of passengers for given range and gross weight
4. Payload - range curve
5. Passenger and fuel offloading
6. Effects of technology advances in aerodynamics, propulsion, and weights
7. Effects of in-flight refueling
8. Mission radius to payload drop
9. Information for preparing an aircraft sizing "thumbprint." (A "thumbprint" is a map of constant value contours, like range or gross weight, plotted as a function of engine and wing size.)

The program can be applied to subsonic, supersonic, or hypersonic aircraft using JP, liquid-methane, or liquid-hydrogen fuel. Jet or propeller propulsion systems can be considered.

Five baseline aircraft have been chosen to illustrate the capabilities of the program. Computer drawings of these aircraft are shown in figure 1. All aircraft are preliminary concepts designed during in-house activities.

METHODS

Component Sizing

Fuselage.- To simplify drag calculations and packaging, the fuselage is approximated by an equivalent body consisting of a constant area midsection with end caps having a Sears-Haack profile (ref. 4). The constant area midsection contains the passengers, door-galley-lavatory sections, cargo, and, if required, cryogenic fuel tanks. Variables that affect the passenger compartment are the number of seats abreast, seat pitch and width, aisle width, and the length and number of door-galley-lavatory sections. Although these quantities may be input, their values may not all be preserved because final values are determined from the baseline aircraft using input values for passenger compartment length and abreast seating arrangement.

The arrangements available for fuselage packaging are shown in figure 2. The first arrangement (fig. 2a) applies to aircraft with one-passenger level and conventional fuel. In addition to the passengers, the arrangement contains the cargo normally stored beneath the floor; however, if not enough space is available, the excess cargo is stored in a section behind the passenger compartment. The cargo is assumed to be stored in cargo containers which occupy 60 percent of the available volume.

If the aircraft uses cryogenic fuel, the second arrangement (fig. 2b) places all the cargo behind the passenger compartment and fuel tanks are located beneath the floor. If more fuel volume is required, it is located in full-depth sections of the same length at both ends of the midsection.

The third arrangement (fig. 2c) has two identical passenger levels with aft cargo storage. If cryogenic fuel is required, it is stored in duplicate tanks fore and aft of the passenger compartment.

In application, the midsection length and diameter are calculated first for the requirements of the baseline aircraft. Then, from the length of the baseline aircraft, the length of the fuselage end caps are found. During sizing, a new midsection of different length and diameter is determined to satisfy the requirements for passengers, cargo, abreast seating, and fuel volume (if the fuel is cryogenic). The new fuselage length is then obtained by adding the end caps to this midsection.

Wing and Tail Surfaces.- From the inputs for the baseline wing and tail surfaces, definitive geometric properties are determined and then normalized by a representative dimension (such as wing root chord or geometric chord). Baseline tail volume coefficients are also found for each surface. During sizing, the nondimensional properties are used to shape the components in a geometrically similar manner. Wing size is specified by wing loading or reference area, while the tail surfaces are sized to keep their volume coefficients equal to baseline values. The locations of the components are established by keeping mean aerodynamic chord positions (25-percent subsonic, 50-percent supersonic) at the same percent body-length station as the baseline aircraft. If overlap occurs between the wing and tail surfaces, the program will output a warning and continue operation.

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Fuel Volume.- Conventional fuel is assumed to be stored in the wings and in the fuselage where wing carry-through structure is located. The maximum wing-fuel volume, V_{FW}, is given by

$$V_{FW}/V_{W,EXP} = K_A + K_B V_{W,EXP}$$

where $V_{W,EXP}$ is the total volume of the exposed wing, K_A a constant determined from the baseline value of maximum wing-fuel volume, and $K_B = 7.16 \times 10^{-6}$, which was derived from studies of wing-fuel capacity performed by the Kentron International Inc., Kentron Technical Center, Hampton, Virginia. The maximum fuselage-fuel volume is scaled from the baseline value and it is assumed to vary directly with root chord, maximum thickness of the wing, and the maximum width of the fuselage.

Cryogenic fuel is contained only in the fuselage at locations covered previously under fuselage sizing. Fuel tanks are simple constant area tanks having a length that provides the required volume. The tank cross-sectional shape is the same as the fuselage after accounting for the wall thickness for cryogenic tankage.

Propulsion System.- The length, L_N, and diameter, D_N, of circular nacelles are sized by the installed, sea level, static thrust, T_{SL}, in the following manner:

$$L_N = L_{N,BL}(T_{SL}/T_{SL,BL})^{N_L}$$

$$D_N = D_{N,BL}(T_{SL}/T_{SL,BL})^{.5}$$

where the subscript BL refers to the baseline aircraft and T_{SL} varies with input thrust-to-weight ratio (or power-to-weight ratio for propeller-driven aircraft). The engine sizing exponent N_L, which varies with engine concept, is an input.

For two-dimensional inlets, the wetted area is assumed to scale directly with thrust. Both the length and width of these inlets, therefore, vary directly with $(T_{SL}/T_{SL,BL})^{.5}$.

In a similar manner, the propeller diameter, D_p, is sized by

$$D_P = D_{P,BL}(T_{SL}/T_{SL,BL})^{.5}$$

and the RPM of the propeller, RPM_P, and engine, RPM_E, by

$$RPM_P = RPM_{P,BL}(T_{SL,BL}/T_{SL})^{.5}$$

$$RPM_E = RPM_{E,BL}(T_{SL,BL}/T_{SL})^{.5}$$

Nacelle positions are established by keeping their lengthwise locations a constant percentage of the local wing chord and their spanwise pod-to-pod and pod-to-fuselage clearances a constant percentage of wing span.

An illustration of the effects of these sizing procedures on the supersonic transport is shown in figure 3.

AERODYNAMICS

The baseline aerodynamic input includes lift and drag polars for both takeoff and higher speed conditions and zero-lift drag items. All, except the takeoff data, are corrected for sizing effects. Corrections are obtained by applying the methods described below to both the baseline and the sized aircraft, then adding the difference in the results to the baseline input value.

Lift-Drag Polars.- For subsonic aircraft, the shape of the lift-drag polars are functions of wing aspect ratio, thickness, and sweep, and also Mach number when compressibility effects become important. To account for these variables, the program uses a method based on the drag build-up system given in reference 5. Some results that the method provides for sizing variations to the subsonic transport are shown in figure 4.

For higher speed aircraft, the program treats only wings that are geometrically similar to the baseline (equal aspect ratio, sweep and thickness ratio). It is therefore assumed that the shape of the lift-drag polars for these aircraft is not affected by changes in component size.

The lift-drag polars at all speeds will shift along the drag axis because of drag increments that result from sizing effects on zero-lift drag.

Zero-Lift Drag.- The items that contribute to C_{D_0} are the friction drag, roughness drag, and wave drag. To these, engine bleed and air-conditioning drag must be added if they are not included in the baseline engine data. All drag items are corrected for sizing effects. The drag coefficients for roughness, $C_{D,RUF}$, air-conditioning, $C_{D,AC}$, and engine bleed, $C_{D,B}$, vary by

$$C_{D,RUF} = (C_{D_{RUF}})_{BL} \; (S_{WET}/S_{REF})/(S_{WET}/S_{REF})_{BL}$$

$$C_{D,AC} = (C_{D,AC})_{BL} \; (T_{SL}/S_{REF})/(T_{SL}/S_{REF})_{BL}$$

$$C_{D,B} = (C_{D,B})_{BL} \; (T_{SL}/S_{REF})/(T_{SL}/S_{REF})_{BL}$$

where S_{WET} is the aircraft wetted area, NPAS, the number of passengers, and S_{REF}, the aircraft reference area.

Wave Drag.- To avoid the long computing times required to determine the wave drag by existing computer codes, a quick, simple, but approximate approach was adopted. The method treats the aircraft as a collection of isolated components, all exposed to free-stream conditions. Since the wing and tail surface vary geometrically along with the aircraft reference area, the wave-drag coefficients for these surfaces are assumed to remain constant as the size of the component changes. Sizing, however, does affect the fuselage wave-drag coefficient. As mentioned previously, the fuselage is composed of a cylindrical midsection with identical end caps. Only the end caps are assumed to contribute to the wave drag and their shape was chosen to be a Sears-Haack profile which allows the fuselage wave-drag coefficient to be obtained (see ref. 6) by

$$C_{DW,F} = 24V \; (S_{MAX}/S_{REF})/L^3$$

where V, L, and S_{MAX} are the total volume, length, and maximum cross-sectional area of the fore- and aft-end cap combination.

The contribution of the engine nacelles to the wave drag is considered to be small enough to ignore the effects of sizing.

A comparison of the results of this simple approach with those from the wave-drag program of reference 7 for the supersonic transport aircraft with JP fuel is shown in figure 5. Although some differences do occur, the method provides an improvement over the assumption that wave drag is unaffected by sizing.

Friction-Drag.- For calculating skin-friction drag, the fuselage, tail surfaces, and engine nacelles are treated as flat plates with corresponding wetted areas and lengths. The wing, however, is treated as a collection of strips with the strip mean geometric chord as the characteristic length. All surfaces are at zero angle of attack. Skin-friction drag corrections are made at all Mach number-altitude combinations required by the mission flight profile.

Two different procedures are used to calculate friction coefficients. One, which applies to fully turbulent flow, uses the reference temperature method (ref. 8) along with the constants for turbulent flow given in reference 9, and the Prandtl-Schlichting formula for incompressible average skin friction (ref. 10). An input value for emissivity is required for the solution of wall temperature.

The other procedure applies to mixed laminar-turbulent flow and is based on assumptions of an adiabatic wall temperature, a recovery factor of .88, and a discontinuous change from laminar to turbulent flow at the specified location. Since these assumptions are more appropriate to wind tunnel, rather than flight conditions, the results are not used directly. They are used, instead, to increment the fully turbulent flow results obtained as described above.

An illustration of the effects of sizing on the zero-lift wave drag and the maximum lift-drag ratio for the supersonic JP-fueled transport under turbulent flow conditions is shown in figure 6.

WEIGHTS

The weight input for the baseline aircraft include component structural weights, propulsion system weights, system and equipment weights, and crew, passenger, and cargo weights. Empirical weight relationships are used to find the effects of sizing on each item. These emperical weight equations and the method in which they are used are described in Appendix A.

An example of the weight results obtained from sizing the supersonic JP-fueled transport is shown in figure 7.

MISSION ANALYSIS

After the aircraft is sized and its aerodynamic, propulsion, and weight characteristics are known, a mission analysis is made to determine the range capability. The mission profile includes taxi, takeoff, climb-to-cruise Mach number, climb-to-cruise altitude, cruise, descent, approach, and reserve segments. For supersonic cruise missions, a subsonic cruise leg may also be specified for the outbound and/or inbound flight segment.

Taxi and Takeoff.- During taxi, the engines are throttled to provide the fuel flow rate and thrust required to overcome rolling friction. The fuel for taxi is found from this fuel flow rate and the input taxi time.

The Mach number-altitude profile during takeoff is not input; it results from influence of the aircraft's aerodynamic and maximum power characteristics on the equations of motion.

$$\frac{1}{g}\dot{V} = (T \cos \alpha - D)/W - \sin \theta$$

$$\frac{V}{g}\dot{\theta} = (T \sin \alpha + L)/W - \cos \theta$$

$$\dot{H} = V \sin \theta$$

$$\dot{R} = V \cos \theta$$

$$\dot{W} = - \dot{W}_F$$

During the ground run, these equations can be solved easily because $\dot{\theta}$ and $\dot{H}$ are zero. But after "lift-off," when these simplifications no longer apply, they are solved by more time-consuming numerical integration using the fourth order Runge-Kutta formula.

The takeoff segment includes the ground run and climb over the obstacle to an altitude of 400 feet. Analyses include "all-engines-go" and "one-engine-out" situations but no analysis of the balanced takeoff field length (ref. 11) is made.

As shown in figure 8, the the ground run begins at zero velocity, zero flap deflection, and ground angle of attack using takeoff aerodynamics that include landing gear drag increments and ground effects. At velocity V_{rotate}, the flaps are deflected and the aircraft begins its rotation to the takeoff angle of attack. After rotation is complete, the angle of attack and flap deflection are held constant until "lift-off" occurs. After "lift-off," the aircraft climbs with angle of attack and flap deflection unchanged; however, the aerodynamics are corrected for landing-gear drag retraction over an input time interval and for the diminishing influence of ground effect over an input altitude interval. The climb continues at constant angle of attack until the input climb gradient is reached; then, angle-of-attack changes are made to maintain this gradient. The end of the takeoff segment occurs when the aircraft reaches an altitude of 400 feet.

When the aircraft reaches the height of the obstacle (typically 35 feet) 115 percent of the horizontal distance covered is the takeoff field length when all engines are operating; but, for the "one-engine-out" condition the takeoff field length is the actual distance.

The minimum takeoff field length, as indicated in reference 11, occurs at an optimum value of the velocity for start of rotation, V_{rotate}. If more than a few aircraft are to be analyzed, however, the computing time required to find the variation in takeoff field length with V_{rotate} becomes prohibitive. A shorter approach was therefore adopted in which an iterative solution is used during the ground run to find the value of V_{rotate} that allows rotation to be completed and the takeoff angle of attack to be attained just at "lift-off." The takeoff field length that results from this value of V_{rotate} is a close approximation to the minimum value as shown in figure 9.

Climb.- After the takeoff phase is complete, the aircraft is at an altitude of 400 feet. Its Mach number and altitude are then phased into the input H-M profile and the climb segment begins. This and all remaining segments of the flight profile use simplified differential equations of motion (ref. 12). These simplifications are based on the following assumptions: the time derivative of the flight-path angle is zero, the angle of attack and flight-path angle are small, and the aircraft's altitude is negligibly small compared to the earth's radius. For climb, over interval points 1 and 2 along the specified flight path, the weight change, when velocity is increasing, is given by

$$\ln\left(W_2/W_1\right) = \frac{-\overline{SFC}}{g}\,\frac{V_2 - V_1 + g\,(DH/DV)\,\ln\left(V_2/V_1\right)}{\left(1 - \overline{D}/\overline{T}\right)}$$

and, where velocity is constant, by

$$\ln\left(W_2/W_1\right) = \frac{-\overline{SFC}}{V}\,\frac{H_2 - H_1}{1 - \overline{D}/\overline{T}}$$

DH/DV is the climb-path slope and the barred quantities represent effective values which are taken to be simple averages of interval point values.

Time and range changes over the interval are:

$$t_2 - t_1 = (W_2 - W_1)/\bar{\dot{W}}_F$$

$$R_2 - R_1 = \frac{(V_1 + V_2)}{2}(t_2 - t_1)$$

where $\bar{\dot{W}}_F$ is the average fuel flow over the interval.

The aircraft follows the input H-M profile up to the cruise Mach number unless, for a supersonic cruise mission, an outboard subsonic cruise leg is specified. If this occurs, the climb stops at the input subsonic cruise Mach number and a search (at constant M) is made for the altitude that provides the best Breguet factor with engines throttled. The subsonic cruise leg is then flown at constant lift coefficient for the specified range. Next, the aircraft accelerates at constant altitude until it intersects the input H-M profile, which it then follows to the supersonic cruise Mach number. During the climb, the acceleration can be controlled by input to occur at maximum power or at partial power settings that use least fuel.

After the cruise Mach number is reached, a climb at constant Mach number is made to the cruise altitude. Unless specified otherwise, cruise will start at the altitude which provides the best Breguet factor; however, the altitude at the start of cruise can be input directly or restricted by inputs for constant angle of attack, constant throttle setting, or minimum rate of climb. After the cruise altitude is reached, the climb fuel is known.

Reserves.- Since the fuel available for cruise and descent is the remainder after taxi, takeoff, climb, and reserve fuel are allotted, the reserve fuel requirements must be determined next. Reserves can include a trip fuel allowance, fuel for a missed approach, a flight to an alternate airport, and a hold at constant Mach number and altitude. A typical reserve flight profile is shown in figure 10.

The solution for reserve fuel, which is iterative since the weight of the aircraft at the end of descent is not known at this time, starts with the trip fuel allowance. This fuel allowance for subsonic aircraft is obtained from the fuel burned for an input time interval using the fuel flow rate at the start of cruise. For other aircraft, the allowance is an input percent of the trip fuel, $W_{F,T}$, which at this time may be obtained from

$$W_{F,T} = W_F - W_{F,R} - W_{F,TAXI}$$

where W_F is the total fuel weight, $W_{F,TAXI}$ the taxi fuel weight, and $W_{F,R}$ the total reserve fuel weight (which must be assumed for the first iteration). The fuel for missed approach is obtained by either calculating a "wave-off" and acceleration to an altitude of 700 feet with landing gear retracted and "out-of-ground" aerodynamics in effect, or, more simply, by the fuel burned for an input time interval (typically 2 minutes) at the takeoff fuel-flow rate. For the detailed calculations, the weight at the start of the missed approach segment is:

$$W = W_G - W_F + W_{F,R} - W_{F,TPA}$$

where W_G is the gross weight and $W_{F,TPA}$, the trip fuel allowance.

For the alternate airport requirement, the aircraft climbs a linear H-M profile from the end of the missed approach to the altitude at the start of cruise, cruises the required distance, then descends to approach conditions. The total range for these segments is the required distance to the alternate airport. The analysis is performed for various climb and cruise throttle settings and cruise Mach number-altitude combinations to find conditions for least fuel.

During the descent to the alternate airport, the hold segment is performed. The time for hold is input and the Mach number-altitude combination is again found for the least fuel requirement. The range covered during hold is not credited to the alternate airport distance.

After all reserve segments are completed, the total reserve fuel is updated and the process repeated until successive values are within .1 percent. An example of the effects of sizing on the reserve fuel requirements for the supersonic transport are shown in figure 11.

Cruise.- The total fuel available for cruise and descent is now known, and solutions of these segments are repeated until the required and available fuel are within .1 percent. The process starts by assuming the fuel weight for descent (about .5 percent of the aircraft gross weight) then finding the fuel for cruise. During cruise, the aircraft flies at the selected cruise option (like constant C_L or others described below) until the cruise fuel is exhausted.

For cruise, the increment in range, R, over interval points 1 and 2 is given by

$$R_2 - R_1 = \overline{BF} \ln \left[1/(1 - W_F/W_1)\right]$$

where W_F is the fuel weight used over the interval, and $\overline{BF}$ is the numerical average of the Breguet factor, which changes over the interval because of the input cruise option selected. The computing interval during the main cruise segment is a fuel weight increment obtained from the weight of cruise fuel and an input number of intervals. For outbound or inbound subsonic cruise legs, the computing interval is the entire cruise leg.

The main cruise segment is normally controlled by different input options. These include: cruise at maximum available Breguet factor, constant lift coefficient (or constant angle of attack), constant altitude, and constant engine throttle setting. The different types of cruise segments, of course, affect the cruise altitude variation and cruise range of the aircraft. Some examples of this behavior for the supersonic transport for several wing sizes are shown in figure 12. For all cruise options, except maximum power, the start of cruise was selected to start at the altitude for maximum available Brequet factor.

With the largest wing (W/S = 50 psf), the altitudes for maximum Breguet factor are above the climb ceiling. Therefore, unless constant altitude is specified, cruise, with the better range, will occur at maximum power.

With the median wing (W/S = 85 psf), the maximum Breguet factor at start of cruise occurs at a lower altitude (60,000 ft) and thrust is now sufficient to provide the altitude variation that meets this condition throughout cruise. For this wing and engine size combination, the constant C_L (or angle of attack) option is equivalent to the maximum Breguet factor option and any of these gives the best cruise range.

With the smallest wing (W/S = 110 psf), the altitude for best Breguet factor at the start of cruise is below the climb path. A constant altitude cruise with decreasing C_L therefore occurs until maximum Breguet conditions can be met and the best cruise range now occurs only for this option.

From these results, regardless of thrust or altitude limitations, it is evident that the best cruise range will always be obtained by selecting the option for maximum available Breguet factor.

Long-Endurance Cruise.- For this type of mission, the cruise segment must use minimum fuel and the program will find the variations in Mach number, altitude, and lift coefficient to provide this condition throughout cruise. If the optimum conditions prove to be unsatisfactory, there are inputs available to specify the cruise Mach number and/or altitude. An example of the effects of optimum and non-optimum conditions on endurance for size variations of the long-endurance aircraft are shown in figure 13.

Descent.- Like the climb, the computing interval for the descent is a Mach number increment. It is defined by the difference between the Mach number for the main cruise segment and the Mach number at the end of descent and an input number of intervals. If velocity is decreasing, the change in time, t, over the interval is:

$$t_2 - t_1 = \frac{W_1}{g} \frac{V_2 - V_1 + g\ (DH/DV)\ \ln\ (V_2/V_1)}{\bar{T} - \bar{D}}$$

and if velocity is constant

$$t_2 - t_1 = \frac{W_1}{\bar{V}} \frac{H_2 - H_1}{\bar{T} - \bar{D}}$$

Again, numerical averages of interval point values are used for the barred quantities and the altitude at point 2 is found at the lift coefficient for $(L/D)_{MAX}$ with $W_2 = W_1$ (a reasonable assumption since fuel expenditure during descent is very low). W_2 is subsequently incremented by

$$W_2 - W_1 = \bar{\dot{W}}_F\ (t_2 - t_1)$$

After cruise, the aircraft enters the descent phase by making the transition to flight at $(L/D)_{MAX}$ during the first computing interval. The remainder of the descent is then performed at $(L/D)_{MAX}$. If the aircraft is supersonic and an inbound subsonic cruise leg is chosen, the descent stops at the specified Mach number and a search is made for the altitude giving the best Breguet factor. A subsonic cruise at constant lift coefficient is then performed over an input range, after which descent to the start of the approach at M = .4 and H = 4000 feet is calculated.

Approach.- This portion of the descent extends from $M = .4$ and $H = 4000$ feet down to an altitude of 370 feet. Using the equation given previously for the descent, an iterative solution is required to find the aircraft weight and velocity at the end of the approach. The angle of attack and flap deflection for approach must be input. The takeoff aerodynamics are used without ground effect but the drag increments for the extended landing gear are included.

Overall Mission Characteristics.- Typical results from different segments of the mission analysis are now presented for several wing and engine sizes on the supersonic transport with JP fuel. For all size changes, the aircraft gross weight was held constant and the cruise segment was specified to occur at maximum available Breguet factor.

Figure 14 shows the flight profile that results from changes in wing size with $T/W = .45$. Controlled by input, the climb profile is restricted, but the cruise and descent profiles are different for all cases.

Takeoff results, presented in figure 15, show that changes in the fuel required due to sizing are small; the spread of values is less than .25 percent of the aircraft gross weight. On the other hand, changing lift (W/S), or acceleration (T/W), capability has a large effect on takeoff field length. The velocity at "lift-off" is seen to be primarily a function of wing loading.

Climb results that show excess thrust capability are given in figure 16. Decreasing with Mach number, the excess thrust reaches its minimum value at the end of the climb, and this general trend is not affected by sizing. Changes in excess thrust are, of course, almost directly proportional to changes in engine size, while those resulting from wing changes are much less pronounced since they reflect only the different drag characteristics encountered during the climb.

The climb time, fuel, and range are shown in figure 17. The effects of engine size are large and aircraft with low acceleration, naturally, take longer times, use more fuel, and cover more range to reach cruise. Wing size does not seem to be too important except for the larger wings (W/S = 70 and 50 psf) at lower engine sizes where time, fuel, and range increase while climbing to the higher cruise altitude.

The fuel available for cruise has a significant effect on cruise range and time as shown in figure 18. Because of the additive affects of wing and engine size on total fuel and the fuel required for other flight phases, the aircraft with the smallest wing (W/S = 110 psf) and medium engine size (T/W = .35) has the maximum available fuel for cruise. The maximum cruise range, however, occurs at W/S = 90 psf because the slightly larger wing improves the L/D characteristics without an appreciable decrease in available fuel. The more efficient larger wings produce lower ranges because their high weight limits the available fuel.

Descent results are given in figure 19. Fuel for descent is less than 1 percent of the aircraft gross weight for all size variations. Because the descent is essentialy a glide at $(L/D)_{MAX}$, aircraft with the largest wings give the longest range. The effect of engine size is primarily due to different nacelle skin-friction drag increments.

Approach speeds (fig. 20) are primarily a function of wing size, although engine size also has an effect, but much smaller, because of its influence on approach weight.

Total trip time and range are shown in figure 21. Because the longer ranges in the climb and descent segments (figs. 17 and 19), the lowest engine size provides the greatest overall range.

APPLICATIONS

To show some of the capabilities of the program, application will now be made to four different types of aircraft which include: two supersonic transports, one using JP fuel, the other, liquid-hydrogen fuel; a subsonic propeller-driven transport; and a hypersonic aircraft using liquid-methane fuel. The baseline aircraft are shown in figure 1. During the discussion, input variables may be referred to. For a definition of these variables, see Appendix B.

Sizing Thumbprints

During each computing cycle, selected output from the sizing and mission analysis are recorded on a file named TAPE14. This data can be used to construct the sizing "thumbprint"--a diagram that pinpoints the best wing and engine size of the aircraft. The "thumbprint" contains contours of quantities that are to be optimized and limit contours of quantities that restrict the choice of wing and engine size. Examples of optimizing contours are range, gross weight, and seat miles/gallon, while takeoff field length, fuel limit, maximum rate of climb and thrust margin are typical limit contours. TAPE14 and an example of all the information it contains for contouring is described in Appendix C.

A typical "thumbprint" for the supersonic transport, using JP-fuel, with a range of 4000 nautical miles is shown in figure 22(a). To obtain the data for this "thumbprint," the essential inputs are the required range (RNGDES), wing sizes (WOSTB), and engine sizes (TOWTB). The contours are for constant gross weight and they show that a minimum occurs at a wing loading, W/S, of approximately 90 psf and a thrust-to-weight ratio, T/W, of about .28. The limit contours, however, show that this combination is unrealistic because the wing is too small to hold the required fuel, and the takeoff field length is longer than 10,000 feet. If design requirements include a maximum lift-off speed of 200 K, a maximum approach speed of 160 K, a maximum takeoff field length of 10,000 feet and a minimum rate of climb during cruise of 300 ft/min., the choice of wing and engine size are those included within the boundaries provided by the limit contours for approach speed, takeoff field length, and rate of climb. Influenced by these restrictions, the conditions for lowest weight aircraft would change to about W/S = 82 psf and T/W = .32.

Although a low gross weight is an important quantity that decreases the cost of the aircraft and its maintenance, it is not the only criteria for selecting wing and engine size. Quantities that relate to the cost of operating the aircraft may also be important. One of these, which could assume a major role if fuel prices multiply, is a high value of the seat-miles/gallon-of-fuel parameter. The corresponding "thumbprint" for the supersonic transport with contours of this parameter is shown in figure 22(b). For this aircraft concept, the conditions for maximum passenger-miles/gallon are about the same as those for minimum gross weight with flight restrictions considered.

"Thumbprints" for the other aircraft are shown in figures 23 to 25. These include the hydrogen-fueled transport, the subsonic transport, and the methane-fueled hypersonic aircraft. The "thumbprints" for the transports are at constant range, whereas the hypersonic "thumbprint" is at constant gross weight. To obtain this "thumbprint," inputs for design gross weight (WGDES), wing sizes (WOSTB), and engine sizes (TOWTB) are required. There are no fuel limit lines on the figures for the aircraft with cryogenic fuel because these aircraft are sized to hold only the required fuel. The symbols on the "thumbprints" define the gross weight and wing and engine sizes of the "design-point" aircraft that will be used to show some of the additional capabilities of the program. Although the capabilities discussed are divided among the different types of aircraft, applications, in most cases, can be made to all types.

Supersonic Transport (JP fuel)

Payload - Range Trade.- With design-point inputs for gross weight (WGDES), wing loading (WOSDES), thrust-weight ratio (TOWDES), and the payload-range trade requested (ICALPRC=1), data for the curve shown in figure 26 will be output. The computing process involves a computing cycle at the design conditions, then additional cycles with payload off-loaded. Two possibilities can occur when the payload is off-loaded. The first occurs when the aircraft has ample fuel capacity, then as payload decreases, fuel is added to keep the gross weight constant. Range increases because of the increased fuel mass fraction (fuel weight divided by gross weight). If, however, the aircraft cannot hold the added fuel, the gross weight is decreased by an amount equal to the weight of the excess fuel. Again the range increases (fuel-mass fraction has increased) but this time, not as rapidly. These two conditions are illustrated by the solid and dashed curves in figure 27.

Radius to Payload Drop.- A fallout from the payload-range analysis is the radius-to-payload drop useful for bomber studies. To provide this output, the program executes two computing cycles--one with full payload and one without payload. The results are then used to find the point at which the outbound range with payload equals the inbound range with payload out. The program does not account for the possibility that the altitudes, with and without payload at the drop, may not be equal. Typical results for the drop radius compared to radii with and without payload are shown in figure 27.

Fuel Off-Loading.- Distances below the design range can be flown with or without fuel off-loading. Both cases can be treated by the program. Reduced ranges without fuel off-loading are initiated by inputs in RRTB and solved simply by shortening the cruise segment the required amount. Reduced ranges with fuel off-loading are obtained by inputs in OLRTB and complete mission analyses are performed which solve for the required fuel. From the standpoint of fuel efficiency, fuel off-loading is the better of the two because the dead weight of excess fuel is not carried along. Figure 28 shows this result as well as the fact that for best fuel efficiency a redesign of the aircraft for the reduced range capability would be required.

Subsonic Cruise Legs.- During a supersonic mission, subsonic cruise may be required during the outbound and/or inbound flight segments to avoid sonic boom problems. If these options are chosen, the range capability of the aircraft is reduced because of the lower cruise efficiency at subsonic speeds. Typical range penalties that result from different subsonic cruise ranges are shown in figure 29. The best subsonic range is, of course, obtained by all subsonic cruise because of the extra cruise fuel gained by eliminating the acceleration to cruise Mach number.

Passenger Load.- Abreast seating arrangements, to some extent, affect the aircraft's range because changes in fuselage length and fineness ratio alter the drag and structural weight. This effect is shown in figure 30 where the gross weight required for a range of 4000 nautical miles with various passenger loads at different seating arrangements are shown along with accompanying changes in fuselage length and fineness ratio. Four or five seats abreast are reasonable choices, but six-abreast seating is not competitive because of high fuselage drag.

Supersonic Transport (Liquid-Hydrogen Fuel)

In this program, the low-density hydrogen fuel is located only in the fuselage. Since the fuel weight is affected by fuselage size and weight, which, in turn, changes with fuel weight, aircraft sizing is an iterative process which continues until the contained fuel equals the required fuel. Because of the large fuel volume, the maximum equivalent cross-sectional area and length of the fuselage is not only dependent on passenger load and seating arrangement, as is the case for noncryogenic fuel, but also on the volume of the fuel tanks. In order to make the fuselage sizing a tractable problem, the process may be controlled, through inputs, to occur at constant fuselage length (KBL), constant maximum equivalent radius (KBR), or constant fuselage fineness ratio (KBFN). The effects of these choices on the range capability of several size variations of the aircraft are shown in figure 31.

An alternative solution to passenger packaging for these large volume aircraft is the use of two-passenger levels (LEVELS = 2). With this choice, the fuselage maximum equivalent cross-sectional area is again dependent on the passenger-abreast seating arrangement and the fuselage length and fineness ratio cannot be controlled by input. For comparison, the range for aircraft with two-passenger levels are also shown in figure 31. For these aircraft, two-level arrangements may be superior and this inference agrees with industry conclusions in reference 13.

Subsonic Propeller Driven Transport

The performance characteristics of this type of aircraft depend on the design conditions (altitude, Mach number, and tip speed) of the propeller. These conditions, which cannot be controlled in the program, must be used to develop the input characteristics of the baseline engine discussed in Appendix B. The effects of these propeller design conditions on the baseline aircraft and some of its size variations, as provided by this program, are discussed in reference 14.

Technology Improvements.- The effects of technology advances are found by simple percentage changes in the required areas with interactions in other areas falling out as a result of the sizing and mission analysis procedures. Areas available for improvement (or decay) are given in Appendix B. To illustrate some results, the sensitivity of gross weight and seat miles/gallon for the subsonic transport to changes in engine weight, propeller weight, specific fuel consumption, drag, and structural weight are shown in figure 32.

Laminar-Turbulent Flow.- Another technical advance that shows considerable promise, if successful, for improving the energy efficiency of the aircraft is laminar flow control which preserves laminar flow over large areas of the aircraft components. Potential gains, predicted by the program, are shown in figure 33 for various percentages of mixed laminar-turbulent flow.

Refueling.- The program will compute a refueling segment but it must occur sometime during cruise. Refuel is initiated by specifying refuel at the start of cruise (IRFSOC = 1), or at end of cruise (IRFEOC = 1), or at a range (RNGSRF). During the refuel segment, the fuel taken onboard and the fuel used while cruising are used to find the net fuel added. Refuel continues until the gross weight of the aircraft with net added fuel equals the input weight after refuel (WGARF). Typical results for various refueling flow rates are shown in figure 34.

CONCLUDING REMARKS

A computer program (ASP) has been developed to allow preliminary sizing and performance evaluations for subsonic, supersonic, and hypersonic aircraft that use either JP, liquid-hydrogen, or liquid-methane fuel. Both jet and propeller propulsion systems can be treated. Some of the output the program provides includes: range for given gross weight and passengers, gross weight for given range and passengers, passengers for given range and gross weight, payload-range trade, passenger and fuel off-loading, effects of technology improvements, effects of in-flight refueling, radius to payload drop, and the basis for preparing aircraft sizing "thumbprints" which allow the selection of wing and engine size for best performance.

The program has been used extensively for in-house studies of subsonic and supersonic transport aircraft concepts, some of which were developed by industry. For these, the results obtained by this program agreed very well with those provided by the companies. For several of the concepts, the program has been used to direct design improvements through changes in wing and engine size. These improvements were later confirmed by in-depth contractual studies.

APPENDIX A

WEIGHT EQUATIONS

This section contains the empirical relationships used to compute the effects of sizing on the weight characteristics of the aircraft. The expressions contain only the essential sizing parameters and, therefore, cannot be used to compute absolute weights. Instead, weight scaling is done by the following general form.

$$W_I = W_{I,\,BL}\ (F/F_{BL})$$

where W_I is the weight of the scaled item, $W_{I,BL}$, the weight of the baseline item, F, the result of the weight equation(s) applied to the scaled item, and F_{BL}, the similar result for the baseline item. In this way, the relationships are used only to account for sizing changes through increments to baseline weights. At hypersonic speeds, aircraft require "hot-structure" solutions to survive severe local temperatures, but, as noted, the relationships do not account for this. Even so, the above approach still seems appropriate, at least from a preliminary standpoint, because the higher weights for the higher temperatures are introduced through the baseline aircraft.

The weight relationships are listed below without proof of their validity. Also, since they have been obtained from several different industry contractual studies, a recognition of their source, in most cases, is omitted.

Subsonic Wing Weight

$$F_W = \frac{K\ W_G\ N_Z\ A\ b\ (.375 + .7\lambda)}{\frac{t}{c}\ K_S} + .57\ S\ W_G^{.1845} + .572\ S^{1.07}$$

where

$$K = 1.427 \times 10^{-6}\ (1 - 0.45\ N_E)(1 + \sqrt{6.75/b})$$

N_E	number of engines on wing
b	wing span
W_G	gross weight
N_Z	ultimate load factor
A	aspect ratio based on basic trapezoidal planform
λ	wing tip chord-root chord ratio
S	wing reference area

t/c	wing thickness-to-chord ratio (weighted average)
K_S	$\cos^2 \Lambda$
Λ	sweep angle of the wing quarter chord line

For a wing with multiple panels and varying t/c, the weighted average t/c is obtained from:

$$t/c = \frac{\sum_{N} .2\, b_p \left[4\, (t/c)_r + (t/c)_t\right]}{b/2}$$

Subscripts t and r refer to the tip and root of the panel, b_p, the span of the panel, and N, the number of panels.

Supersonic Wing Weight

$$F_W = .0241 \frac{(S\, W_{DM})^{.53}\, M_D^{\ .1}}{T_{HM}^{\ .22}}$$

where

$$W_{DM} = \frac{N_Z\, (W_M - W_{RM})}{\mathrm{Cos}\ \Lambda}$$

$$W_M = W_G\, (C_A + \frac{WB}{2})$$

$$W_{RM} = W_{RM,1} + \sum_{\text{nacelles}} Y_N\, (W_E + W_{TR} + W_N)$$

$$W_{RM,1} = W_{F,W}\, (C_R + \frac{WB}{2}) + W_{MLG}\, W_B + Y_W\, F_W$$

An iterative solution of this cycle of equations is required until the initial estimate and final value of the wing weight, F_W, are about equal. Quantities that do not change during the iterations are:

$$W_{MLG} = .8803\, W_{LG}$$

$$C_R = Y_D \frac{W_{F,W}}{W_{F,W,MAX}}$$

if there are no fuel tanks in the wing, $C_R = 0$.

$$T_{HM} = T_A + T_C$$

$$T_A = T_R + P_{CR} \left(1 - \frac{P_{CR}}{2}\right)$$

$$T_C = P_{CO}^{\ 2} \left(\frac{T_R}{6} + \frac{T_T}{3}\right)$$

$$T_R = \frac{t}{c} C_{BK}$$

$$T_T = \frac{t}{c} C_{0,1}$$

$$C_{BK} = C_{I,1} P_{CO} + C_{0,1} P_{CR}$$

$$P_{CR} = \frac{W_B}{b}$$

$$P_{CO} = 1 - P_{CR}$$

$$Y_D = Y_W (1 - P_{CR})$$

$$C_A = \frac{(.24 + .0225A)}{.5 (b - W_B)}$$

$$Y_W = \frac{\frac{b}{2} \left(A_0 + \frac{AM}{2}\right)}{A_I + A_0 + A_M}$$

$$A_M = A_I + A_0 + C_{I,1} T_{0,1} + C_{0,1} T_{I,1}$$

$$A_0 = C_{0,1} T_{0,1}$$

$$A_I = C_{I,1} T_{I,1}$$

$$T_{I,1} = \frac{t}{c} C_{I,1}$$

$$T_{0,1} = \frac{t}{c} C_{0,1}$$

$$C_{0,1} = \lambda C_{I,1}$$

$$C_{I,1} = 2.2994 \frac{S}{b}$$

In these equations

S	wing reference area
b	wing span
$\frac{t}{c}$	weighted average of wing thickness-to-chord ratio
A	aspect ratio, b^2/S
λ	wing taper ratio
Λ	sweep angle of wing mid chord
W_G	gross weight
W_E	engine weight (one)
W_{TR}	thrust reverser weight (one)
W_N	nacelle weight (one)
Y_N	spanwise distance to nacelle-engine combination
W_{LG}	landing gear weight
$W_{F,W}$	weight of fuel in wing
$W_{F,W,MAX}$	maximum weight of fuel in wing
W_B	maximum width of fuselage

The equations for both subsonic and supersonic wings were provided by Kentron International, Inc., Kentron Technical Center, Hampton, Virginia.

Canard, Horizontal and Vertical Tails

The weights of these items are directly proportional to their total wetted areas.

Fuselage

$$F_F = (N_Z \, W_G \, S_{W,F})^{.6}$$

where $S_{W,F}$ is the total wetted area of the fuselage

Landing Gear

$$F_{LG} = (W_G \, L_F)^{.25}$$

where L_F = length of fuselage

Nacelles

The weight of the nacelles is directly proportional to their total wetted area.

Engines

$$F_E = N_E \, T^{E_W}$$

where N_E = number of engines

T sea-level static thrust of one engine

E_W engine weight exponent

Thrust Reverser

$$F_{TR} = N_E T^{.88}$$

where N_E and T are defined above.

Propeller

$$F_P = N_E T^{(.5 \, E_P)}$$

where E_P propeller weight exponent.

Gear Box

$$F_{GB} = N_E T^{1.5}$$

Miscellaneous Systems

The weight of this item is assumed to be unaffected by sizing.

Fuel Systems for Conventional Fuel

Only the weight of the plumbing is considered for these systems. For subsonic design Mach numbers

$$F_{PS} = 8.117\ (N_E)^{.825}\ (T)^{.38}$$

and for supersonic design Mach numbers

$$F_{PS} = \frac{(W_{F,MAX})^{.565}}{(1. + \frac{W_{F,W,MAX}}{W_{F,MAX}})}$$

where

$W_{F,MAX}$ maximum fuel load

$W_{F,W,MAX}$ maximum fuel load in wing

Fuel Systems for Cryogenic Fuel

These systems include the weight of the plumbing, fuel tanks and insulation. Plumbing weight is given by:

$$F_{PS} = .01569\ (T_T)^{.75} + 25.433\ (N_E)^{.825}\ (T)^{.38}$$

where

T_T total sea-level static thrust

The weights for the fuel tank and its insulation are both directly proportional to the total wetted area of the fuel tank.

Surface Controls

If the design Mach number is subsonic

$$F_{SC} = \frac{(L_F + b/\cos\Lambda)S^{.5}}{A_{TR}^{.85}}$$

where

L_F = length of fuselage

b = wing span

Λ = sweep angle of quarter chord

S = total wing area

A_{TR} = wing aspect ratio

If design Mach number is supersonic, the weight of the surface controls is directly proportional to the gross weight of the aircraft.

Auxiliary Power Unit

The weight of this item is assumed to be unaffected by sizing.

Instruments

$$F_{IN} = N_E^{.354}\ L_F^{.5}\ b^{.68}$$

Hydraulics

$$F_{HY} = \left(\frac{W_G}{S_{CS}}\right)^{.34} (L_F + b)^{.52} (1 + M_D)\ N_E$$

where

S_{CS} total area of surface controls

M_D design Mach number

Avionics

$$F_{AV} = W_G^{.7}$$

Electrical System

$$F_{EL} = (N_E)^{.424} (L_F + b)^{.69} (W_{AV})^{.473}$$

where

W_{AV} weight of the avionics

Furnishings and Equipment

The weight of this item is directly proportional to the number of passengers.

Air Conditioning

$$F_{AC} = (N_{PAS})^{1.2} + 11.17 (M_D)^{.6} (V_P)^{.58}$$

where

V_P volume of passenger compartment

N_{PAS} number of passengers

Anti-icing

$$F_{AI} = b^{.95}$$

Unusable Fuel

$$F_{UF} = 100 N_E + .176 S$$

Engine Oil

$$F_{EO} = W_{E,T}^{.26}$$

where

$W_{E,T}$ weight of all engines

Passenger Service

The weight of this item is directly proportional to the number of passengers.

Cargo Containers

The weight of cargo containers is directly proportional to the maximum cargo weight.

Crew

Weights for the flight and cabin crew are directly proportional to the number of crew members.

Passengers and Baggage

Weights for these items are directly proportional to the number of passengers.

APPENDIX B

DEFINITIONS OF INPUT

The program is coded in FORTRAN Extended Version 4 (ref. 15). Provisions are made for two input files. One file contains propeller design data and is required only if propeller output data is to be computed. The data on this file must be input in the following format.

Column	Type of Data
9-10	number of propeller blades, a right justified integer
11-20	Mach number
21-30	propeller advance ratio
31-40	propeller power coefficient
41-50	propeller thrust coefficient

Data is listed by increasing power coefficient at constant advance ratio, then by increasing advance ratio at constant Mach number, then by increasing Mach number. During program execution, the file containing this data must be named TAPE3.

The other file contains the input for the baseline aircraft and sizing options. It is always required and during execution it must be called TAPE5. The input segments on TAPE5 are listed below in their order of occurrence.

Input segments for sized aircraft

Aircraft Identification
$PRNTCON
$DESGNVB
$TWINFUS
$MISSVB
$RESRV
$TECHCHG

Input segments for baseline aircraft

Wave-Drag Geometry Deck or $SACGEM
$AIN
$WTIN
$ENIN
Baseline Engine Characteristics

Segments prefixed by a $ sign are inputs in the NAMELIST format (ref. 15). Definitions of input variables follow, with default values, if they exist, enclosed in parenthesis behind each definition. Variables with parenthesis are arrays and the included numbers indicate their maximum size.

INPUT SEGMENTS FOR SIZED AIRCRAFT

The first input is the aircraft identification. It is one free-field line of 80 characters.

$PRNTCON

Inputs in this segment control program output. All inputs are integers with a value of either 1 or 0. Unless noted, a value of 1 activates the option; 0 suppresses it.

IPPRNT	= 1 prints all output = 0 prints only output for sized aircraft (default)
IPAERO	prints aerodynamic data, (0)
IPRPROP	prints engine characteristics (0)
IPRWTSM	prints weight statement, (0)
IPRMPRF	prints mission profile data, (0)
ISCOPE	prints output showing progress of execution during interactive terminal sessions, (0)

$DESGNVB

This input segment contains aircraft design and sizing information. For clarity, the inputs have been separated into typical groups.

Miscellaneous Design Input

ISSAC	= 0 for supersonic aircraft (default) = 1 for subsonic aircraft
ISGEOM	= 0 if aircraft geometry is input in wave-drag format (default) = 1 if aircraft geometry is input in $SACGEM
IJP	= 1 for aircraft using JP fuel, (0)
IH2	= 1 for aircraft using hydrogen fuel, (0)
IMTH	= 1 for aircraft using methane fuel, (0)
NOFIW	= 1 for aircraft with no fuel in wing, (0)
IBLAC	= 0 for sizing of baseline aircraft (default) = 1 for no sizing of baseline aircraft
RHOJP	density of JP fuel, lb/gal, (6.75)

RHOH2	density of liquid hydrogen fuel, lb/gal, (.592)
RHOMTH	density of liquid methane fuel, lb/gal, (3.54)
RHOCAR	density of cargo, lb/ft^3, (10.)
EIPEN	reduction in thrust to account for interference effects between propeller and wing, percent, (0)

The next three variables apply to aircraft using hydrogen or methane fuel.

KBFN	= 1	for constant fuselage fineness ratio, (0)
KBL	= 1	for constant fuselage length, (1)
KBR	= 1	for constant fuselage radius, (0)

Passenger Cabin Design Input

DGLW	width of door-galley lavatory, ft, (7.3)
NPPDGL	number of passengers per door-galley-lavatory, integer, (75)
STSAB	number of seats abreast; 0 provides the baseline value STSABR, (0)
LEVELS	number of passenger levels, 0, 1, or 2; 0 provides the baseline value, (0)
TP	wall thickness of passenger cabin, inches, (4)
TF	wall thickness of fuel tanks for liquid hydrogen or methane fuel, inches (9)

Specific Design Inputs

FNDES	design fuselage fineness ratio
IPASDES	number of passengers, integer
NENDES	number of engines, integer
NPDES	number of engine nacelles, integer
RMAXDES	design radius of fuselage, ft
ZLBDES	design length of fuselage, ft
NCARDES	design cargo load, lb
TOWDES	design thrust-to-weight ratio
TPEDES	design single engine thrust, lb
WOSDES	design wing loading, psf

REFADES	design wing reference area, ft^2
WGDES	design gross weight, lb
RNGDES	design range, n.mi.
ZMCRDES	design cruise Mach number

The next six variables apply to subsonic aircraft.

ASPRDES	design wing aspect ratio
EDES	design endurance, h
POWDES	design shaft horsepower-to-weight ratio, hp/lb
SHPDES	design shaft horsepower, hp
SQCDES	design sweep of wing quarter chord line, deg
WTOCDES	design thickness ratio of wing, percent

If RNGDES is not input, the program solves for the range at input gross weight and passenger load. If RNGDES is input, the program solves for the gross weight that provides this range at input passenger load.

To find the passenger load for a given range and gross weight, use the following integer variable.

IGRAWFP = 1 (default is 0)

along with inputs for WGDES and RNGDES.

Each of the above variables, which defaults to its baseline value, is used to hold that design parameter constant through one or more sizing passes during program execution. If design parameters are to be changed in each sizing pass during execution, the following design variable arrays must be used. All arrays are one-dimensional.

Design Variable Arrays.-

TOWTB(7)	an array containing design thrust-to-weight ratios
TPETB(7)	an array containing design thrusts for a single engine, lb
NTOW	the number of values in either the TOWTB or TPETB arrays, (0)
WOSTB(7)	an array containing design wing loadings, psf
REFATB(7)	an array containing design wing reference areas, ft^2
NWOS	the number of points in either the WOSTB or REFATB arrays, (0)
ARTB(10)	an array containing design wing aspect ratios

NASPR	the number of points in ARTB, (0)
POWTB(7)	an array containing shaft horsepower-to-weight ratios
NPOW	the number of values in POWTB, (0)

Restrictions on Use of Variables.- Not all of the design variables are independent parameters. The following restrictions, therefore, are placed on the use of several of these variables.

1. Since POWDES, TOWDES, TPEDES, POWTB, TOWTB, and TPETB all control engine sizing, use only one of these variables.
2. Similarly, WOSDES, REFADES, WOSTB, and REFATB all affect wing sizing, therefore, use only one.
3. The ARTB array must not be used with any other design variable array.
4. The integer variable IGRAWFP may not be used with any design variable array.

$TWINFUS

This input segment contains input for the geometry of twin-fuselage aircraft. The only component of this aircraft that can be sized is the propulsion system; therefore, only the design variables WGDES, TOWDES, TPEDES, and RNGDES are allowed. If changes in any other design variable, like wing size, passenger load, etc., are required, a new baseline aircraft (with its aerodynamics weights and propulsion) must be developed and input.

The only geometry input necessary for twin-fuselage aircraft are the reference lengths and wetted areas of the components. These are required for skin-friction calculations during the mission analysis. To prevent program aborts, however, a complete geometry input segment in either the wave-drag format or $SACGEM is also required but any available input segment will suffice because it will not affect results.

ITWINF	= 0 for conventional aircraft, (default) = 1 for twin-fuselage aircraft
FURLIN	fuselage reference length, ft
FUSWTIN	fuselage wetted area, total of both fuselage, ft^2
TWFREFA	wing reference area, ft^2
IWSEGIN	number of wing segments
WRLIN(20)	a one-dimensional array containing the reference length of each wing segment, ft
WSWETIN(20)	a one-dimensional array containing the wetted area of each wing segment, ft^2

CRLIN	canard reference length, ft
CSWETIN	canard wetted area, ft^2
HRLIN	horizontal tail reference length, ft
HSWETIN	horizontal tail wetted area, ft^2
IFINS	number of vertical fins
FRLIN(6)	a one-dimensional array continuing the reference lengths of the vertical fins, ft
FSWETIN(6)	a one-dimensional array containing the wetted areas of the vertical fins, ft^2
PRLIN	the reference length of one engine pod, ft
PSWETIN	the wetted area of one engine pod, ft^2

$MISSVB

This segment provides the inputs required for the flight profile analysis. The inputs, again, have been separated into typical groups.

Overall Mission Input

IENDUR	= 1 mission profile for long endurance aircraft, integer, (0)
IRADIUS	= 1 provides range to payload drop, integer (0)
OEW	operating empty weight, lb, (if greater than 0, this value will replace the calculated OEW)
PAYLOAD	total payload weight, lb, (if greater than 0., this value will replace the calculated payload)
POLF	payload factor, percent (100% gives full payload), (100.)
NPASOL	number of passengers in off-loaded aircraft, integer (-1, the default, gives no off-loading)
WCAROL	cargo weight in off-loaded aircraft, lb (-10, the default, gives no off-loading)
ICALPRC	= 1 provides data for the range-payload curve, integer, (0)
OLRTB(10)	a one-dimensional array containing the ranges for fuel off-loading, n.mi.
NOLR	the number of values in OLRTB, integer, (0)

RRTB(10)	a one-dimensional array containing reduced ranges with no fuel off-loading, n.mi.
NRR	the number of values in RRTB, integer, (0)
IRFSOC	= 1 start refueling at start of cruise, integer, (0)
IRFEOC	= 1 start refueling at end of cruise, integer, (0)
RNGSRF	range to start of refuel, n.mi. (refueling must occur sometime during cruise. If RNGSRF is set too low, refuel will begin at the start of cruise; if set too high, refuel will begin at the end of cruise. To activate refueling, the value of RNGSRF must be greater than 10.), (0)
RFRIGPM	refuel flow rate, gal/min, (600.)
WGARF	the aircraft gross weight after refueling, lb (-10, the default value, gives the design gross weight)
DELTCG	standard day temperature increment during main mission, deg., C (0.)
EM	surface emissivity, (.8)
TDFLM	thrust deflection during main mission, deg., (0)

Takeoff Input

NOTO	= 1 no takeoff calculations, (0)
FWDTO	fuel weight used during takeoff, lb (may also be input as a fraction of gross weight), (0.)
ALFDOT	aircraft rotational speed, deg/sec, (3.)
DELTCTO	standard day temperature increment during takeoff, deg, C, (0.)
DTGRUP	time for landing gear retraction, sec, (10.)
I1EOUT	= 1 one engine out during takeoff, integer, (0)
RFF	rolling friction factor, (.02)
TXTME	taxi time, min, (10.)
GRALFA	angle of attack before start of rotation, deg (-4)
TOALFA	angle of attack after rotation, deg, (5.5)
TODELF	flap deflection during takeoff, deg, (30.)
TOFLTO	thrust deflection during takeoff, deg, (0.)

TFACT	factor for increasing or decreasing net thrust during takeoff, (1.)
WFFACT	corresponding factor for fuel flow, (1.)
HOBS	obstacle height, ft, (35.)
HNOGE	altitude for disappearance of aerodynamic in-ground effect, ft, (wing span)
TOCLGR	takeoff climb gradient, percent, (6.8)

Climb Input

HASNT(50)	a one-dimensional array containing the altitudes in the climb profile
ZMASNT(50)	a one-dimensional array containing the corresponding Mach numbers in the climb profile
ICLPR	the number of points in the climb profile
ZMSTTH	Mach number at which engine throttling may begin to conserve climb fuel, (.6)
ZMMPCL	Mach number above which maximum engine thrust is used, (1.)

Cruise Input

NCRP	the number of points at which cruise calculations are made, (4)
ZMCR	cruise Mach number
ROCMIN	the minimum rate of climb during cruise, ft/min
CRALT1	altitude for start of cruise, ft (-10)
CRALT2	altitude for second leg of two-step cruise (-10)
IBFCR	= 1 gives cruise at best available Breguet factor, integer, (0)
ICACR	= 1 gives cruise at constant altitude, integer, (0)
ICLCR	= 1 gives cruise at constant lift coeffficient, integer, (0)
ALFCR	angle of attack for cruise, deg (Note: this input may be used only if CLAR or ALPHAT are input in NAMELIST segment $AIN)
CRTOTM	cruise throttling factor (0.) (if CRTOTM = 1., full power is applied; if defaulted, CRTOTM is not used)

The following input is for subsonic cruise legs on a supersonic mission. Range or time for cruise may be input, but not both at the same time. Cruise on both legs may occur.

For subsonic cruise on the outbound leg:

ZMSBCOB	cruise Mach number
HSBCOB	cruise altitude, ft
SSRNGOB	cruise range, n.mi.
TSBCOB	cruise time, min

For subsonic cruise on the inbound leg:

ZMSBCIB	cruise Mach number
HSBCIB	cruise altitude, ft
SSRNGIB	cruise range, n.mi.
TSBCIB	cruise time, min

Input for Long-Endurance Cruise

CLMAX	maximum lift coefficient, (2.2)
NENCR	number of engines operating during cruise (-1)
DCFACT	increment in drag coefficient for engines not operating, (0.)
VKCR1	velocity at start of cruise, k
ICONVCR	= 1 for constant cruise velocity, (0)

Descent Input

ICALDS	= 1 descent calculations are made = 0 descent calculations are not made
NDSP	the number of points at which descent calculations are made, (4)
DSFF	the fraction of fuel flow at maximum power that is used during descent, (.067)
WFDRCF	an initial estimate of the fuel used during descent normalized by aircraft gross weight, (.005)

Approach Input

APALFA	angle of attack during approach, deg, (-40)
APDELF	flap deflection during approach, deg, (30.)
IFXAFLP	= 1 uses input flap deflection = 0 finds flap deflection for minimum drag, (default) (used only if VAPIN is input)
VAPIN	approach speed, k, (-10) (if defaulted, approach speed is calculated internally) Note: VAPIN is used only if aerodynamic data for more than one flap deflection is input in $AIN.

$RESRV

The input for the reserve fuel legs are placed in this segment.

RFWT	reserve fuel weight, in either pounds or as fraction of gross weight. (use this input only if reserve fuel calculations are to the bypassed)
IRCRO	= 0 calculates climb, cruise, and descent segments of reserve fuel legs = 1 calculates only cruise segments of reserve fuel legs, (1)

Trip Fuel Allowance

TPFATME	time at fuel flow at start of cruise, h or min (use for subsonic aircraft), (0.)
TPFA	percent of trip fuel (use for supersonic aircraft), (0.)

Missed Approach

ICALMA	= 0 uses RMAFA to calculate fuel requirement = 1 calculates missed approach to find fuel requirement, (1)
RMAFA	time at takeoff fuel flow, min, (2.0)

Alternate Airport

AAD	distance to alternate airport n.mi., (0.)

For this leg, the program normally iterates through Mach number, altitude, and engine thottling during climb to find the conditions for least fuel. If any of the following variables are input, iteration on that condition will not be performed.

HALT	altitude for cruise to alternate airport

TOTMALT	factor for engine throttling during climb to cruise, value between 0 and 1.
ZMALT	Mach number for cruise to alternate airport

Hold

THLD	time for hold, min
HHLD	altitude for hold, ft
ZMHLD	Mach number for hold

Again, optimum conditions for least fuel are normally determined but inputs in HHLD and/or ZMHLD will eliminate the iteration on that condition.

$TECHCHG

This segment contains the inputs for finding the effects of changes in the technology of the various aircraft systems.

TIML	the lowest Mach number at which changes apply, (-1)
TIMH	the highest Mach number at which changes apply, (10.)
TDCDT(15)	a one-dimensional array of percentage changes in total drag coefficient, a function of Mach number; a positive value gives drag reductions
TMDCDT(15)	the Mach numbers corresponding to the values in TDCDT
NDCDT	the number of values in the TDCDT array, (0)

The following input is all in percentages. A positive value gives a technology improvement. Default values for all inputs are 0.

DSFC	engine specific fuel consumption
DCDW	wave drag
DCDRUF	roughness drag
DCDAC	air-conditioning drag
DCDBL	bleed drag
DCDO	zero-lift drag
DCDL	drag due to lift
DCDT	total drag

Friction Drag Changes

DCDFWNG	wing
DCDFCS	canards, horizontal tails, and vertical fins
DCDFBDY	fuselage
DCDFPDS	nacelles
DCDF	total friction drag

Weight Changes

DWWING	wing
DWCHV	canard, horizontal tail, vertical fin
DWFUS	fuselage
DWLG	landing gear
DWNAC	nacelles
DWST	total structure weight
DWENG	engines
DWTR	thrust reversers
DWTPR	propellers
DWTGB	gear box
DWMIS	miscellaneous propulsion system weights
DWPLM	plumbing system
DWFT	fuel tank for hydrogen or methane fuel
DWINS	fuel tank insulation for hydrogen or methane fuel
DWPPS	total propulsion system weight
DWSC	surface controls
DWAP	auxiliary power
DWINST	instruments
DWHYD	hydraulics
DWELE	electrical

DWAVON	avionics
DWFEQ	furnishings and equipment
DWACOND	air conditioning
DWANTICE	anti-icing
DWSEQ	total systems and equipment weight
DWEMP	empty weight
DWOEW	operating empty weight

Laminar Flow

The following inputs express the percentage of laminar flow on the surface. A value of 0. gives all turbulent flow; a value of 100. gives all laminar flow. All default values are 0.

PCLAMW	wing
PCLAMF	fuselage
PCLAMC	canard
PCLAMH	horizontal tail
PCLAMBV	body vertical fins
PCLAMWV	wing vertical fins
PCLAMP	nacelles

INPUT FOR BASELINE AIRCRAFT GEOMETRY

The geometry for the baseline aircraft can be input by one of two methods. The first method which applies only to supersonic aircraft uses the zero-lift wave-drag program format described in reference 7. This input is very detailed and unless it is already available from the analysis of wave drag, the effort required to assemble the information is not justified for this program. The alternate method available is the use of $SACGEM.

$SACGEM

Wing

REFA	wing reference area, ft^2
WXO	distance from fuselage apex to wing apex at wing centerline, ft

WRC	root chord at wing centerline, ft
WTC	tip chord, ft
WSPAN	wing span, ft
WDXT	longitudinal distance from wing apex to leading edge of tip chord, ft (positive rearward)
YWCREX	spanwise distance from wing centerline to exposed root chord, ft
NWBP	number of breakpoints in wing leading and trailing edges, an integer. Wing apex and tip are not included. If leading edge and trailing edge break at the same spanwise station, count as one breakpoint.
WDXBP(12)	a one-dimensional array of the longitudinal distances from wing apex to leading edge at breakpoints, ft (positive rearward)
WYBP(12)	a one-dimensional array of the spanwise distances to the breakpoints ft
WBPC(12)	a one-dimensional array of wing chords at the breakpoints, ft
WTOC	average maximum wing thickness-chord ratio in percent

Fuselage

FLGTH	length, ft
FDPTHMX	maximum depth, ft
FWDTHMX	maximum width, ft
FRAD	maximum radius, ft (Note: If FRAD is input, FDPTHMX and FWDTHMX inputs are not required)
FWETA	total fuselage surface area, ft^2
FVOLTOT	total fuselage volume, ft^3

Horizontal Surfaces

The dimensions for horizontal surfaces are input in the folloiwng one-dimensional arrays.

NH	the number of horizontal surfaces, (2 maximum)
HDXT(2)	the longitudinal distance from the apex of the surface to its leading edge at the tip, ft
HRC(2)	root chord, ft
HTC(2)	tip chord, ft

HSPAN(2)	span, ft
HTOC(2)	average thickness-to-chord ratio, percent
HXO(2)	longitudinal distance from fuselage apex to surface apex, ft

Vertical Surfaces

The dimensions for the vertical surfaces are input in the following one-dimensional arrays. A spanwise mounted surface is assumed to be located symmetrically about the fuselage centerline and is counted as one surface.

NV	the number of vertical surfaces, (4 maximum)
VDXT(4)	the longitudinal distance from the apex of the surface to its leading edge at the tip, ft
VRC(4)	root chord, ft
VTC(4)	tip chord, ft
VSPAN(4)	span, ft
VTOC(4)	average thickness-to-chord ratio, percent
VXO(4)	longitudinal distance from fuselage apex to surface apex, ft
VYO(4)	spanwise distance from fuselage centerline to surface, ft

Nacelles

XOP(9)	a one-dimensional array containing the longitudinal distances from the fuselage apex to the nacelle, ft
YOP(9)	a one-dimensional array containing the spanwise distances from the fuselage centerline to the nacelle centerline, ft
NPI	the number of nacelles in the above arrays

Spanwise mounted nacelles are counted in the same manner as the vertical surfaces.

$AIN

The baseline aerodynamic input is located in this segment. Trimmed angle of attack, lift, and drag data are preferred.

Takeoff Aerodynamic Input With Ground Effect

TALPTOG(15,4)	a two-dimensional array of angle of attack for various flap deflections, deg
TCLTOG(15,4)	a similar array for the lift coefficients, C_L
TCDTOG(15,4)	a similar array for the drag coefficients, C_D
NTOG	the number of values in each of the above arrays at each flap deflection, (15 maximum) (If NTOG = 0, an internal routine is used to calculate values in the above arrays when the following takeoff input is provided.)

Takeoff Aerodynamic Input Without Ground Effect

TALPHTO(15,4)	angle-of-attack array
TCLTO(15,4)	lift-coefficient array
TCDTO(15,4)	drag-coefficient array
NTOP	the number of values in the above arrays at each flap deflection, (15 maximum), (0)
NFD	the number of flap deflections, (4 maximum) (0)
TFSET(4)	a one-dimensional array containing the flap deflections, deg
CDGRT(15)	a one-dimensional array of increments in drag coefficient of the landing gear as a function of lift coefficient
CLGRT(15)	the corresponding array of lift coefficients
NLGD	the number points in the above arrays, (0)
DCDLG	increment in drag coefficient of landing gear (independent of lift coefficient, use if NLGD = 0

Main Mission Aerodynamic Input

CLT(15,15)	a two-dimensional array of lift coefficients for various Mach numbers
ALPHAT(15,15)	the corresponding array for angles of attack, deg
CDPT(15,15)	the corresponding array for the drag coefficients
NAI	the number of values in each of the above arrays at each Mach number (the value of the first dimension; NAI points must be input at each Mach number)

IPBOL	= 0 aerodynamic input in CLT, ALPHAT, and CDPT will be used for aerodynamic data (the default value)
	= 1 the parabolic polar inputs (CDOR, CLAR, DLFR, and CLOR defined below will be used for aerodynamic data
CDOR(15)	a one-dimensional array containing the minimum drag coefficients at various Mach numbers
CLAR(15)	a similar array for the lift-curve slope, per deg
DLFR(15)	the array for drag-due-to-lift factors
CLOR(15)	the array for lift coefficients at minimum drag coefficient
NAJ	the number of Mach numbers for the lift and drag data (15 maximum)
MAEROT(15)	a one-dimensional array containing the Mach numbers for the lift and drag data
THARO(15)	a one-dimensional array containing the altitudes at each Mach number at which the skin friction contributions to drag were calculated
DELCD(15)	a one-dimensional array containing increments in zero-lift drag coefficient for the Mach numbers in MAEROT
CDW(15)	a one-dimensional array containing the wave-drag coefficients at each Mach number in MAEROT
CDRUF(15)	a similar array of roughness drag coefficients
CDAC(15)	a similar array of air-conditioning drag coefficients
CDBL(15)	a similar array of engine-bleed drag coefficients

Note: Input for CDAC and CDBL is required only if values are included in CDPT or CDOR.

$WTIN

This segment contains the weights and all other input for the baseline aircraft but not the engine data. Except where noted default values are 0 and input weights are in pounds.

Structural Weight Input

WWING	wing
WHT	horizontal tail

WVT	vertical tails (sum of all)
WCAN	canard
WFUS	fuselage
WLG	landing gear

Weight Input for Cryogenic Tanks (Hydrogen on Methane Fuel)

WFT	fuel tank, total
WINS	insulation, total
WFTINS	combined weight of fuel tank and insulation (required only if WFT and WINS cannot be separated)
TSA	total surface area of fuel tank, ft^2

System and Equipment Weight Input

WSC	surface controls
WAP	auxiliary power
WINST	instruments
WHYD	hydraulics
WELE	electrical
WAVON	avionics
WFEQ	furnishings and equipment
WACOND	air conditioning
WANTICE	anti-icing

Operating Weight Inputs

WFCR	weight of flight crew
IFCR	number of flight crew members, integer
WCCR	weight of cabin crew
ICCR	number of cabin crew members, integer
WUFUEL	unusable fuel

WENO	engine oil
WPSER	passenger service
WCCONT	cargo containers
WOPIN	sum of all operating weights (use only if all individual weights cannot be supplied)

Payload Weight Input

WPAS	weight of passengers
IPASR	number of passengers, integer
WPB	passenger baggage
WCAR	weight of cargo

Miscellaneous Input

WGREF	gross weight of baseline aircraft
ULF	design load factor, (3.5)
ZMDESBL	design Mach number for baseline aircraft
STSABR	number of seats abreast
LVLR	number of passenger levels, (2 maximum)
XPASC	length of passenger compartment, ft
VCARMX	maximum volume for cargo, ft^3
BFCILBS	maximum fuel capacity in fuselage, lb
WFCILBS	maximum fuel capacity in wing, lb
BFCIGAL	fuel capacity in fuselage, gal
WFCIGAL	fuel capacity in wing, gal (Note: input for BFCIGAL and WFCIGAL is not required if BFCILBS and WFCILBS are used)

$ENIN

Data for the engine and nacelle are input in this segment.

NENR	the number of engines, integer
NEW	the number of engines mounted on the wing, integer
NEF	the number of engines mounted on the fuselage, integer
NPODSR	the number of engine nacelles, integer
PDAVG	the average diameter of the nacelle, ft
PLGTH	the length of the nacelle, ft
ESEXP	nacelle length sizing exponent, (.438)
EWEXP	engine weight sizing exponent, (1.085)
SLSTHR	sea level static thrust for the engine having the following weight, lb
WENG	weight of one engine, lb
WTR	weight of one thrust reverser, lb
WNAC	weight of one engine nacelle, lb
WMIS	total miscellaneous propulsion system weight, lb
WPLM	total propulsion plumbing system weight, lb

The following three variables are provided for engine bleed and air-condition drag. These variables should be used only if the drag items are not included in gross thrust values or by entries in CDAC and CDBL in $AIN.

DOQINT(15)	a one-dimensional array containing the sum of engine bleed and air-condition drags divided by dynamic pressure for a range of Mach numbers, ft^2
DOQMT(15)	the corresponding array of Mach numbers
NBDP	the number of Mach numbers in the above arrays

Note: These variables cannot be used for engines with two-dimensional inlets.

Input for Propeller-Engine Combinations

Propeller-driven aircraft require no additional input if: (1) propeller output data is not required, (2) the weight of the propeller and gear box are included in the engine weight, WENG, and (3) the design inputs TOWDES, TPEDES, TOWTB, or TPETB, rather than POWDES, SHPDES, or POWTB are used to size the propulsion system. This analysis treats the aircraft as a jet-driven aircraft.

The propeller will be treated in more detail, however, if TAPE3, described previously, is provided and the following data is input.

ADVRDES	design advanced ratio
CPDES	design power coefficient
CTDES	design thrust coefficient
EPRDES	propeller efficiency at design conditioning
EOVDES	overall efficiency of the propeller-engine combination at design conditions
POD2DES	shaft horsepower-propeller diameter squared ratio at design conditions, hp/ft^2
PTIPS	propeller tips speed at design conditons, fps
DIAMPBL	propeller diameter, ft (-10.)
SHPREF	shaft horsepower of the engine at sea level static conditions and having its weight entered in WENG
RPMEBL	engine RPM
RPMPBL	propeller RPM
PSEXP	propeller weight sizing exponent (2.488)
WTGB	weight of one gearbox, lb (-10.)
WTPR	weight of one propeller, lb (-10.)

The propeller weight, WTPR, is used to test if a jet analysis the (default case) or a propeller analysis is to be made. When WTPR is input, all of the above propeller inputs and the P/D^2 values, described below, are required.

Input for Engine with Two-Dimensional Inlets

INL2D	= 1 engine nacelles are two-dimensional = 0 engine nacelles are circular, (default)
PWID2D	width of the nacelle, ft
PHGT2D	height of the nacelle, ft
PLGTH	length of the nacelle, ft
PSWET2D	wetted area of one nacelle, ft^2

BASELINE ENGINE CHARACTERISTICS

This final input segment contains four groups of data for the installed engine. These include the identification of the baseline engine, full-power data as a function of altitude and Mach number, part-power data, and for engines with two-dimensional inlets, full-power data as a function of Mach number, angle of attack, and altitude. The engine identification, the first input of this segment, is one line of free-field input limited to 80 characters.

The next input provides the full-power characteristics of the engine as a function of Mach number and altitude. The data format is as follows:

Column	Type of Data
1-5	Mach number
6-15	altitude, ft
21-30	gross thrust, lb
31-40	ram drag, lb
41-50	fuel flow, lb/h
51-60	P/D^2, hp/ft^2

Where P/D^2 is the shaft horsepower-propeller diameter squared ratio. P/D^2 data is required only if the propeller data described above is input.

The data is arranged by increasing altitude at constant Mach number, then by increasing Mach number. Up to 15 separate values of altitude and 15 separate values of Mach number are allowed. On the last line of this data segment, the characters 9. located in columns 2 and 3 are required.

The next group of data pertains only to engines with two-dimensional inlets and is required only if the effects of angle of attack are to be included in the full-power data. To indicate the presence of this data group, which is restricted to supersonic and higher Mach numbers, the first line of input must contain the three characters -9. in columns 2, 3, and 4. On succeeding lines thereafter, the data is input in the following format.

Column	Type of Data
1-5	Mach number
6-15	altitude, ft
16-20	angle of attack, deg
21-30	gross thrust, lb
31-40	ram drag, lb
41-50	fuel flow, lb/h

The data is arranged by increasing altitude at constant angle of attack and constant Mach number, then by increasing angle of attack at constant Mach number, then by increasing Mach number. Input is restricted to 15 values of Mach number, 3 values of angle of attack at each Mach number, and 3 values of altitude at each angle of attack--Mach number combination. Sufficient data must be input to provide the same number of angles of attack at each Mach number and the same number of altitudes at each angle of attack--Mach number combination. If this requirement is not met, the program will abort. To end this data group, the two characters 9. must be located in columns 2 and 3 on the last line of input.

The last input provides the part-power characteristics of the engine. The format for this data is:

Column	Type of Data
1-5	Mach number
21-30	gross thrust, lb
31-40	ram drag, lb
41-50	fuel flow, lb/h

Data is arranged by increasing thrust at constant Mach number, then by increasing Mach number. The last input of this group must contain the two characters 9. located in columns 2 and 3.

SAMPLE INPUT LISTING

An input listing that illustrates the content of the previous section is given in Table B1. This input is for the design point of the supersonic transport (JP fuel) shown in figure 22 and the resulting output is discussed in Appendix C.

While the sizing "thumbprint" (fig. 22) provides fairly accurate values of W/S and T/W for the design point, the gross weight value is very approximate. To more accurately determine this value, the computer must be directed to find the gross weight that provides the design range at the design point conditions. This is done in input segment $DESGNVB by inputs for the required range (RNGDES = 4000.), wing loading (WOSDES = 82.), and thrust-weight ratio (TOWDES = .32). These and the other inputs for the sized aircraft are shown in Table B1.

ENDIX C

OUTPUT

The output from the program is contained on three mass storage files. Unless changed by the user at execution time, these files are labeled TAPE6, TAPE11, and TAPE14. TAPE 6 contains a listing of all the results provided by the program, TAPE11 contains selected data in a format suitable for input to a plotting program, and TAPE14 contains the basis for preparing sizing "thumbprints."

TAPE6

On this file, several types of output are available. These include the preliminary output, sized aircraft output, a short listing of selected output quantities, weight statement, and a mission profile output.

Preliminary Output.- This printout, which is optional and obtained with IPPRNT=1 in $PRNTCON, contains a listing of the input values for all input segments. Because of its length, an example of this output is not given here.

Sized Aircraft Output.- This printout, which cannot be suppressed, contains the results for each sizing variation requested. A listing of the output that results from the input for the design-point aircraft given in Table B1 is given in Table C1. A short summary of this listing is also output and this is shown in Table C2. A listing of the weight statement, if selected by IPRWTSM=1, is given in Table C3. With IPRMPRF=1, mission profile results are output and these are listed in Table C4.

TAPE11

This file, produced for every computer cycle, contains the same parameters as the short output list (Table C2) located on TAPE6. The file is formatted to allow the sizing and performance results to be plotted during interactive plotting sessions where the abscissa and ordinate of the plots are identified by the indices of the chosen variables. The indices are the numbers of the variables on the short output list in Table C2. An illustration of the listing this file contains is shown in Table C5 and the different sections of data correspond to different computer cycles in which the sizing parameters are varied. The first section contains the same results as the short output list (Table C2) for the design point aircraft; the remaining sections contain the results for a systematic variation in thrust-to-weight ratio at constant wing loading. The integer at the beginning of each section has a constant value for all sections of data that belong to the same curve (in this case, a constant value of wing loading).

TAPE14

This file contains the basis for preparing sizing "thumbprints" like that shown in figure 22. Unlike TAPE6 and TAPE11, this file is produced only when a matrix of wing and engine size variations are to be computed. To produce the "thumbprint" for the supersonic transport, (fig. 22), inputs were required for the design range

(RNGDES = 4000.), an array of values for wing loading (WOSTB = 110., 100., 90., 80., 70., 60., 50.), an array of thrust-to-weight ratios (TOWTB = .25, .30, .35, .40, .45, .50, .55), along with NWOS = 7 and NTOW = 7. The values that resulted from one computer run are shown in Table C6. The listing contains the abscissa values of wing loading, the ordinate values of thrust-to-weight ratio, and the values of the parameters to be contoured that are functions of wing and engine size. The rows provide the change in data with W/S at constant T/W, whereas the columns give the data change with T/W at constant W/S. The large negative values (-1000000) are default values used where no solutions were obtained.

Table C6 identifies all the parameters that are available for contouring. To obtain the coordinates of the actual contours, the data on this file can be either cross-plotted by hand or TAPE14 can be used to prepare an input file for a contouring program.

APPENDIX D

JOB CONTROL CARDS

The program executes on the Network Operating System (NOS) Version 1.4 currently in use at the Langley Research Center. The control cards required for execution are:

```
GET, ASP/UN = 273347N
ASP (F5, F6, F11, F14)
```

where

F5 is the file containing the baseline aircraft input and sizing options (TAPE5)

F6 is the output file (TAPE6)

F11 is the file containing plot data (TAPE11)

F14 is the file containing the data for contour plots (TAPE14)

Note: Although the file containing the propeller design data (TAPE3) does not appear in the execution card ASP, it must be a local file during execution.

The storage requirement for program execution is about 210,000 (octal) words.

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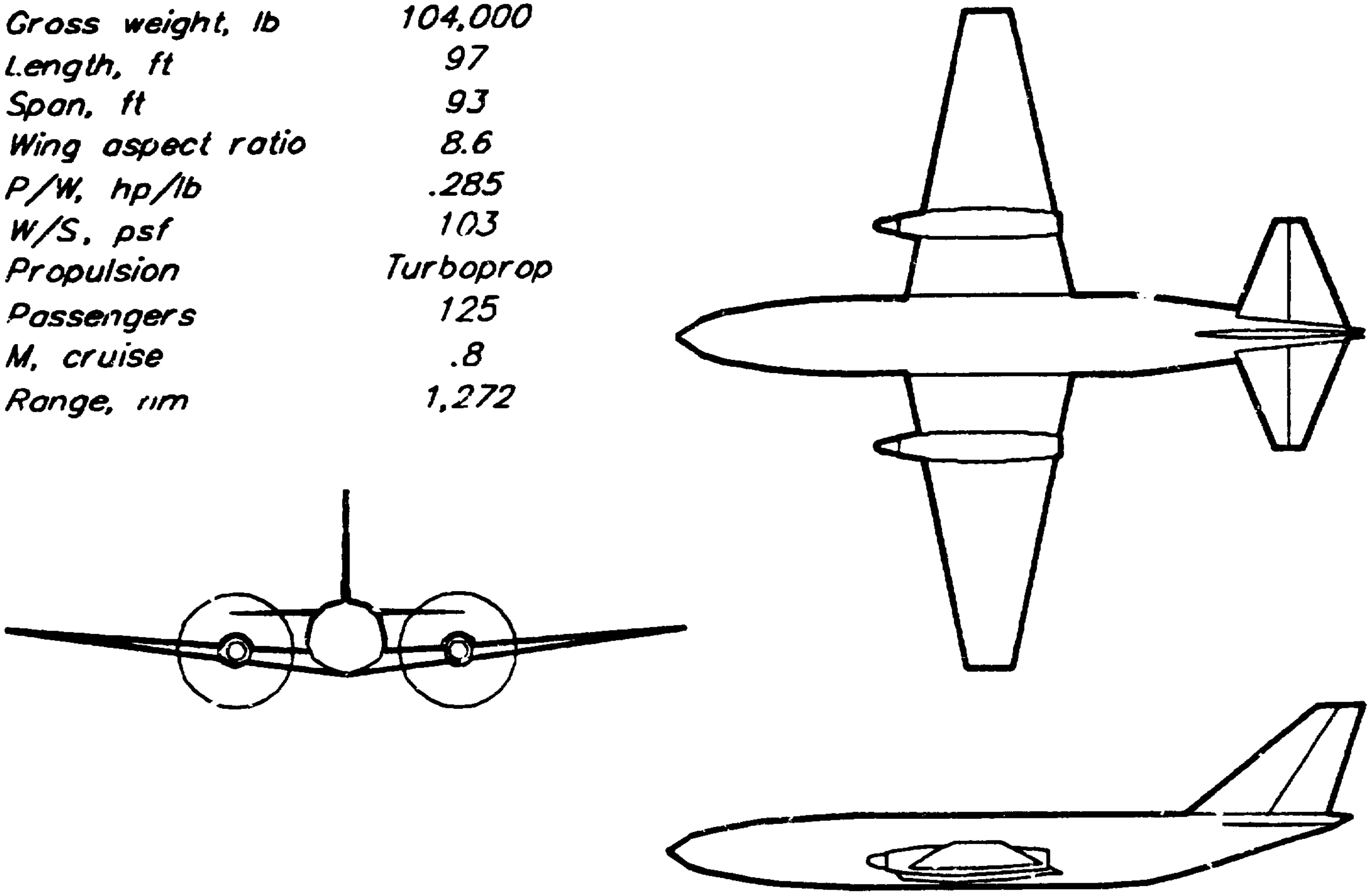
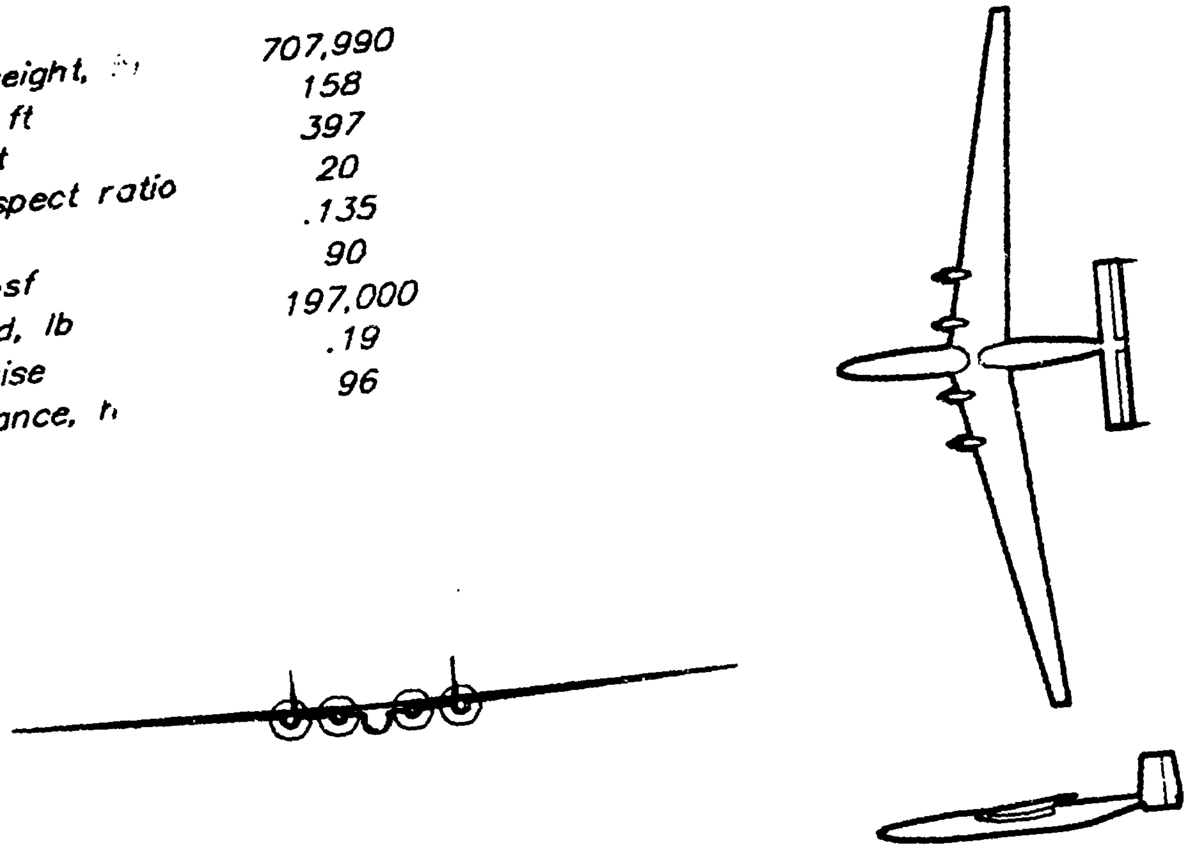
Gross weight, lb	104,000
Length, ft	97
Span, ft	93
Wing aspect ratio	8.6
P/W, hp/lb	.285
W/S, psf	103
Propulsion	Turboprop
Passengers	125
M, cruise	.8
Range, nm	1,272



(a) Subsonic transport

Figure 1.- Baseline aircraft.

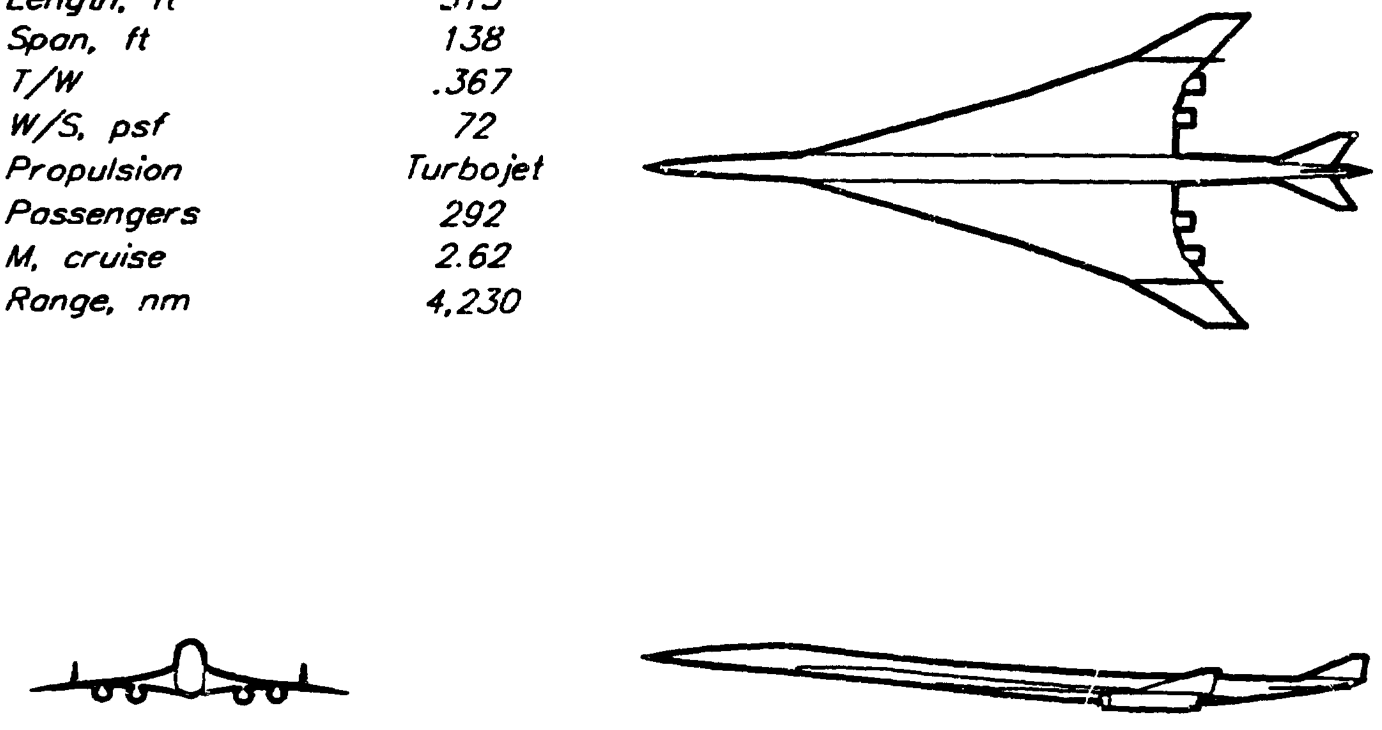
Gross weight,	707,990
Length, ft	158
Span, ft	397
Wing aspect ratio	20
T/W	.135
W/S, psf	90
Payload, lb	197,000
M, cruise	.19
Endurance, h	96



(b) Long endurance aircraft

Figure 1.- Continued.

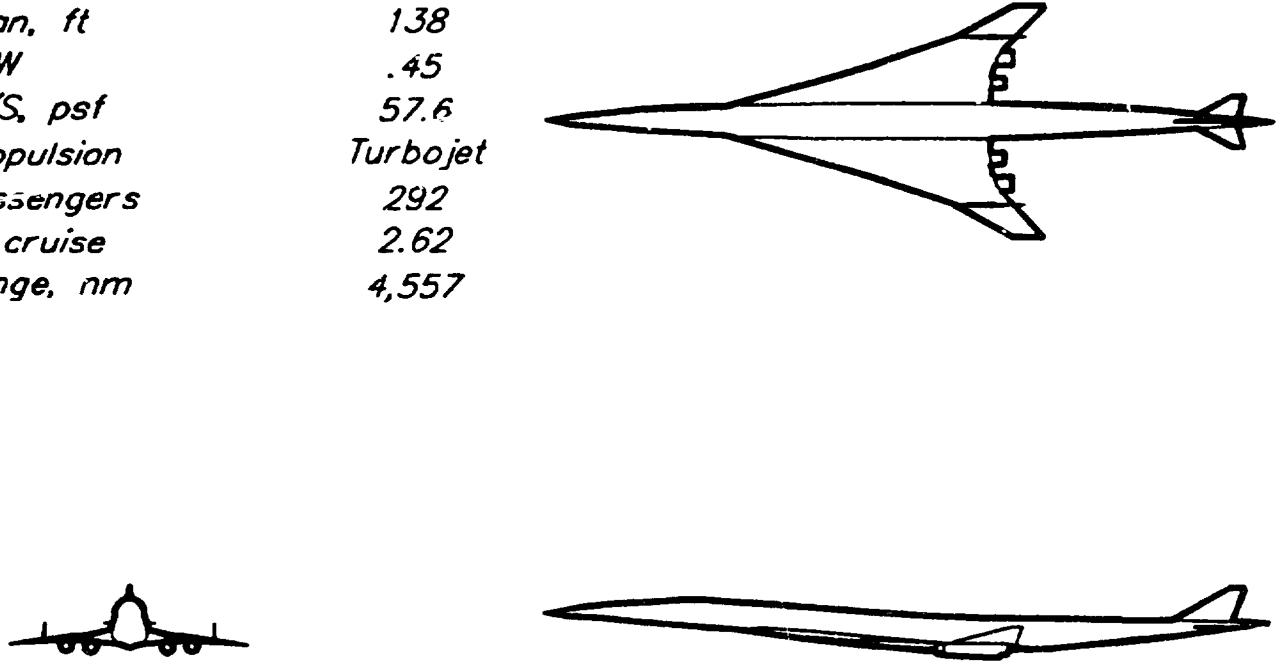
Gross weight, lb	718,000
Length, ft	315
Span, ft	138
T/W	.367
W/S, psf	72
Propulsion	Turbojet
Passengers	292
M, cruise	2.62
Range, nm	4,230



(c) Supersonic transport, JP fuel.

Figure 1.- Continued.

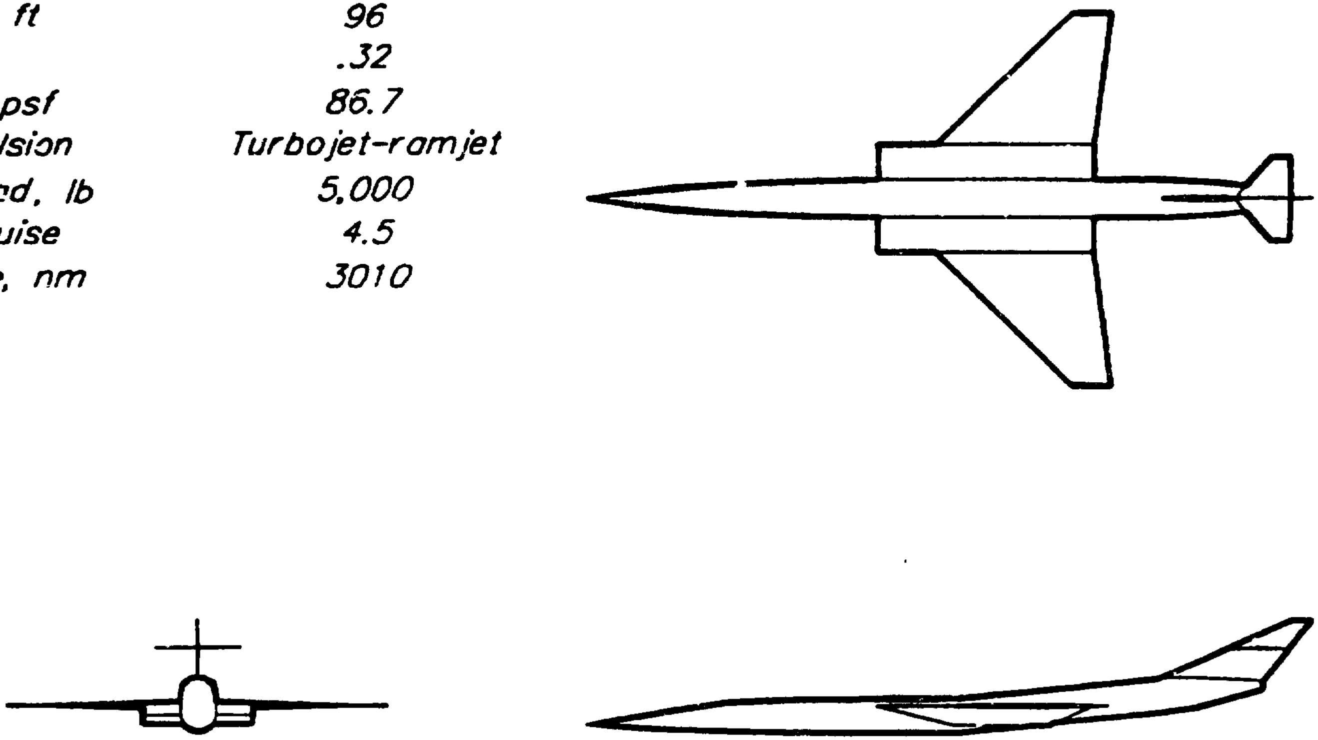
Gross weight, lb	574,736
Length, ft	424
Span, ft	138
T/W	.45
W/S, psf	57.6
Propulsion	Turbojet
Passengers	292
M, cruise	2.62
Range, nm	4,557



(d) Supersonic transport, Liquid hydrogen fuel.

Figure 1.- Continued.

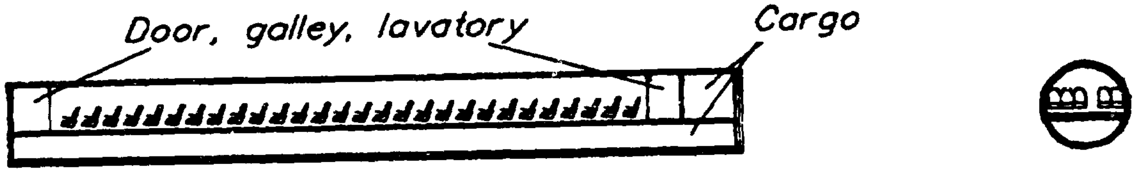
Gross weight, lb	260,000
Length, ft	170
Span, ft	96
T/W	.32
W/S, psf	86.7
Propulsion	Turbojet-ramjet
Payload, lb	5,000
M, cruise	4.5
Range, nm	3010



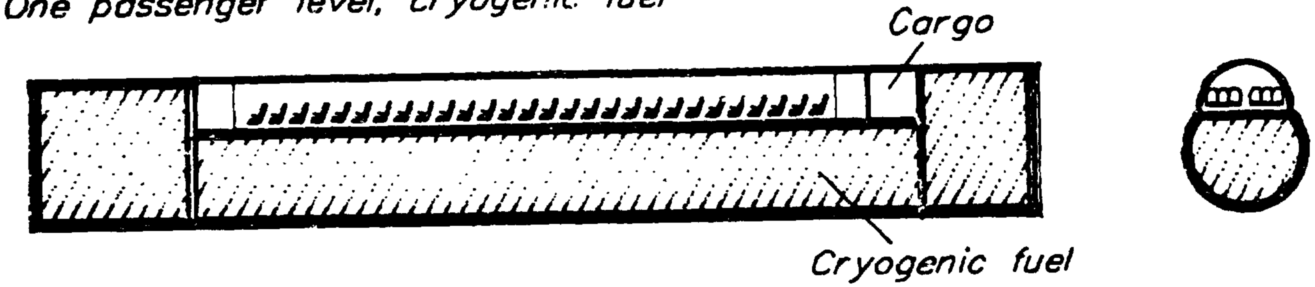
(e) Hypersonic aircraft, Methane fuel.

Figure 1.- Concluded.

(a) One passenger level, JP fuel



(b) One passenger level, cryogenic fuel



(c) Two passenger levels, JP or cryogenic fuel

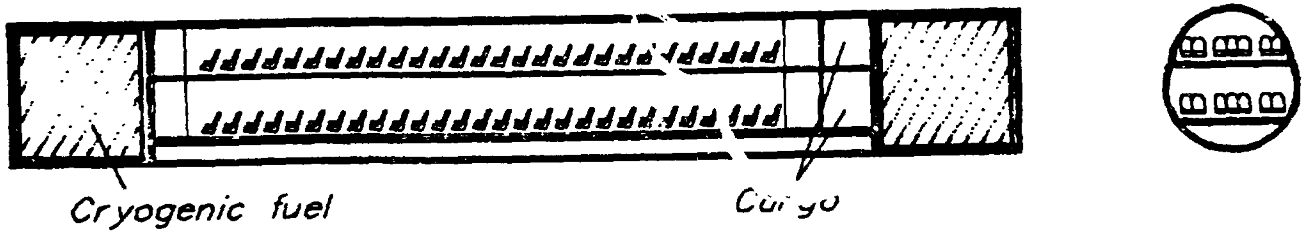


Figure 2.- Fuselage packaging.

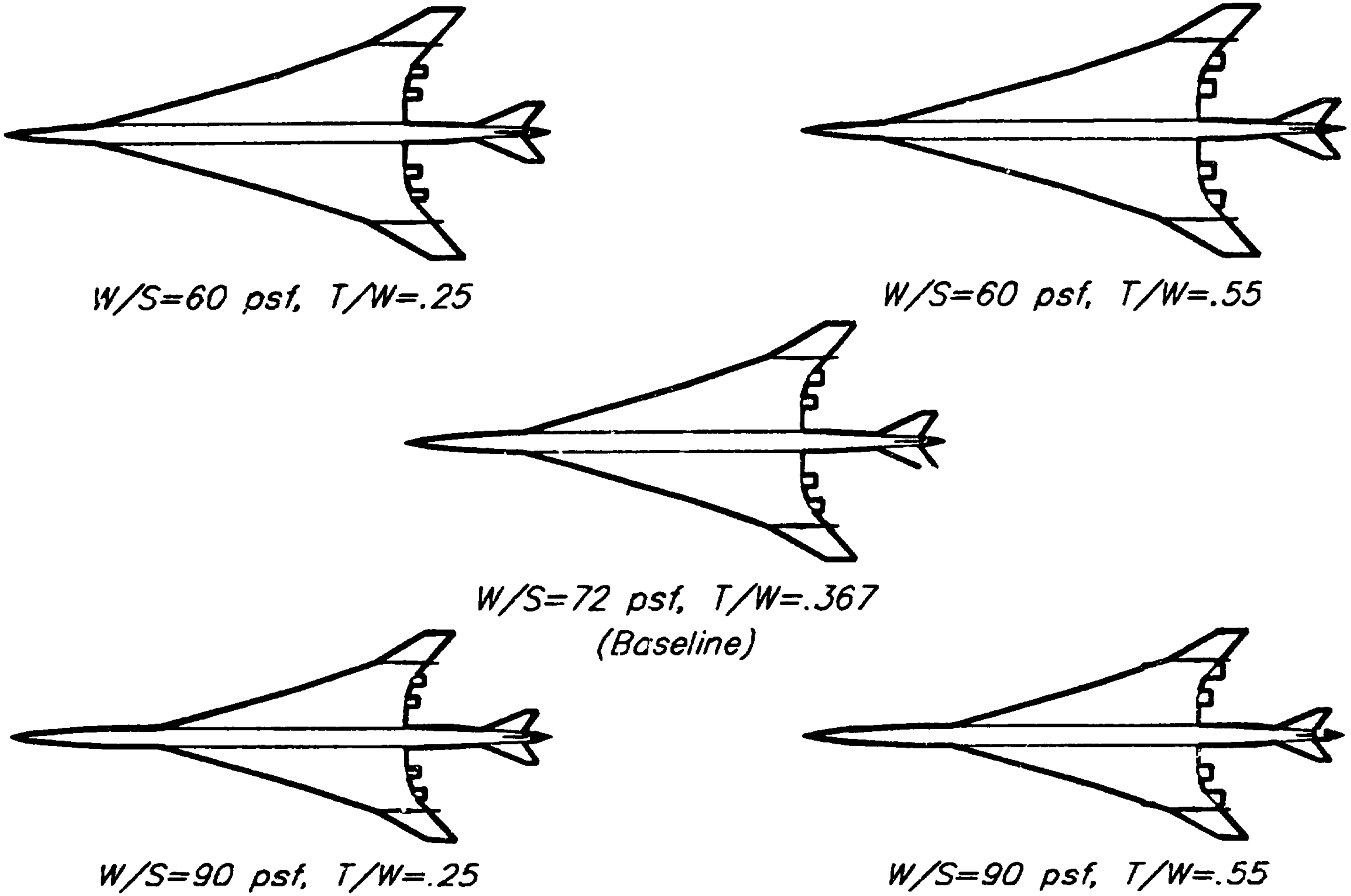


Figure 3.- Effect of sizing on planform of supersonic transport. JP fuel, W_G = 718,000 lb.

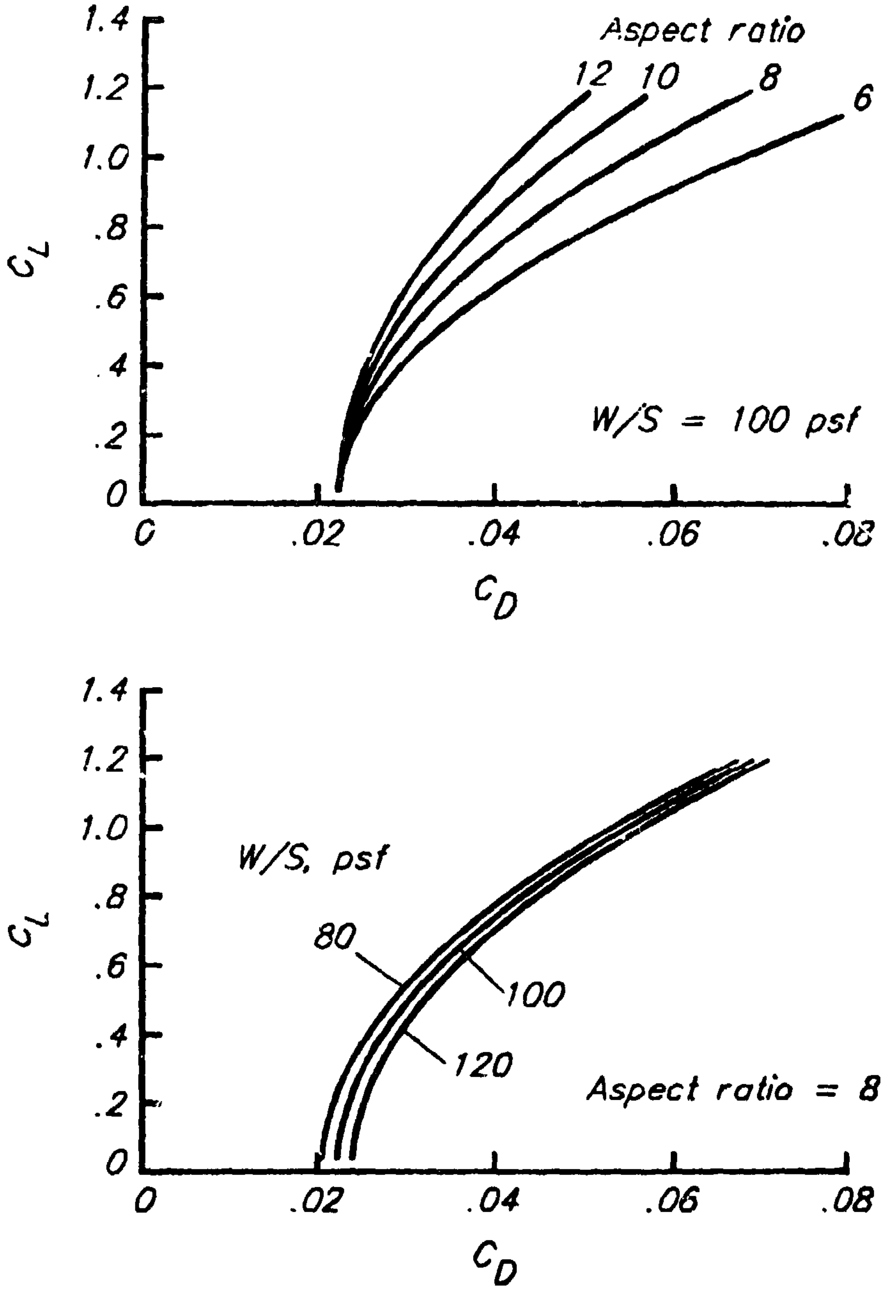
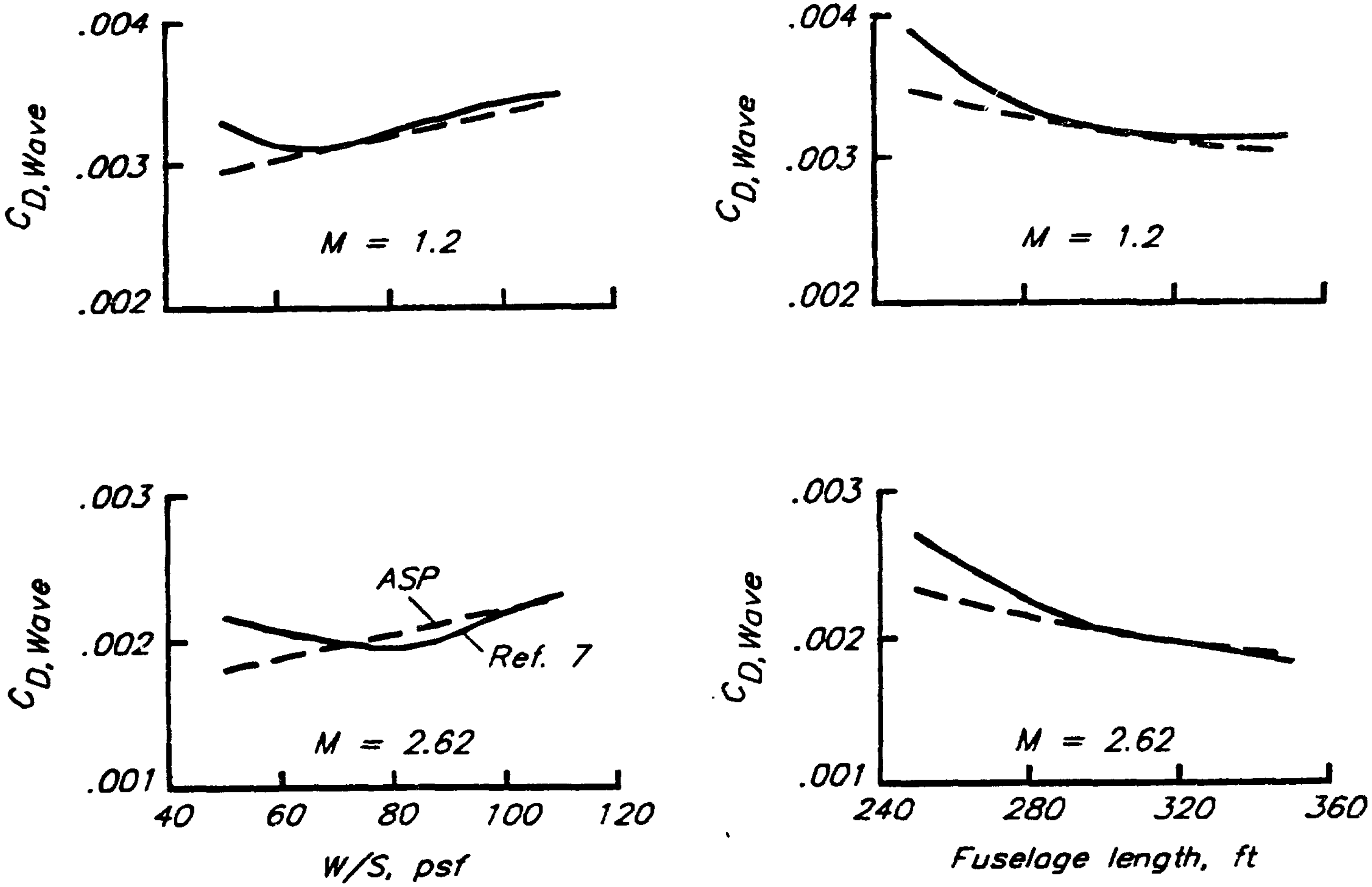


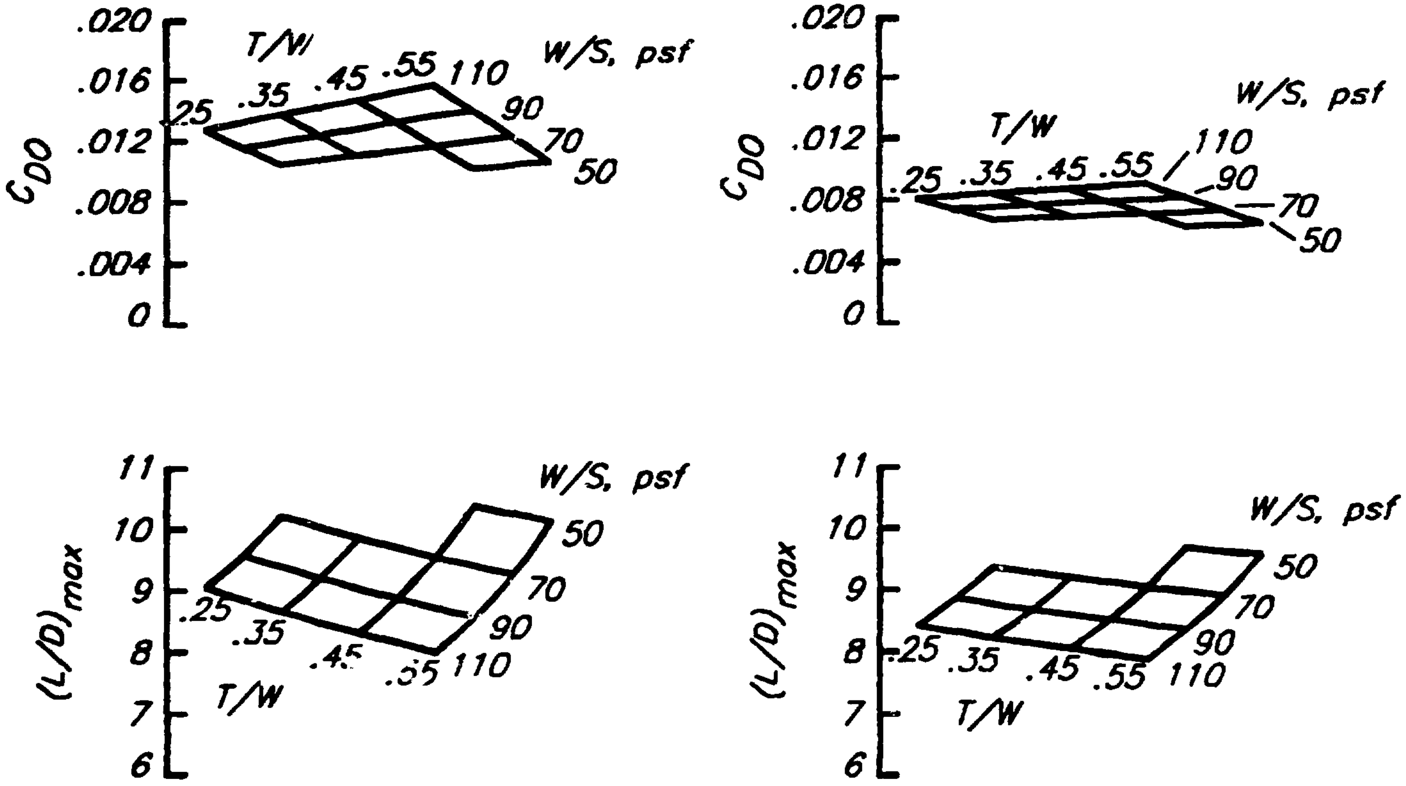
Figure 4.- Effect of sizing on lift-drag polars. Subsonic transport, $M = .8$, $W_G = 104{,}000$ lb



(a) Fuselage length = 315 ft

(b) W/S = 72 psf

Figure 5.- Comparison of wave drag results. Supersonic transport, JP fuel, W_G = 718,000 lb



(a) M=1.2, H=34,833 ft

(b) M=2.62, H=57,711 ft

Figure 6.- Effect of sizing on aerodynamics. Supersonic transport. JP fuel, W_G = 718,000 lb

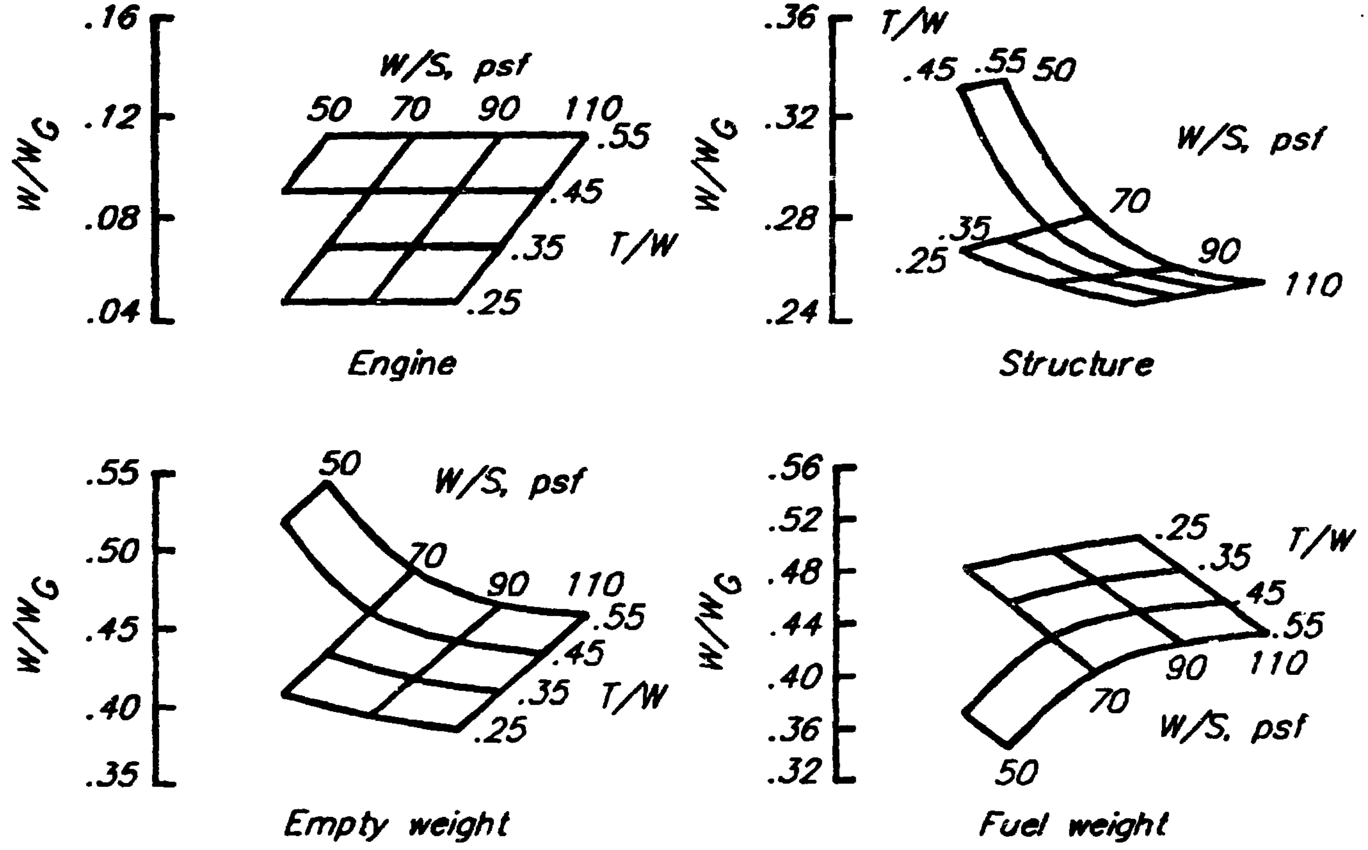


Figure 7.- Effect of sizing on weights. Supersonic transport, JP fuel, W_G = 718,000 lb

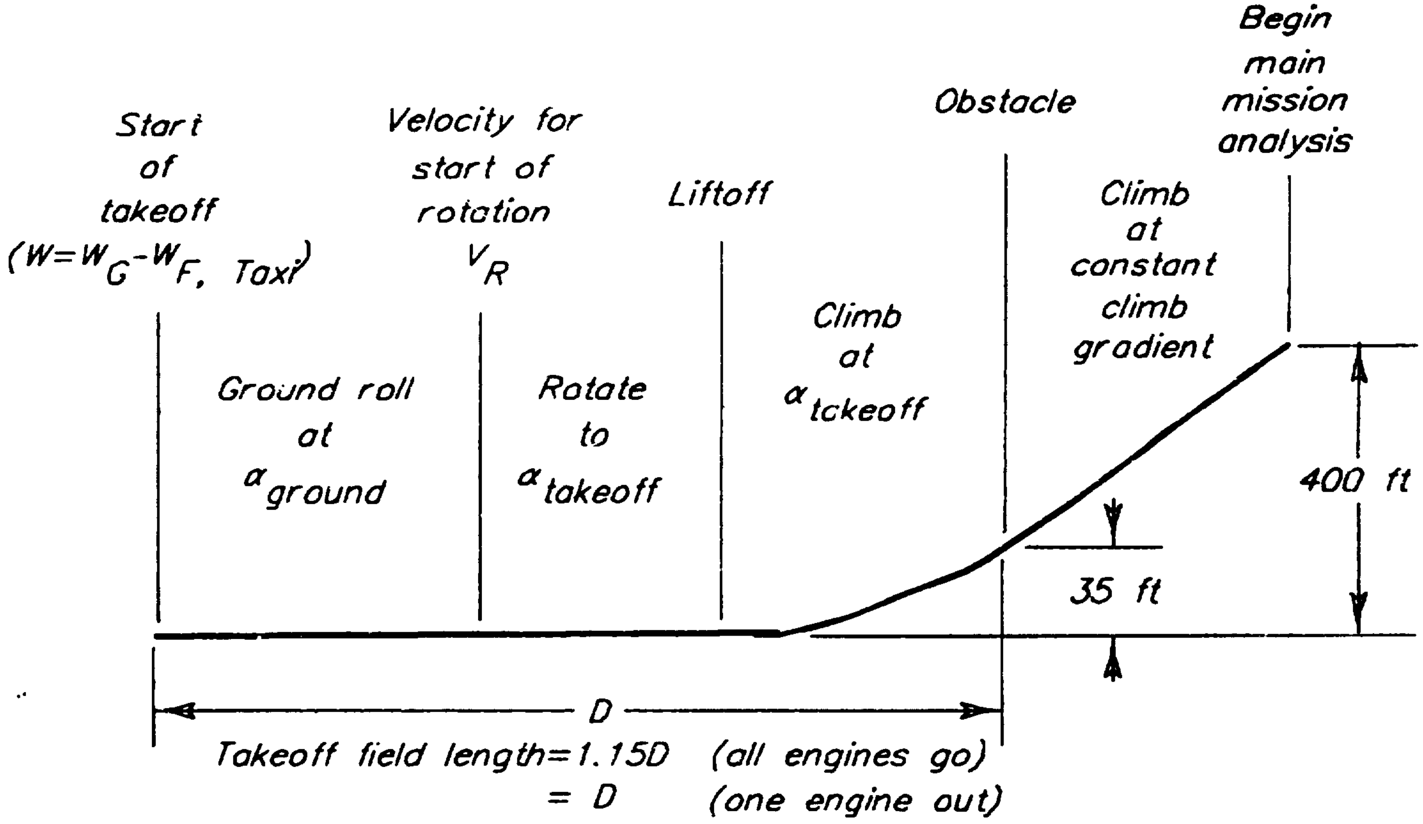
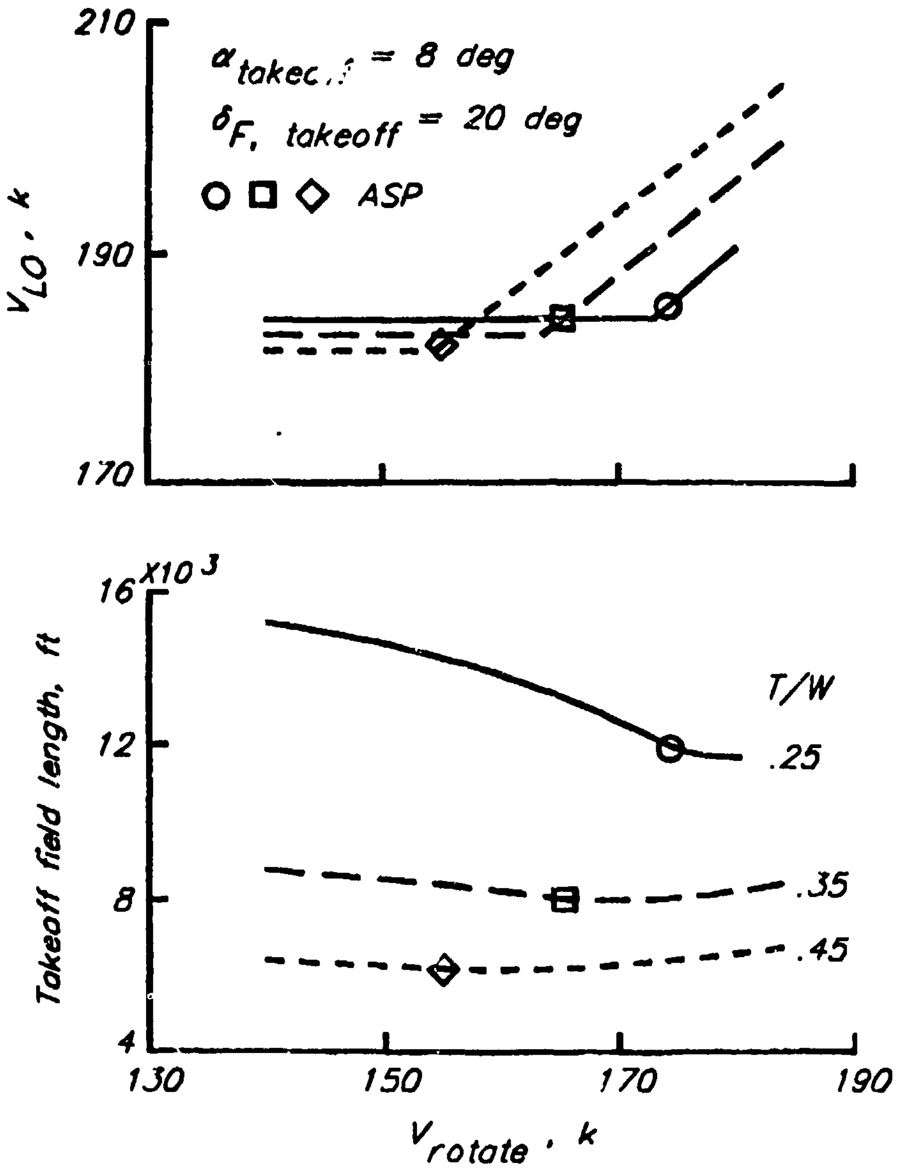
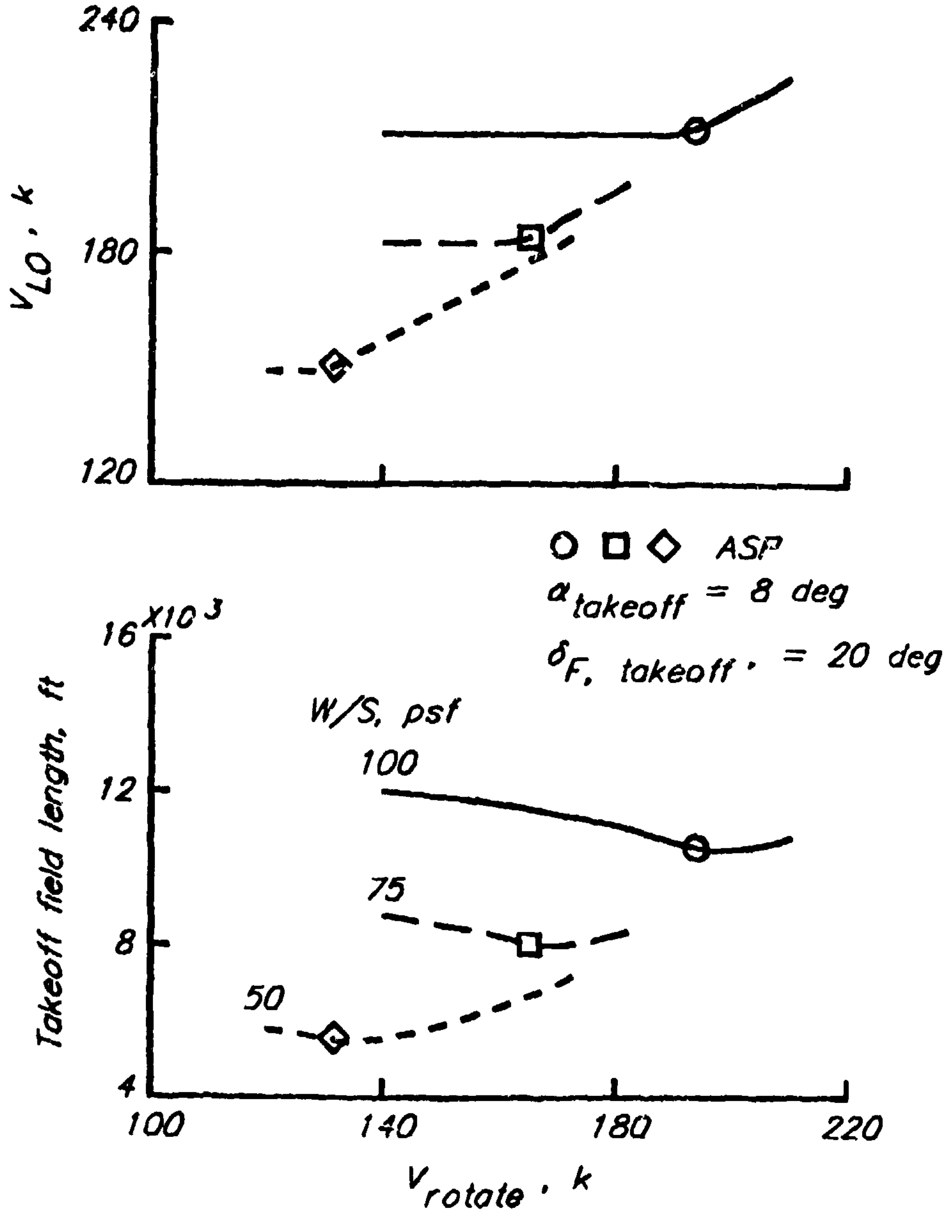


Figure 8.- Typical takeoff flight profile.



(a) $W/S = 75$ psf

Figure 9.- Effect of velocity at start of rotation on takeoff characteristics. Supersonic transport, JP fuel, $W_G = 718{,}000$ lb.



(b) $T/W = .35$

Figure 9.- Concluded.

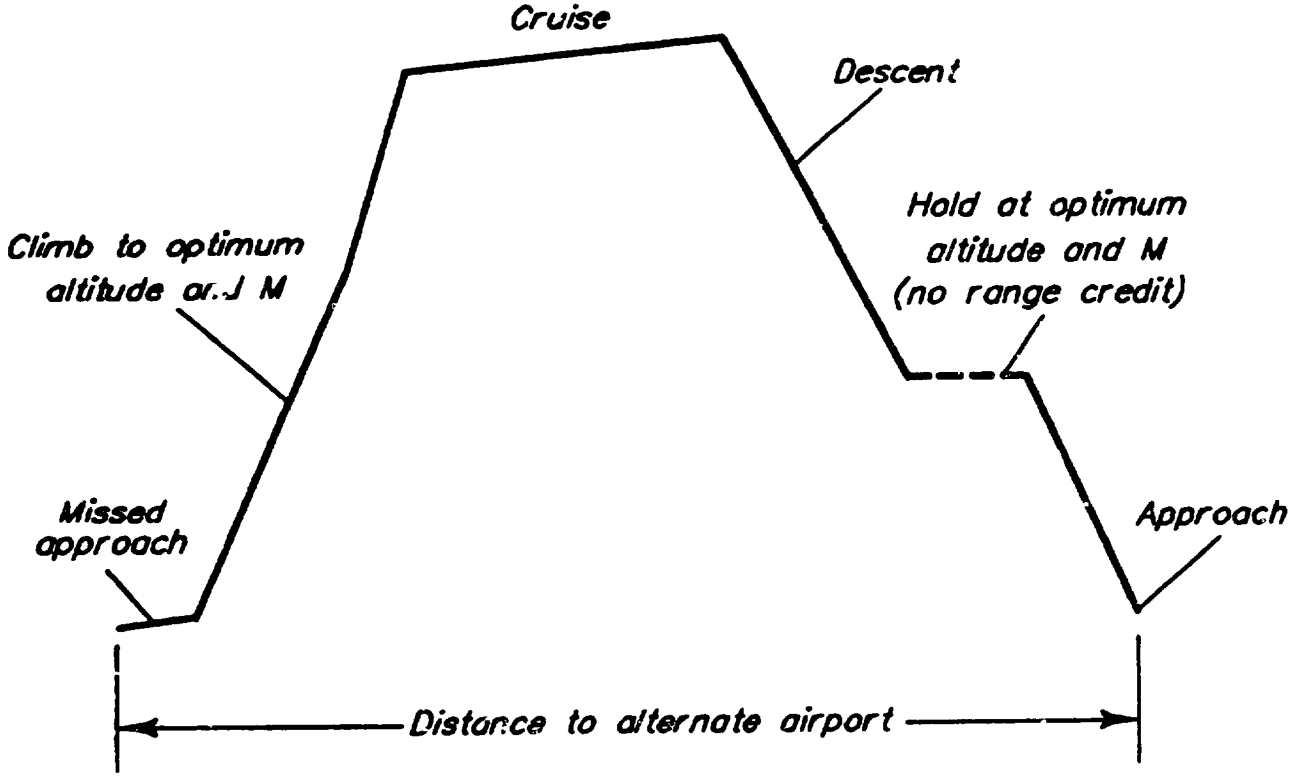
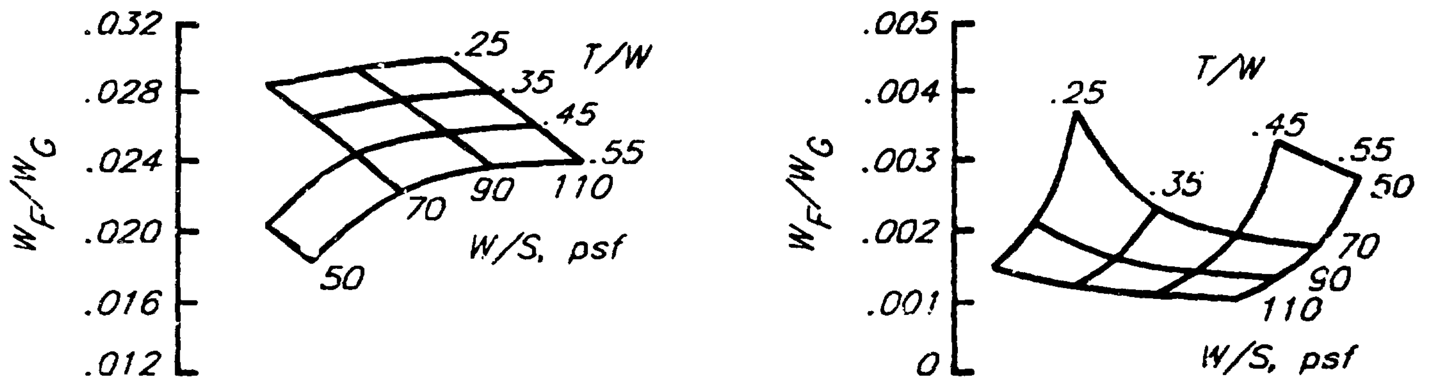
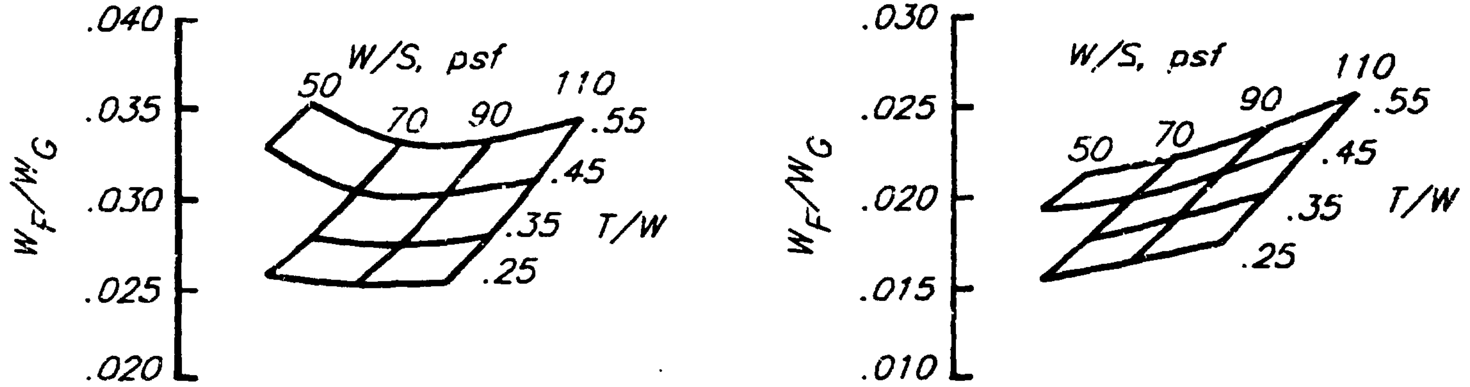


Figure 10.- Typical flight profile for reserve fuel.



(a) Trip fuel allowance, 7 percent

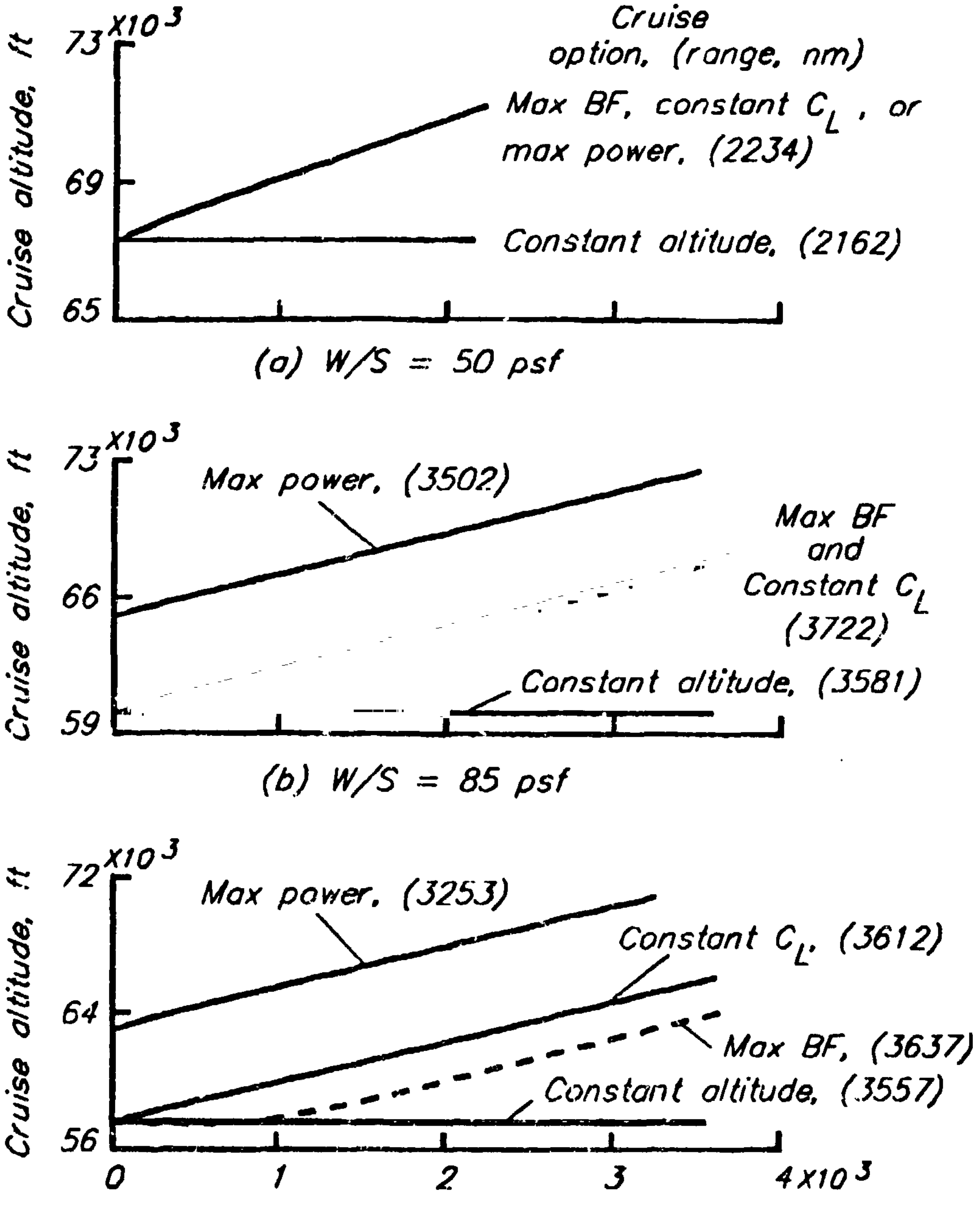
(b) Missed approach



(c) Alternate airport, 260 nm

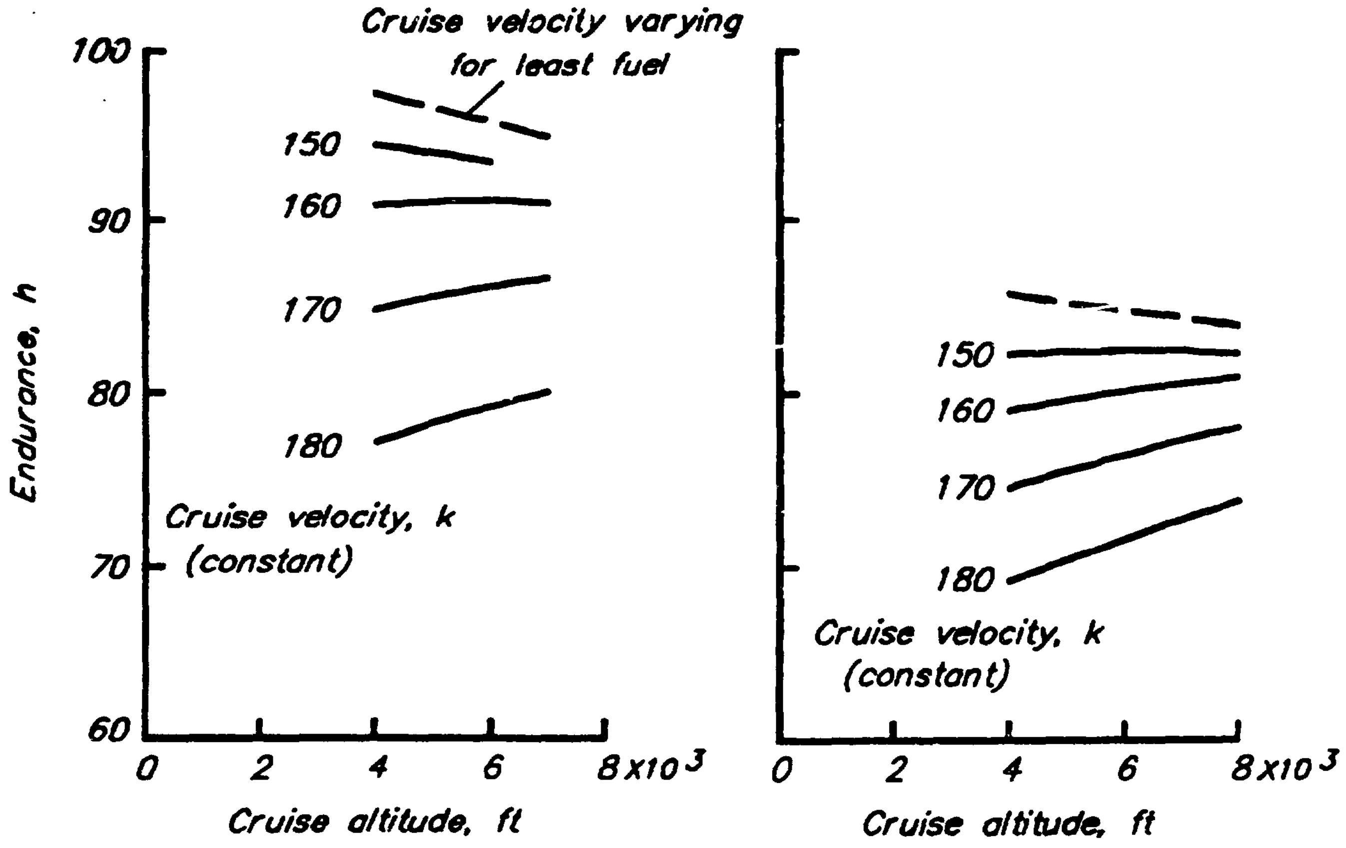
(d) Hold, 30 min

Figure 11.- Effect of sizing on reserve fuel. Supersonic transport. JP fuel, W_G = 718,000 lb



(c) W/S = 110 psf

Figure 12.- Effect of cruise options on altitude and range. Supersonic transport, JP fuel, T/W = .367, W_G = 718,000 lb



(a) Cruise with two engines (b) Cruise with all engines

Figure 13.- Effect of cruise altitude and velocity on endurance. Long endurance aircraft, W_G = 707,990 lb

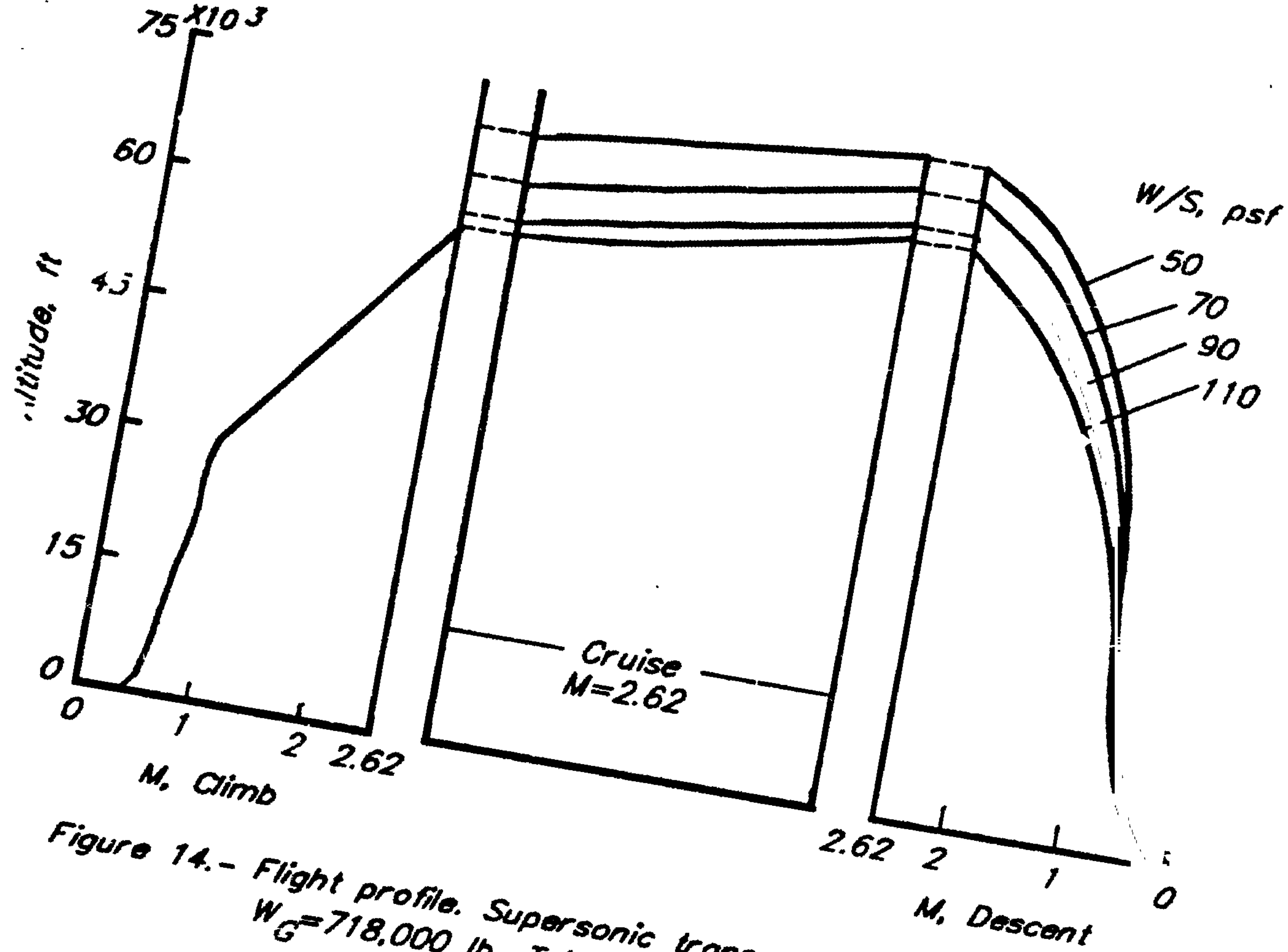


Figure 14.- Flight profile. Supersonic transport, JP fuel, W_G=718,000 lb. T/W=.45

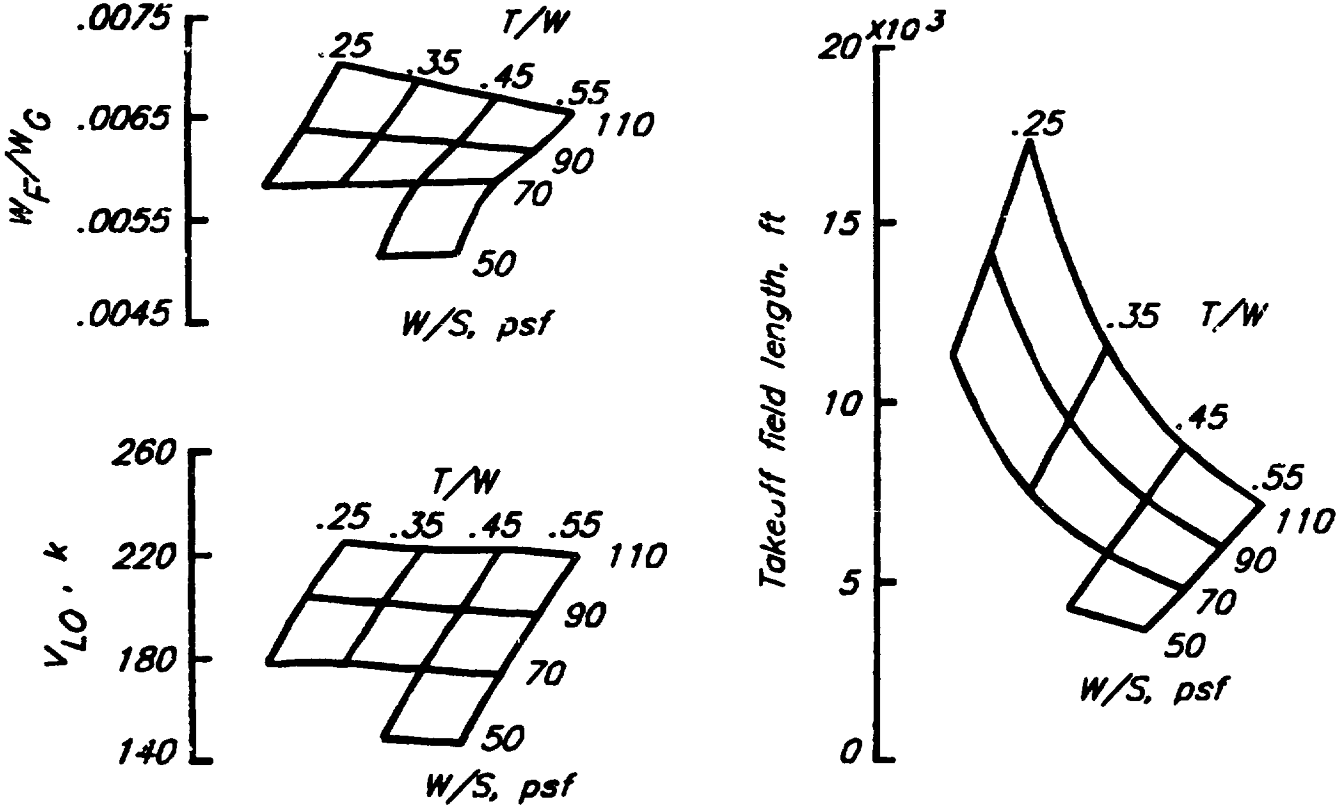
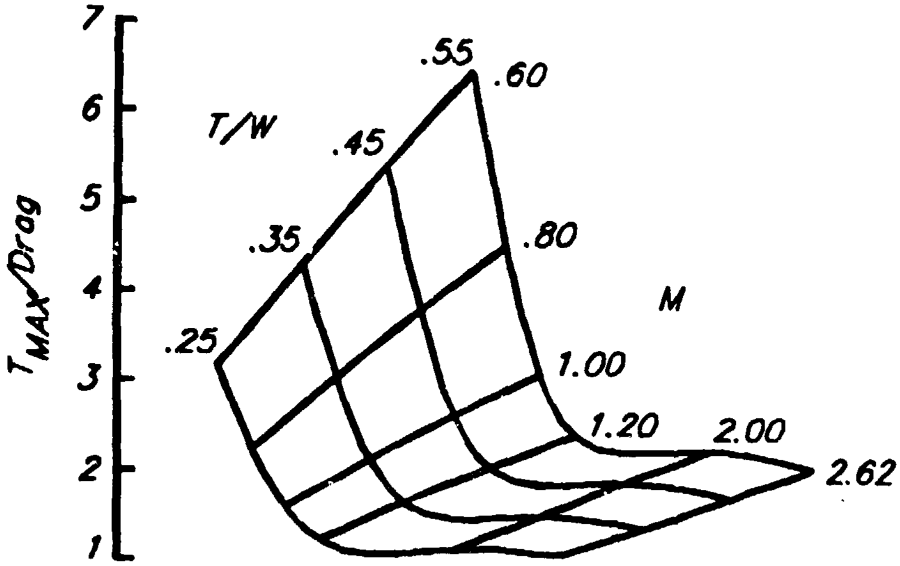
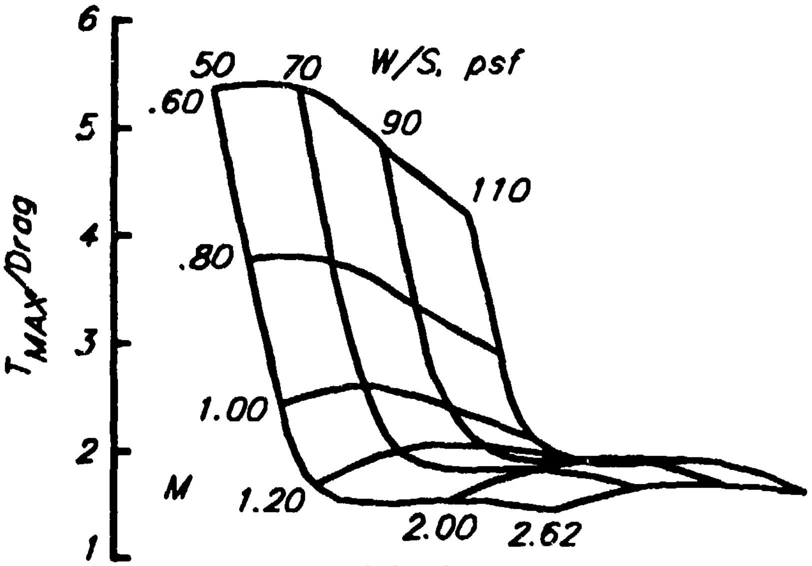


Figure 15.- Effect of sizing on takeoff characteristics. Supersonic transport, JP fuel, α_{LO} = 8 deg, δ_F = 20 deg, W_G = 718,000 lb.



(a) W/S=70 psf



(b) T/W=.45

Figure 16.- Excess thrust during climb. Supersonic transport, JP fuel, W_G=718,000 lb

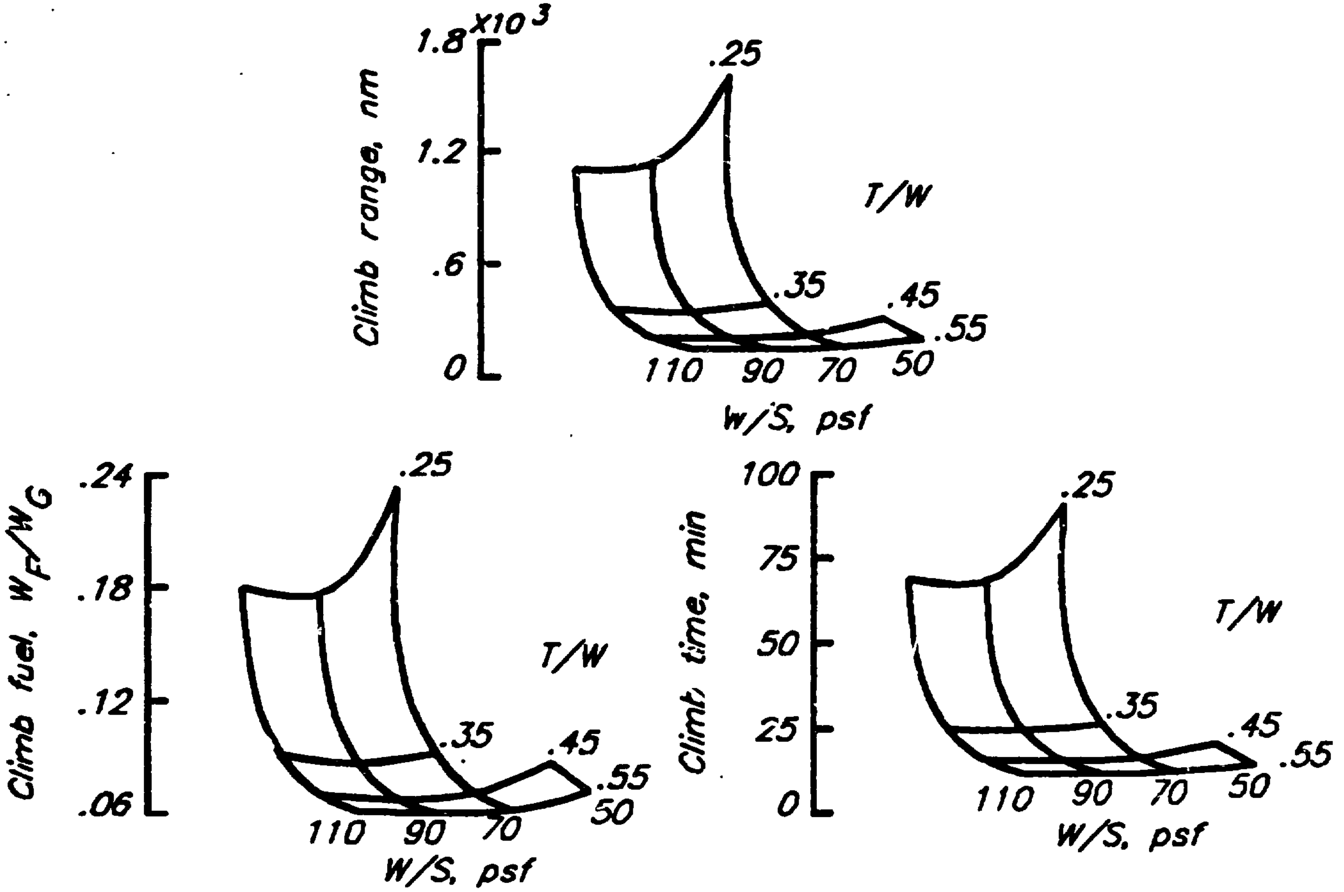


Figure 17.- Effect of sizing on climb characteristics. Supersonic transport, JP fuel, W_G = 718,000 lb

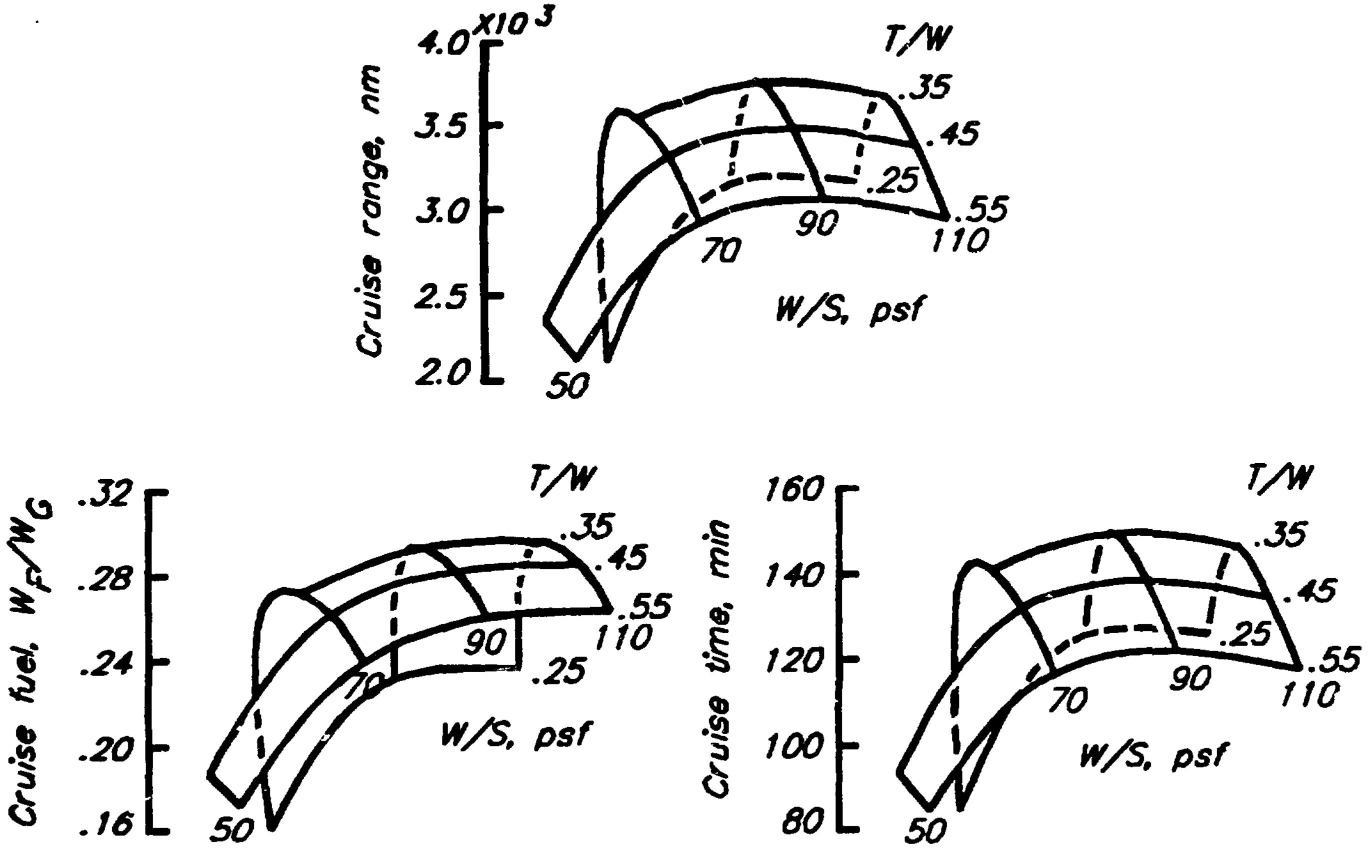


Figure 18.- Effect of sizing on cruise characteristics. Supersonic transport, JP fuel, W_G = 718,000 lb

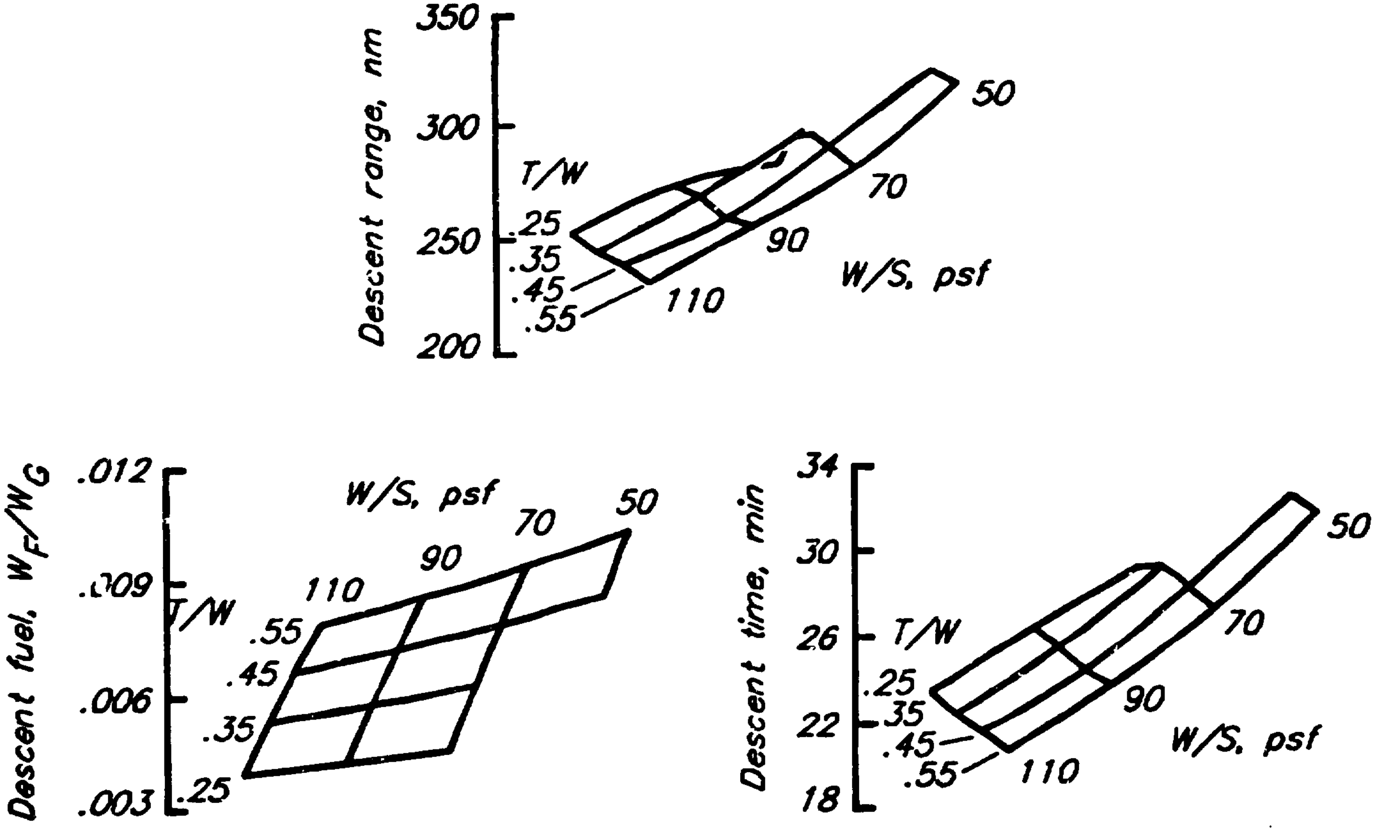


Figure 19.- Effect of sizing on descent characteristics. Supersonic transport, JP fuel, W_G = 718,000 lb

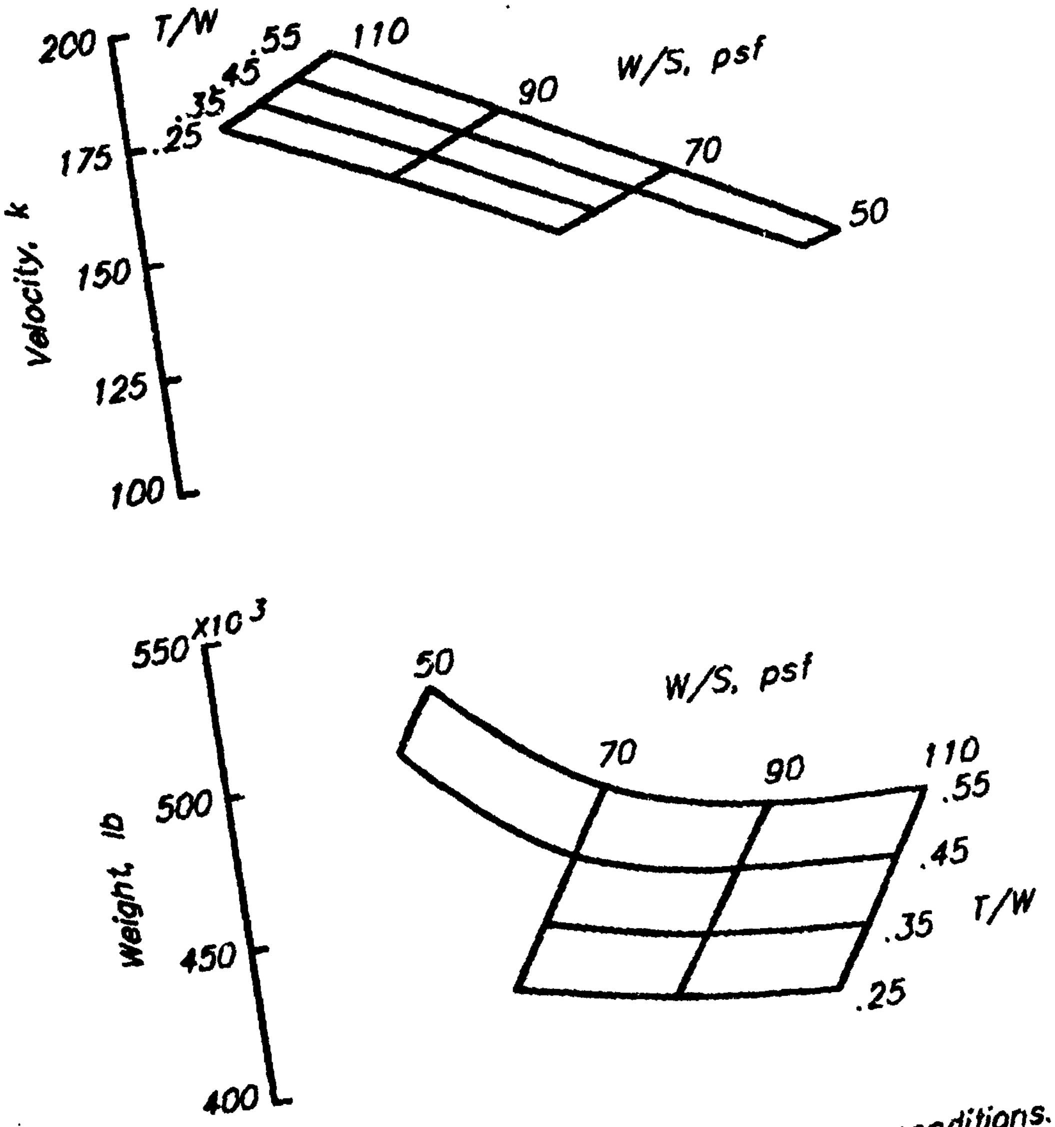


Figure 20.- Effect of sizing on approach conditions. α = 9.5 deg, δ_F = 20 deg, Supersonic transport, JP fuel W_G = 718,000 lb

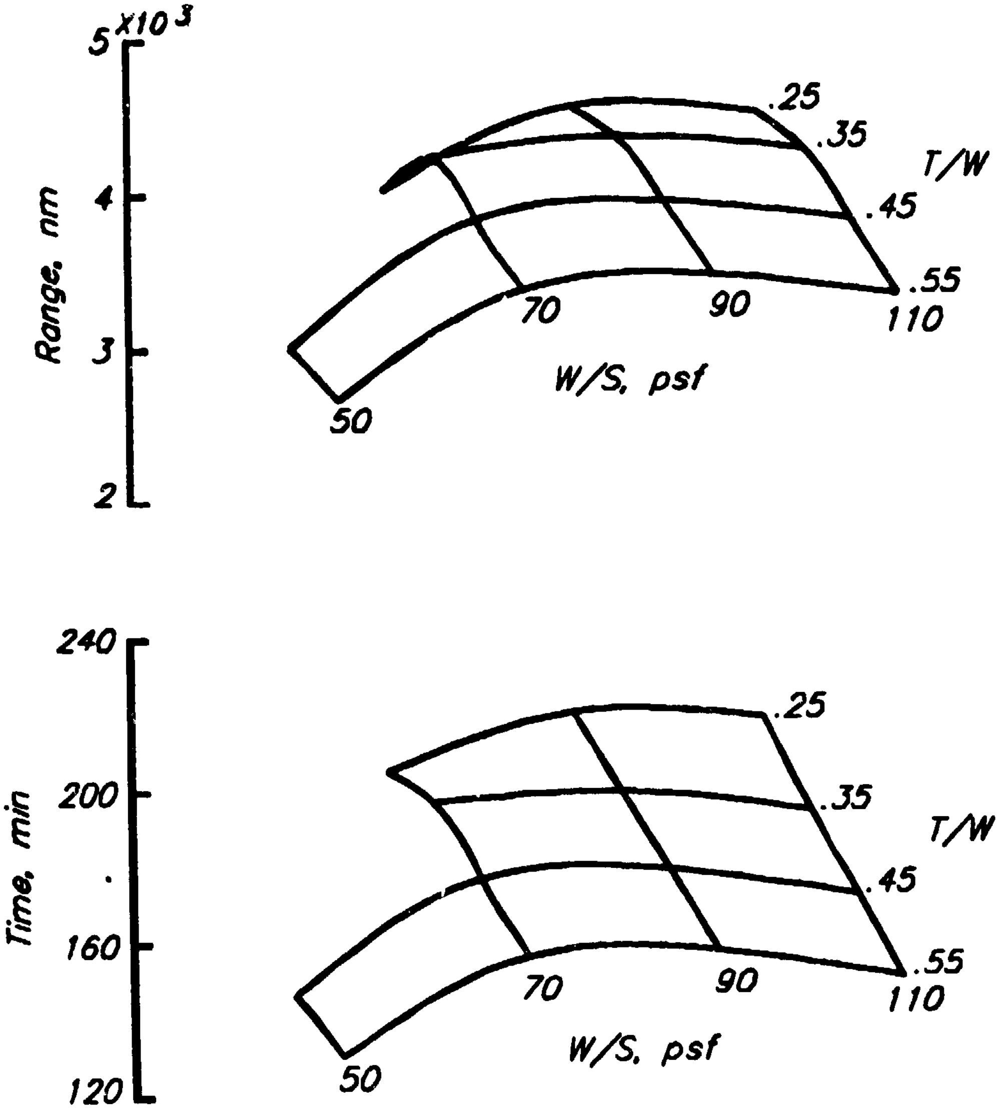
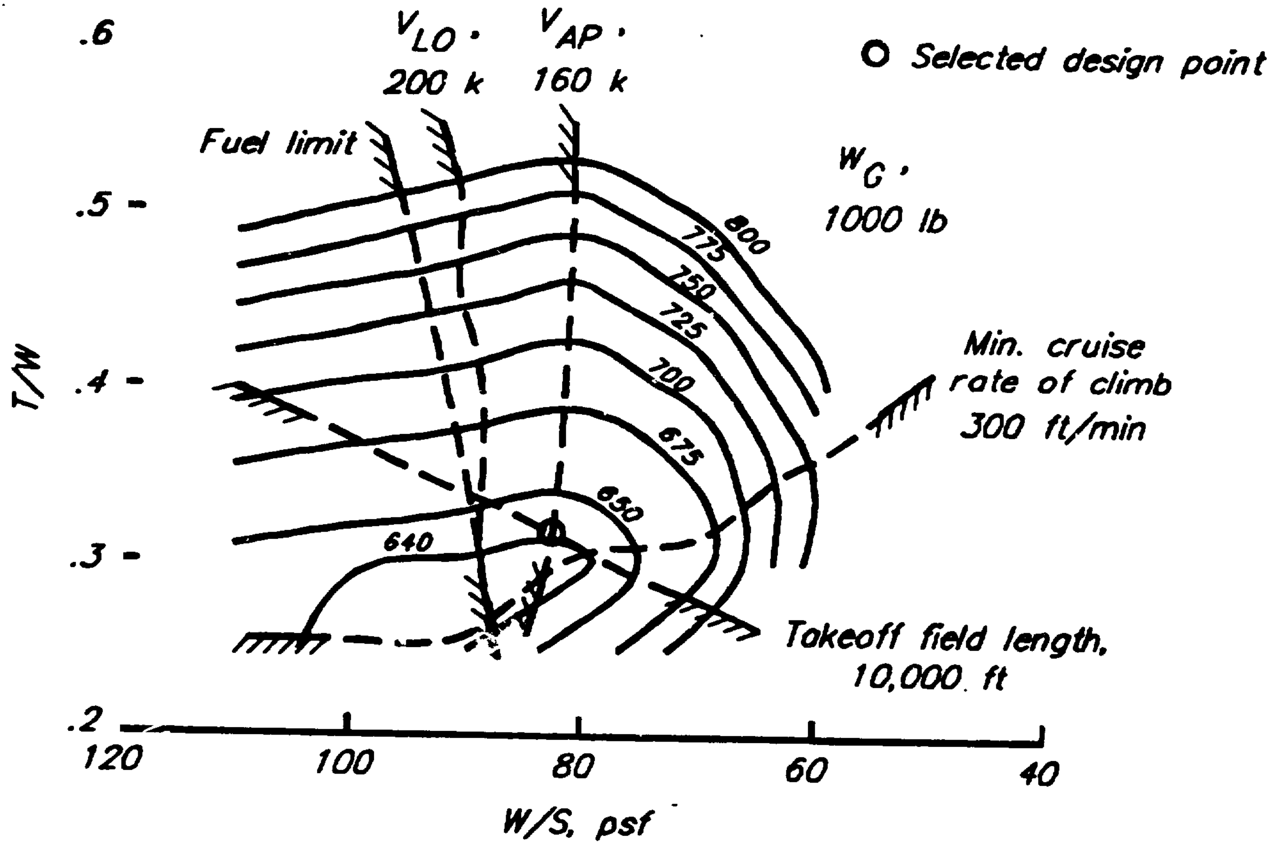
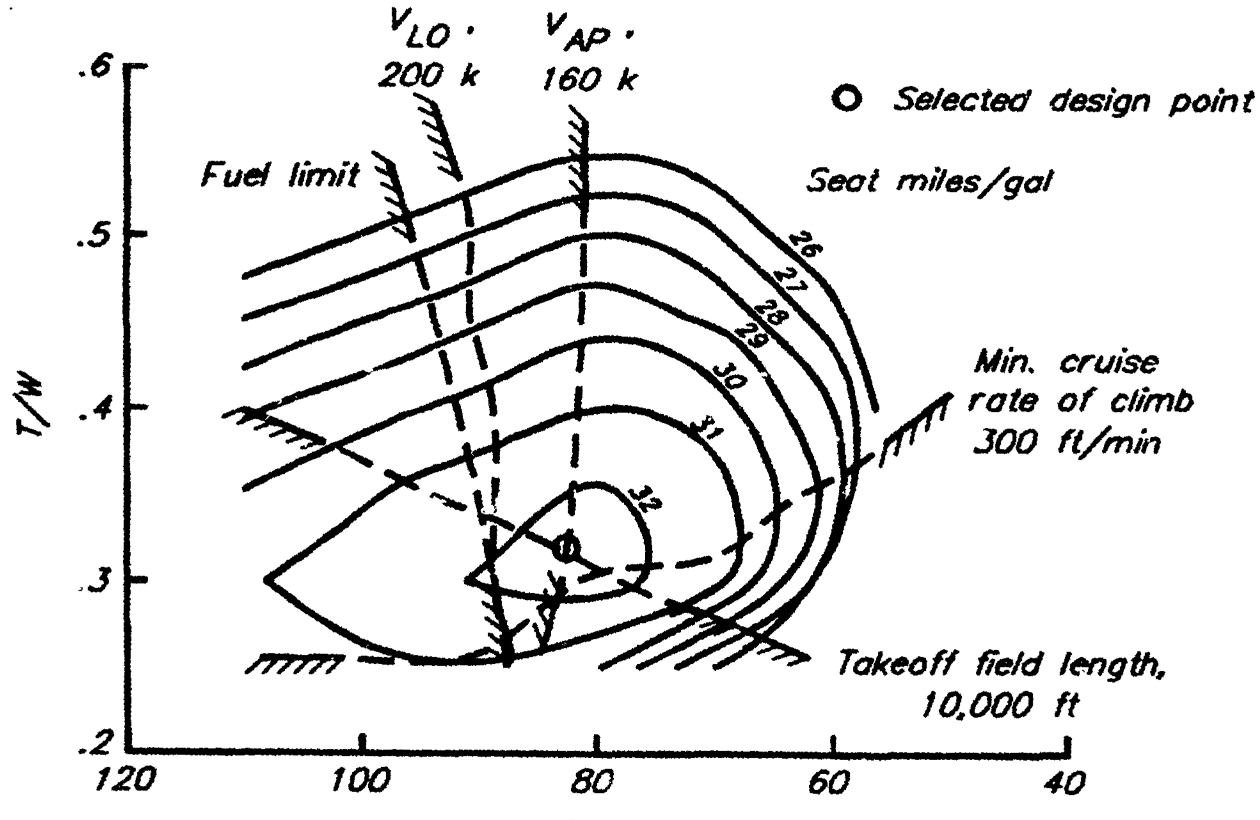


Figure 21.- Effect of sizing on trip time and range.
Supersonic transport, JP fuel.
W_G = 718,000 lb



(a) Gross weights

Figure 22.- Sizing thumbprint for supersonic transport JP fuel, range = 4000 n.m.



(b) Seat miles/gal

Figure 22.- Concluded.

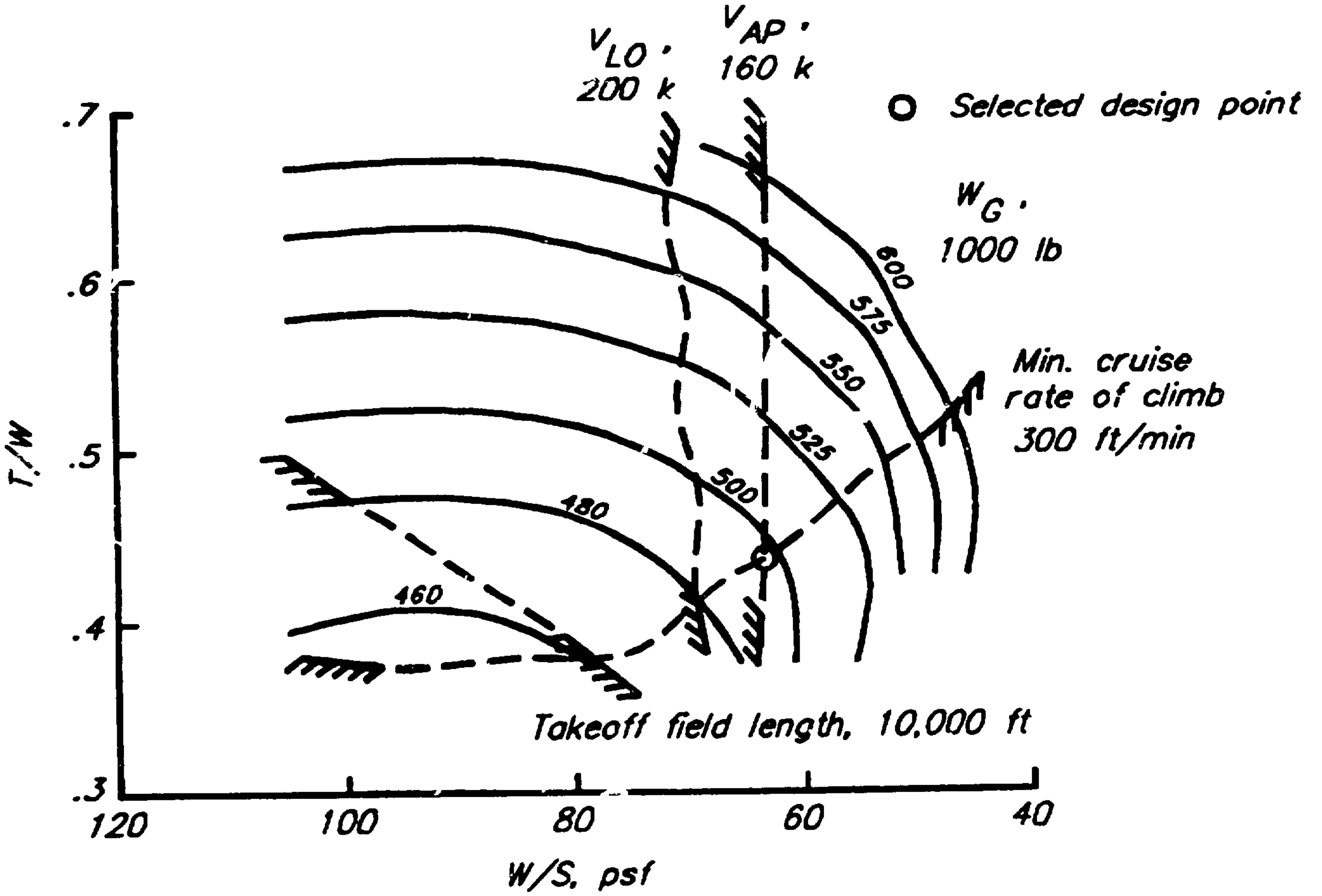


Figure 23.- Sizing thumbprint for supersonic transport. Liquid hydrogen fuel, range = 4000 nm.

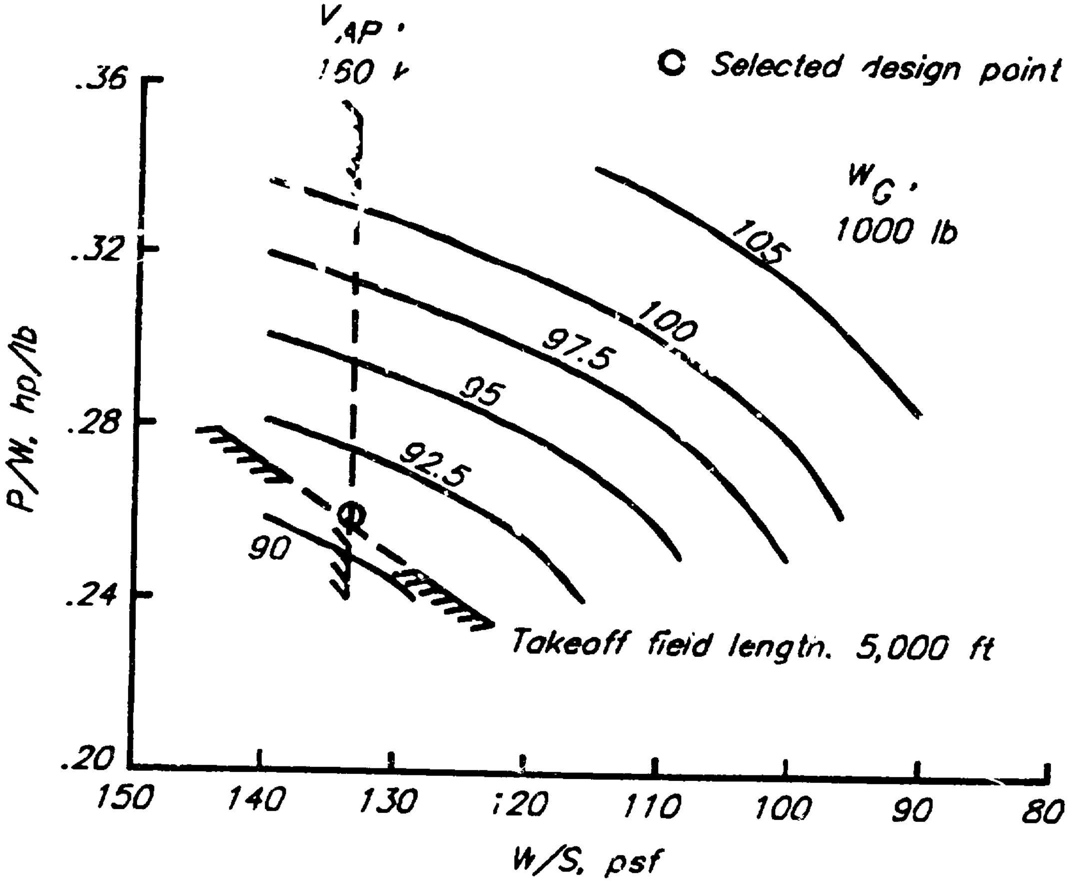


Figure 24.- Sizing thumbprint for subsonic transport, range = 1,000 nm, M_{cruise} = .8.

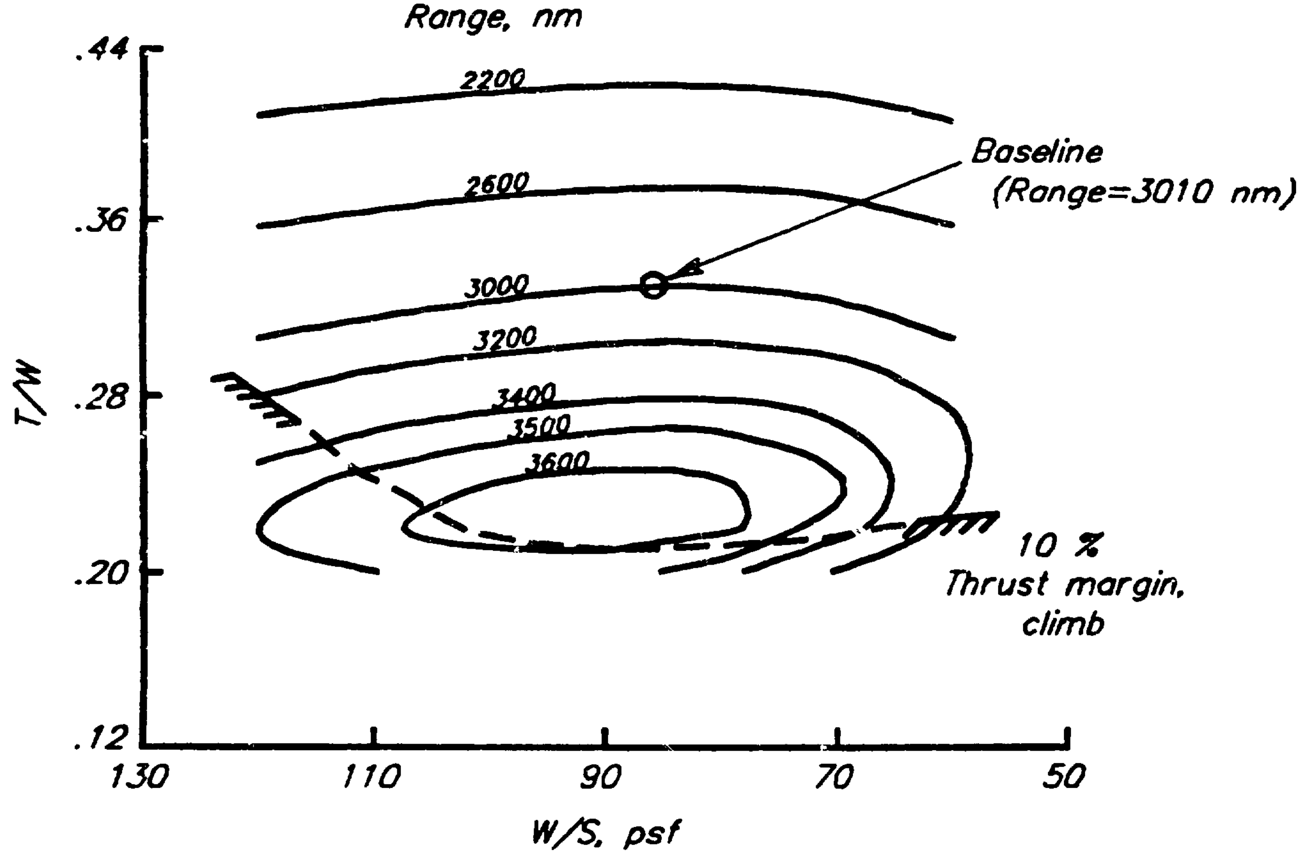


Figure 25.- Sizing thumbprint for hypersonic aircraft, methane fuel, W_G = 260,000 lb, M_{cruise} = 4.5

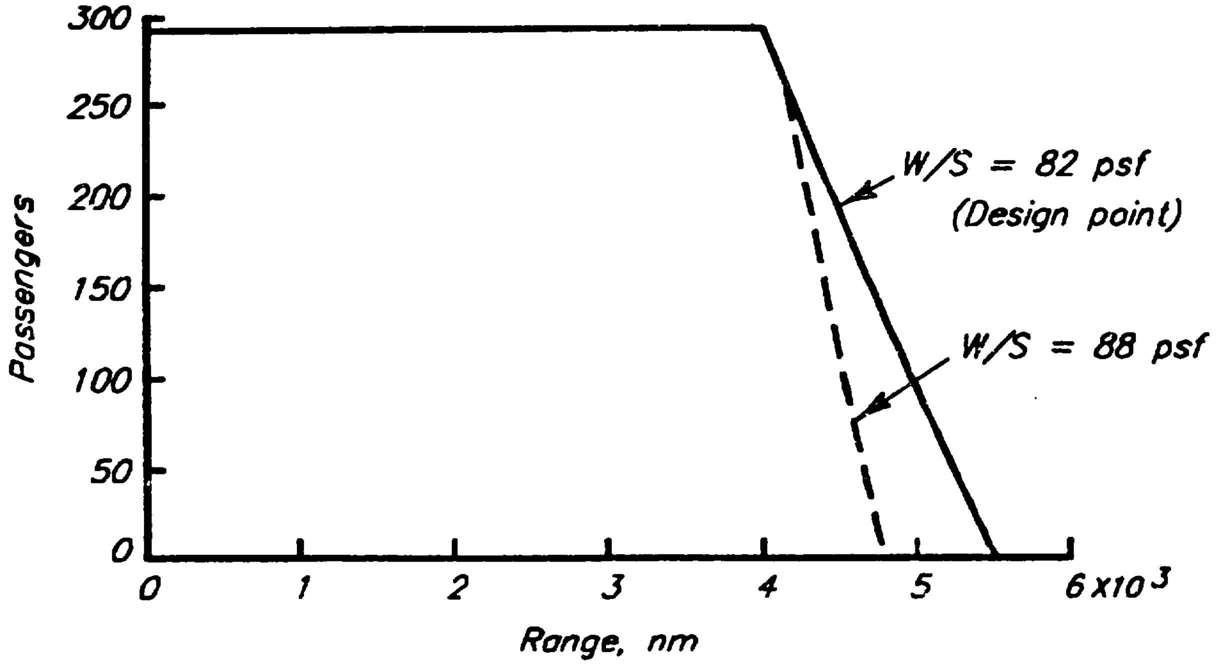


Figure 26.- Effect of design conditions on payload-range trade.
Supersonic transport, JP fuel, T/W = .32,
W_G = 643,633 lb.

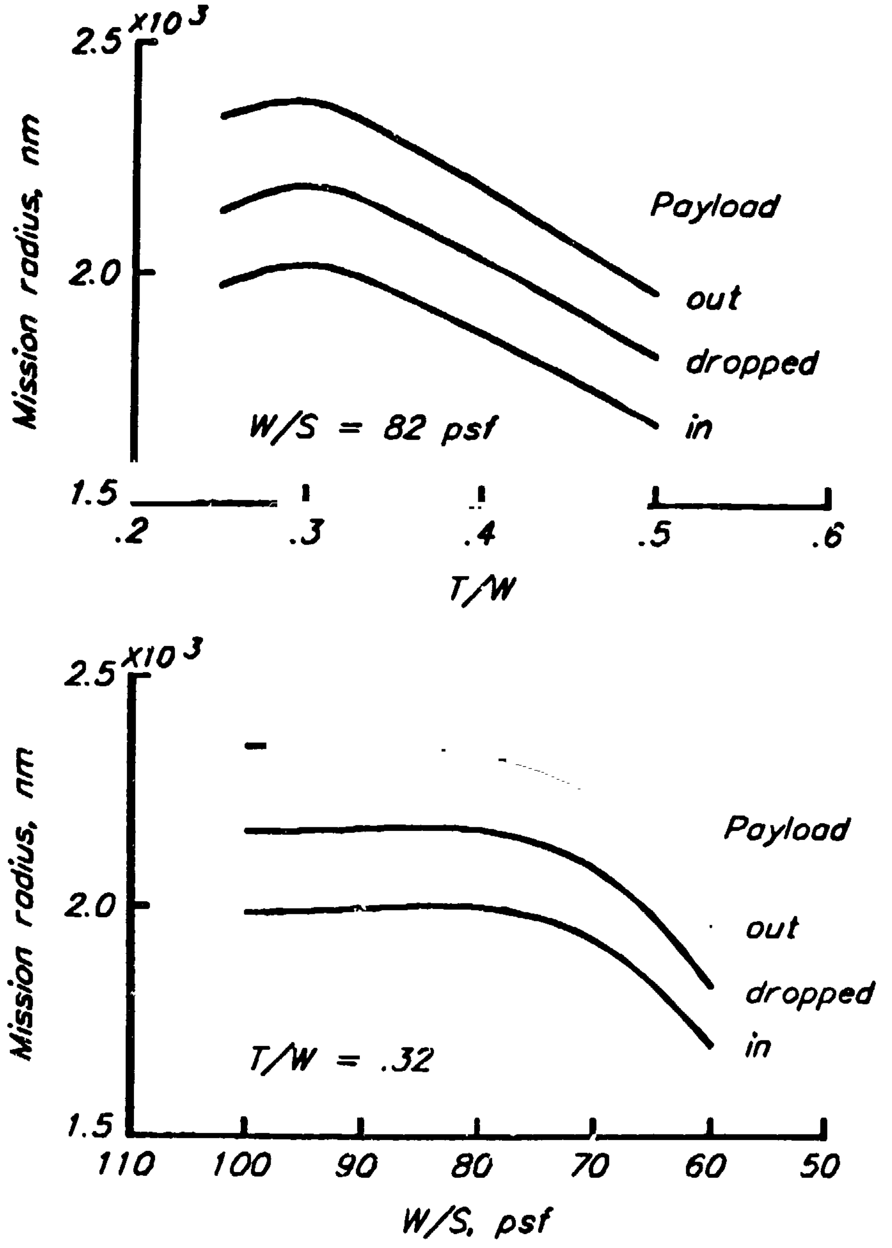
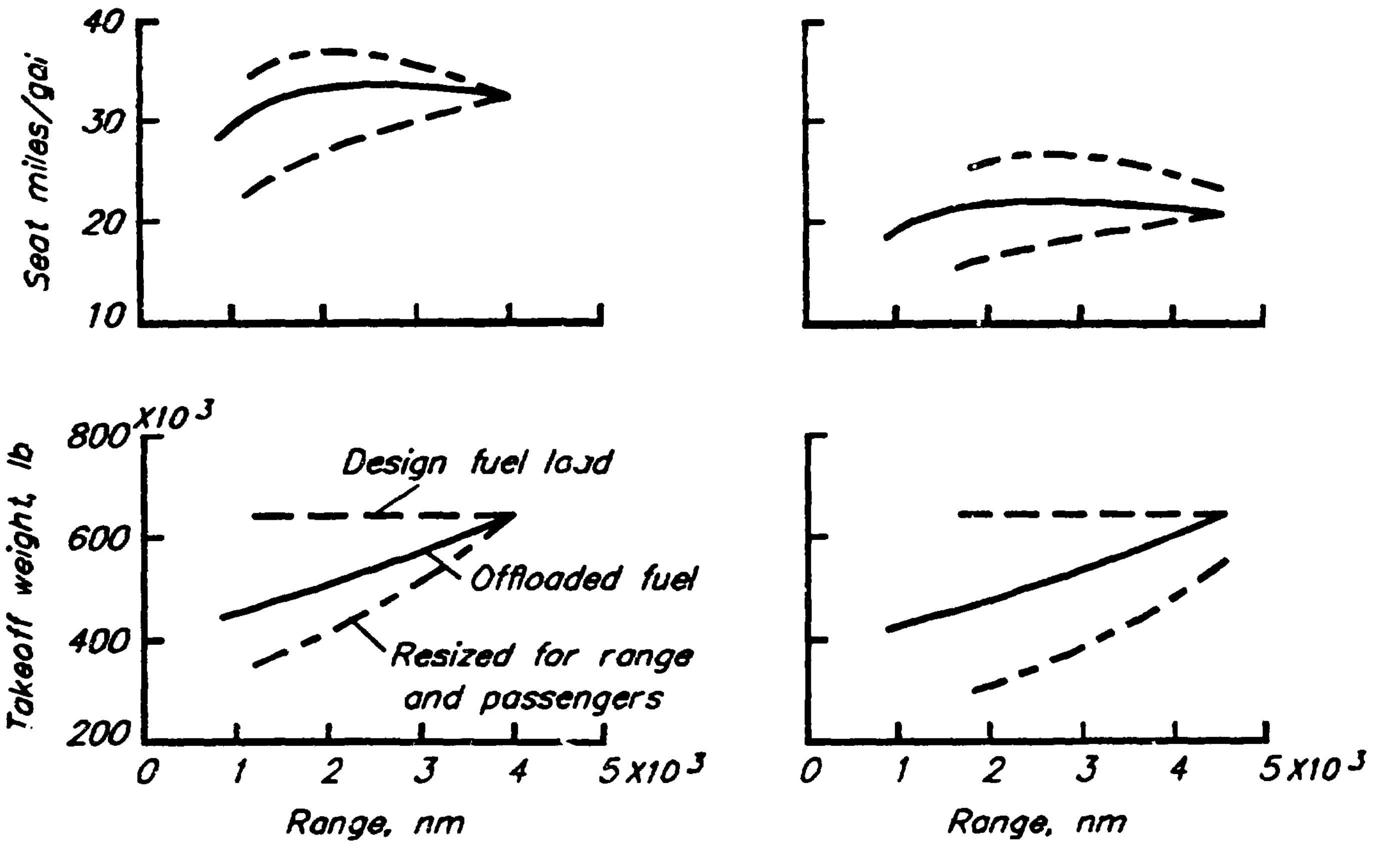


Figure 27.- Effect of sizing on mission radius. Supersonic transport. JP fuel, W_G = 643,633 lb



(a) 100 % Load factor (b) 60 % Load factor

Figure 28.- Offload range results for supersonic transport, JP fuel, W/S = 82 psf, T/W = .32, W_G = 643,633 lb

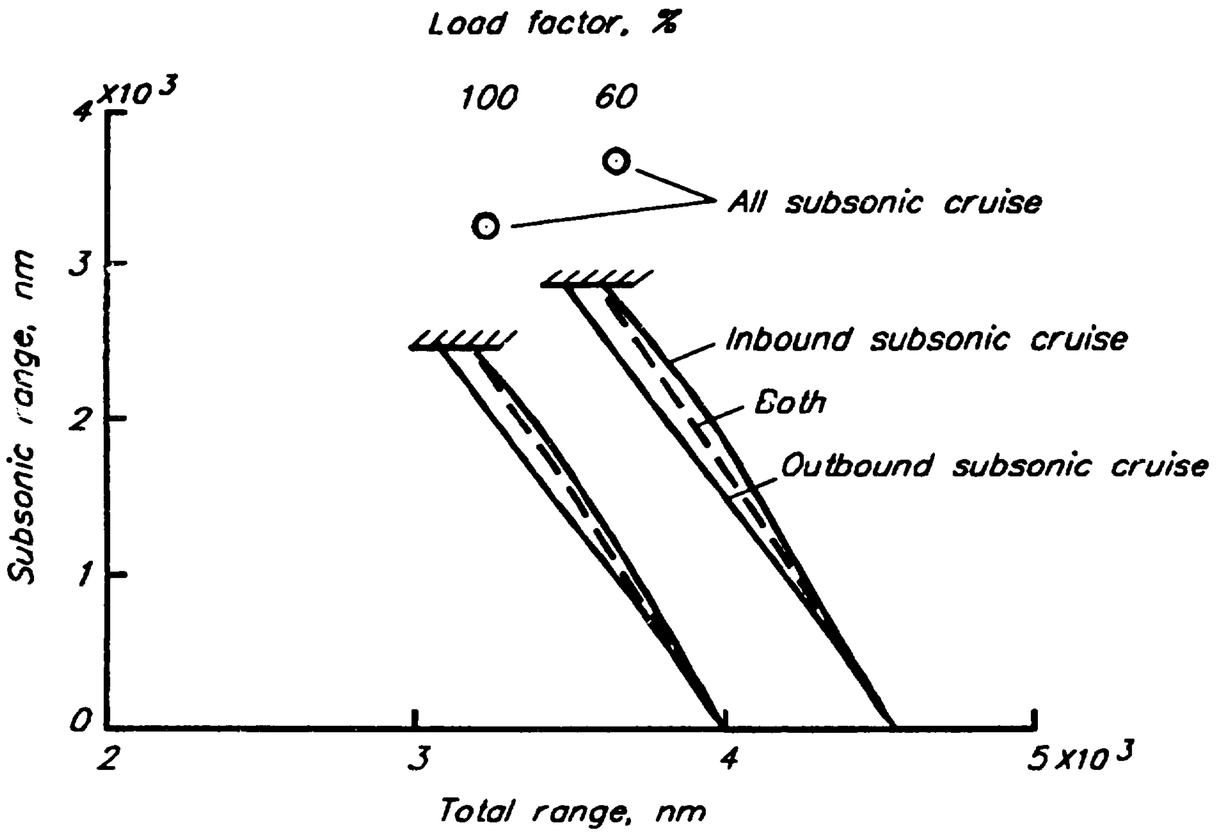


Figure 29.- Subsonic range-total range trade for supersonic transport. JP fuel, $W/S = 82$ psf, $T/W = .32$, $W_G = 643,633$ lb, $M_{cruise} = .9$ and 2.62.

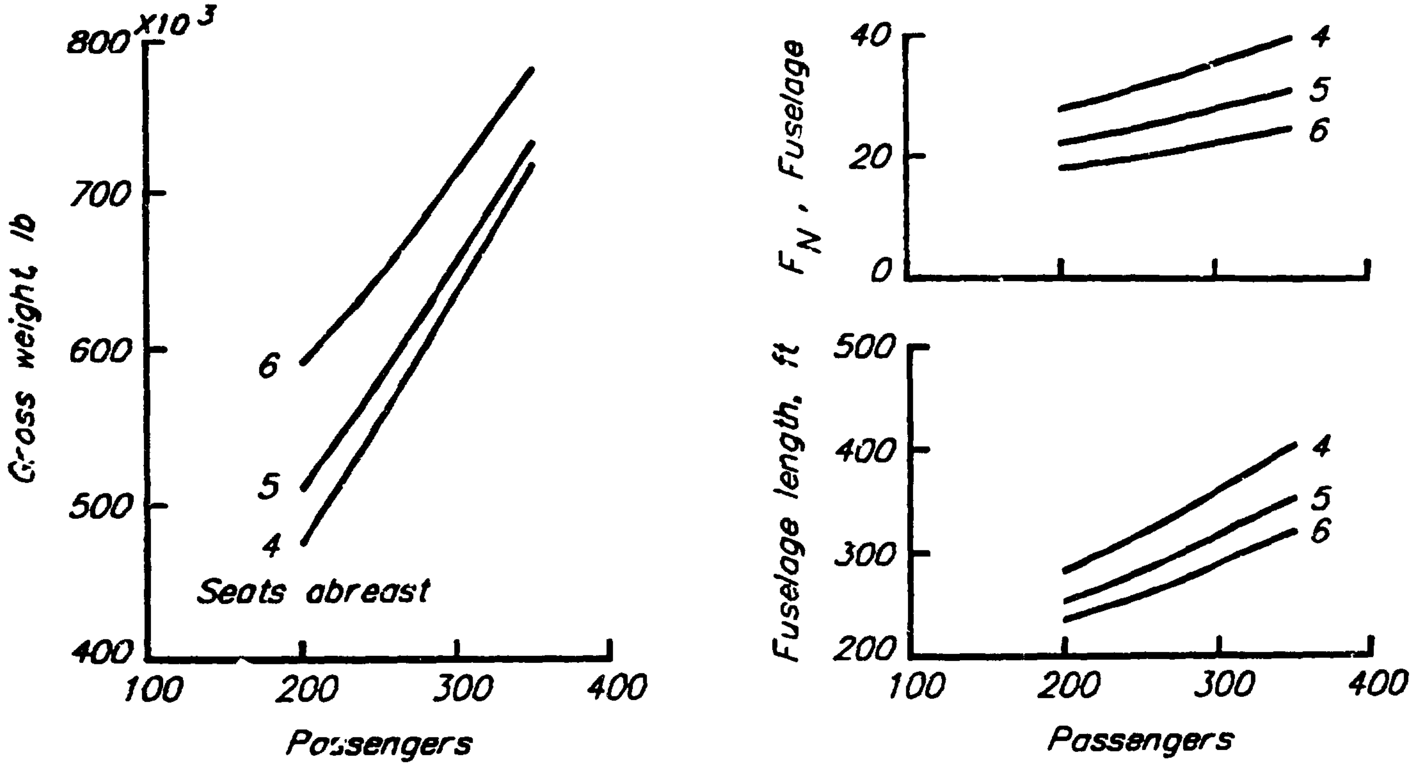
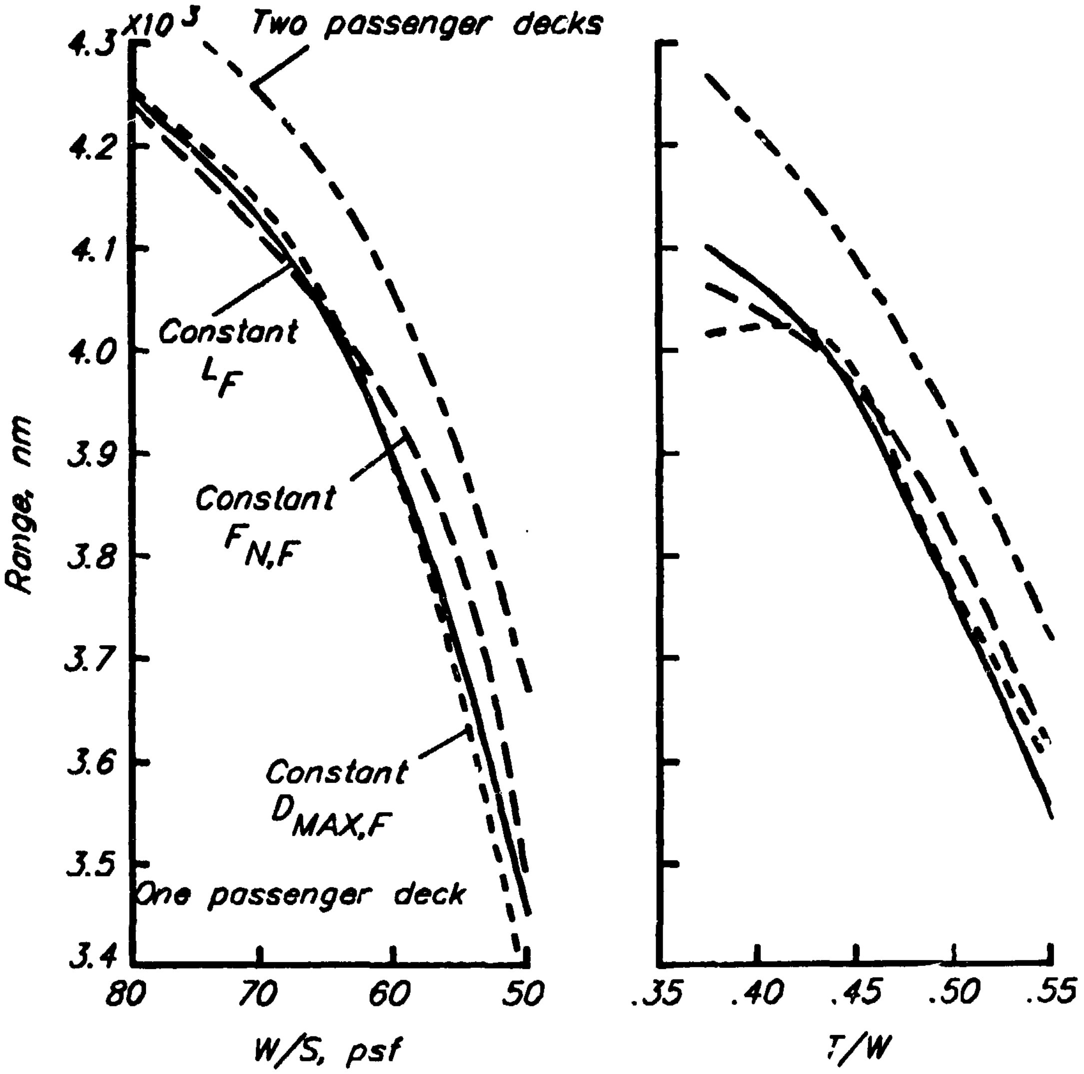


Figure 30.- Effect of passenger seating on gross weight and fuselage size. Supersonic transport, JP fuel, range = 4,000 nm, W/S = 82 psf, T/W = .32.



(a) T/W = .435

(b) W/S = 63.5 psf

Figure 31.- Effect of fuselage design variables on range. Supersonic transport, liquid hydrogen fuel, W_G = 494,000 lb.

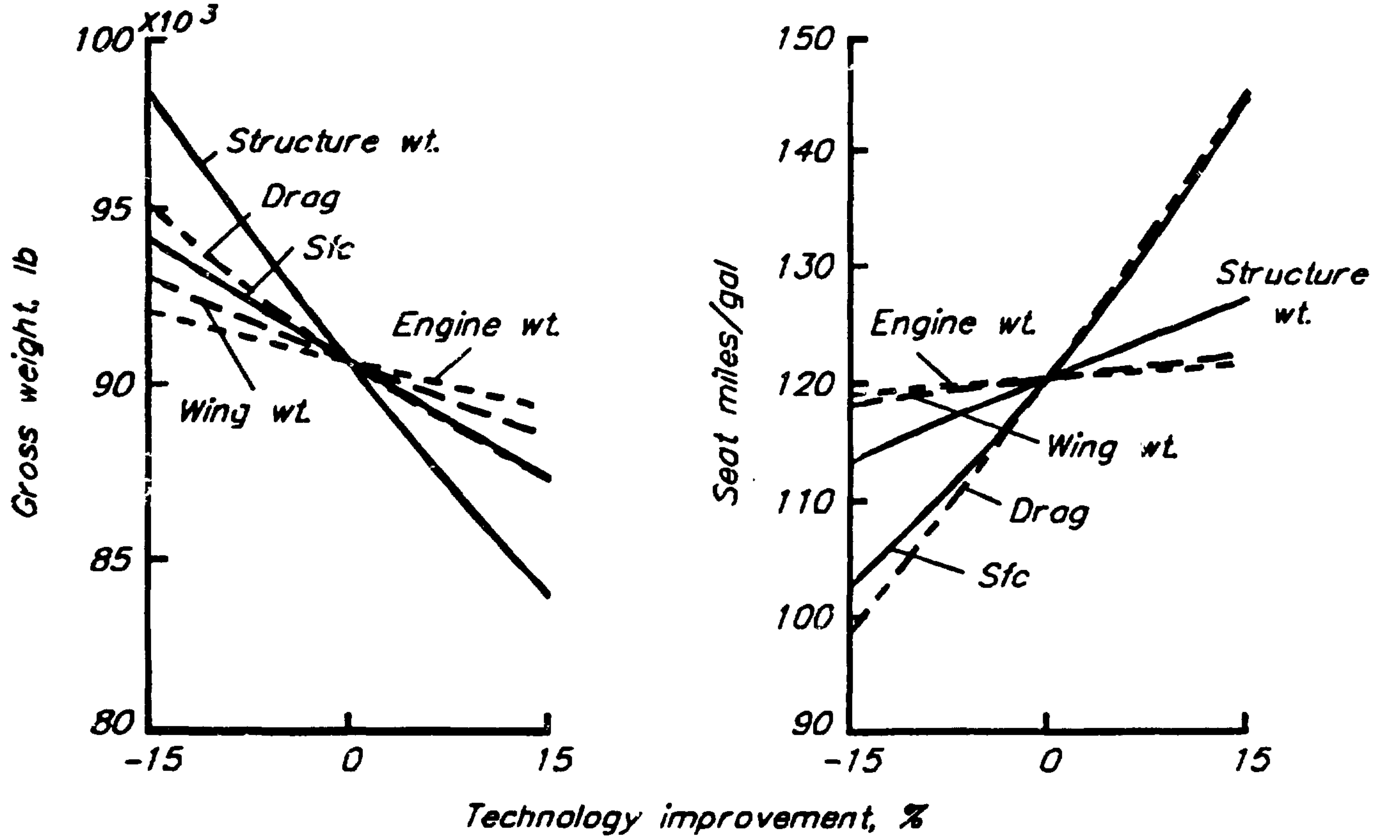


Figure 32.- Effect of technology changes on gross weight and seat miles/gallon. Subsonic transport, range = 1,000 nm, W/S = 133.5 psf, P/W = .257 hp/lb, M_{cruise} = .8.

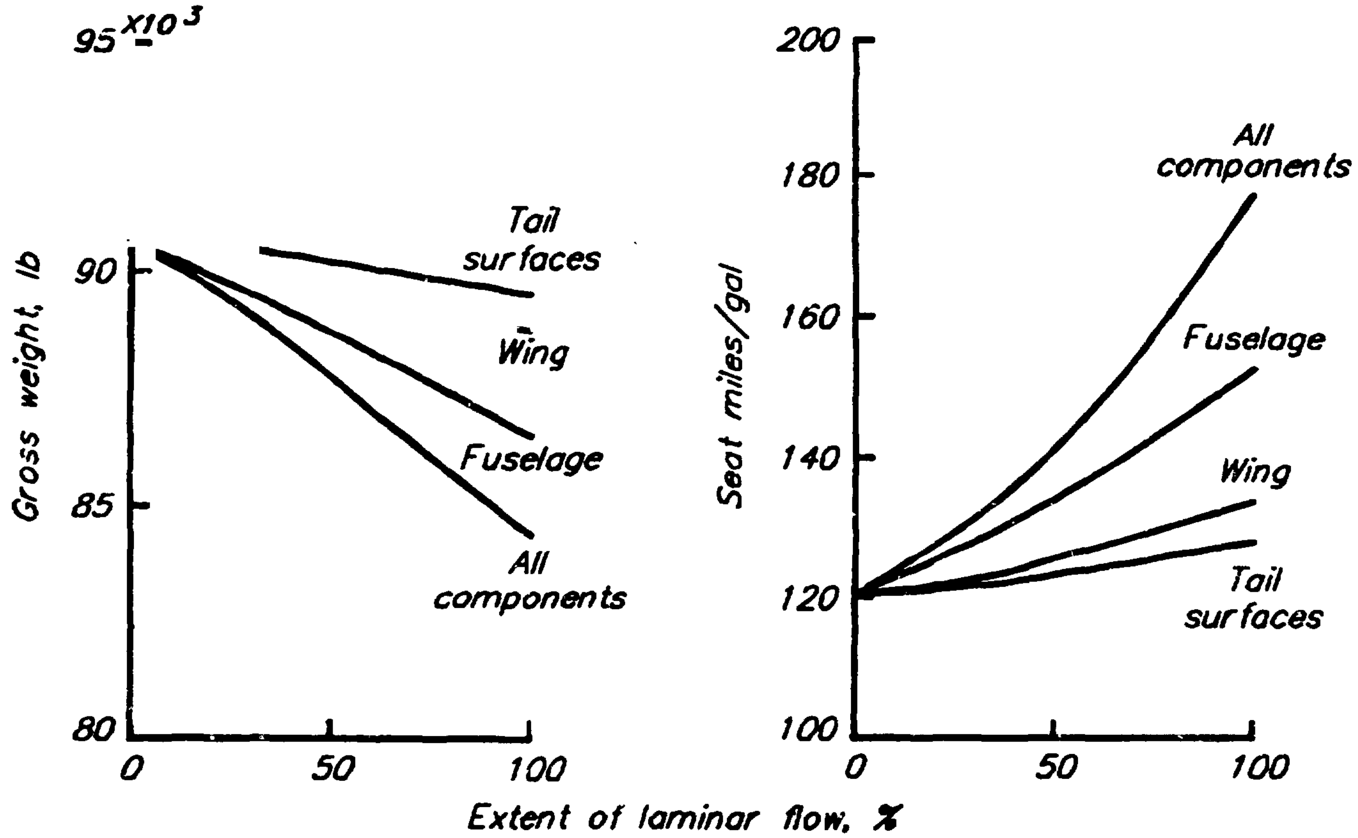
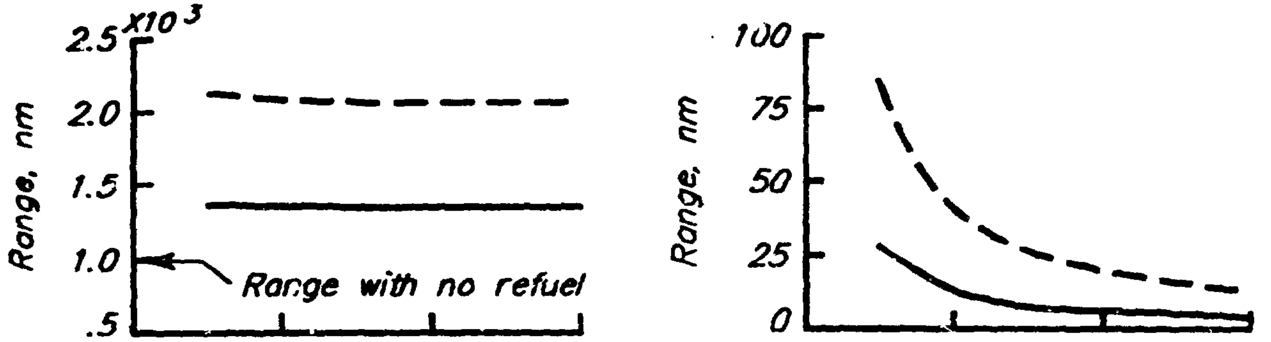
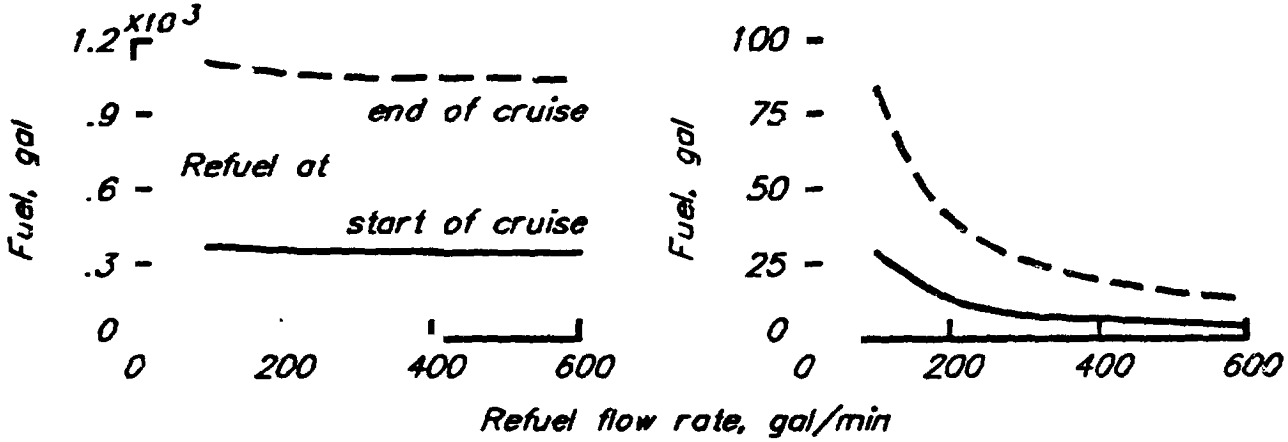


Figure 33.- Effect of laminar flow control on gross weight and seat miles/gallon. Subsonic transport, range = 1,000 nm, W/S = 133.5 psf, P/W = .257 hp/lb, M_{cruise} = .8.



(a) Total range

(b) Range during refuel



(c) Total fuel transfer

(d) Fuel used during refuel

Figure 34.- Refuel characteristics for subsonic transport. W/S = 133.5 psf, P/W = .257 hp/lb, W_G = 90,645 lb, M_{cruise} = .8.

TABLE B1. - INPUT LISTING (TAPE5).

```
  SUPERSONIC TRANSPORT, JP-FUEL
$PRNTCON
  IPRWTSM=1, IPRMPRF=1,
$
$DESGNVB
  RNGDES=4000., WOSDES=82., TOWDES=.32, ISGEOM=1, IJP=1,
$
$TWINFUS
$
$MISSUB
  ICLPR=4,ZMASNT(1)=0.,.55,.9,2.7,HASNT(1)=0.,3500.,30000.,59000.,
  GRALFA=-4., TOALFA=8., TODELF=20.,
  ZMCR=2.62,
  APALFA=9.5, APDELF=20.,
$
$RESRU
  TPFA=7., ICALMA=1, AAD=260., THLD=30.,
$
$TECHCHG
$
$SACGEM
  WRC=183.1, WTC=17.6, WSPAN=137.8, WXO=47.8, WDXT=196.5,
  WTOC=2.82, REFA=9969., NWBP=7,
  WBPC(1)=159.39,149.74,135.70,102.39,71.53,57.99,33.67,
  WYBF(1)=6.75,9.50,13.51,22.99,32.6,37.80,50.0,
  WXBP(1)=23.55,33.13,47.10,80.21,113.68,128.65,163.75,
  FLGTH=315., FRAD=5.765, FVOLTOT=26002., FWETA=9744.,
  NH=1, HRC(1)=26., HTC(1)=7.67, HSPAN(1)=31.98, HTOC(1)=3.0,
  HXO(1)=272.45, HDXT(1)=28.42,
  NV=2, VRC(1)=29.04,39.2, VTC(1)=6.98,5.21, VSPAN(1)=9.46,10.75,
  VXO(1)=284.42 211.67, VDXT(1)=23.66,36.10, VTOC(1)=3.0,3.0,
  VYO(1)=0.,[illegible],
  NPI=2, XOP(1)=199.7,203.75, YOP(1)=23.0,37.3,
$
$AIN
  NAI=15, NAJ=10,
  THARO(1)=0.,7286.,22429.,30306.,32417.,34833.,38056.,44500.,
           50944.,57711.,
  MAEROT(1)=0.,.6,.8,.95,1.05,1.2,1.4,1.8,2.2,2.62,
  CLT(1,1)=0.0,.02,.04,.26,.08,.10,.12,.14,.16,.18,.20,.22,.24,.26,.30,
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              0.0,.02,.04,.06,.08,.10,.12,.14,.16,.18,.20,.22,.24,.26,.30,
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              0.0,.02,.04,.06,.06,.10,.12,.14,.16,.18,.20,.22,.24,.26,.30,
              0.0,.02,.04,.06,.08,.10,.12,.14,.16,.18,.20,.22,.24,.26,.30,
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              0.0,.02,.04,.06,.08,.10,.12,.14,.16,.18,.20,.22,.24,.26,.30,
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TABLE B1. - CONTINUED.

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   .011337,.010283,.009535,.009095,.008963,.009138,.009620,.010410,
   .011508,.012912,.014625,.016645,.018972,.021607,.027799,
   .012019,.010832,.009967,.009424,.009203,.009305,.009729,.010476,
   .011544,.012935,.014648,.016684,.019042,.021722,.028049,
   .015074,.013456..012206,.011326,.010815,.010672,.010899,.011495,
   .012460,.013794,.015496,.017568,.020009,.022819,.029546,
   .018740,.016783,.015252,.014149,.013473,.013223,.013401,.014006,
   .015038,.016497,.01[illegible]83,.020696,.023436,.026603,.034218,
   .019133,.017231,.[illegible]88,.014802,.014275,.014205,.014583,.015438,
   .016742,.018503,.020723,.023400,.026535,.030128,.038687,
   .016657,.014980,.013772,.013033,.012763,.012962,.013630,.014767,
   .016373,.018448,.020991,.024004,.027486,.031436,.0408,
   .012656,.011424,.010677,.010417,.010641,.011352,.012549,.014231,
   .016400,.019054,.022194,.025820,.029932,.0345,.0451,
   .010687,.009731,.009298,.009388,.010001,.011136,.012795,.014976,
   .017681,.020908,.024658,.028932,.033728,.0391,.0513,
   .009694,.008689,.008324,.008597,.009509,.011061,.013251,.016080,
   .019548,.023655,.028401,.033726,.039810,.0465,.0617,
  CDRUF(1)=.000254,.000254,.000254,.000254..000589,.000589,0.,0.,0.,
    .000242,
  CDU(1)=0.,0.,0 ,0.,0...003057,0.,0.,0...002050,
  CDFC(1)=.00023,.00023,.000245,.000255,.000265,.000280,.0003,.00034,
   .00038,.000072,
  CDBL(1)=.000579,.000579,.000765,.001246,.002278,.001851,.00121,
   .000596,.000623,.000405,
  NFD=1,
  TFSET(1)=20.,
  NTOF=8,
  TALPHTO(1,1)=2.,4.,6.,8.,10.,12.,14.,16.,
  TCLTO(1,1)=.323,.396,.470,.542,.616,.689,.762,.836,
  TCDTO(1,1)=.043,.058 .078,.102,.131,.166,.209,.251,
  NTOG=11,
  TALPTOG(1,1)=-5.,-2.,0.,2.,4.,6.,8.,10.,12.,14.,16.,
  TCLTOG(1,1)=.065,.195,.281,.367,.453,.540,.625,.713,.797,.885,.972,
  TCDTOG(1,1)=.033,.031,.034,.044,.060,.083,.111,.146,.188,.245,.306,
  NLGD=2,
  CLGPT(1)=0.,100.,
  CDGRT(1)=.0079,.0079,
$
$UTIN
  WGPEF=718000.,
  WWING=85913.,WHT=4763.,WVT=5892.,WFUS=52410.,WLG=27293.,
  WFT=0.,WINS=0.,WSC=9405.,WAP=0.,
  WINST=3400.,WHYD=5600.,WELE=5050.,WAVON=2690.,WFEQ=25111.,WACOND=8200.,
  WANTICE=210.,
  WFCR=675.,WCCP=1640.,WUFUEL=2335.,WENO=715.,WPSCR=8852.,WCCONT=2960.,
  WPAS=48180.,IPASR=292,
  WPB=12848.,WCAR=0.,IFCR=3,ICCP=10,LVLR=1,
  WFCILBS=377780.,BFCILBS=101860.,
  STSABR=5.,
  ULF=3.75,
  ZMDESBL=2.7,
$
```

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OF POOR QUALITY

TABLE B1. - CONTINUED.

```
$ENIN
  PDAVG=6.1, PLGTH=38.98  SLSTHP=65876.5,
  WENG=13000., WNAC=4201, WTR=0., WPLM=5781., WMIS=1780.,
  NENR=4,NEW=4,NEF=0,NPODSR=4,
$
 TURBOJET ENGINE FOR SUPERSONIC TRANSPORT, JP-FUEL
0.00       0.0        65978.0        0.0   66751.6
0.00    5000.0        57743.2        0.0   58242.0
 .40       0.0        75212.1    10279.0   73430.9
 .40    5000.0        65675.6     8697.6   63999.2
 .40   15000.0        48896.6     6111.7   47592.5
 .60       0.0        84165.7    16927.3   79525.8
 .60    5000.0        73865.1    14410.0   69702.8
 .60   15000.0        55484.8    10172.9   52293
 .60   25000.0        39507.6     6857.4   37367.9
 .80       0.0        97608.5    25595.1   88367.2
 .80    5000.6        85099.3    21664.6   77145.6
 .80   15000.0        64188.7    15371.1   58233.9
 .80   25000.0        46559.2    10595.9   42358.2
 .80   36152.0        30782.8     6519.0   28156.8
1.00   15000.0        75749.2    22122.7   65728.5
1.00   25000.0        55348.0    15247.4   48280.1
1.06   36152.0        36966.2     9529.4   32473.7
1.00   45000.0        24140.3     6240.1   21231.2
1.20   25000.0        66680.0    21582.6   55502.1
1.20   36152.0        45437.2    13698.5   38160.8
1.20   45000.0        29583.4     8969.3   24953.1
1.40   36152.0        55513.2    19159.7   44492.9
1.40   45000.0        36281.2    12545.3   29100.7
1.80   36152.0        84574.4    36244.2   61125.5
1.30   45000.0        55309.2    23731.4   39993.8
1.80   55000.0        34215.7    14712.5   24762.7
2.00   45000.0        67780.0    31831.8   46385.3
2.00   55000.0        41943.5    19733.0   28724.6
2.00   65000.0        25941.6    12229.7   17786.4
2.40   55000.0        62238.6    34217.2   37758.0
2.40   65000.0        38526.2    21221.5   23391.4
2.40   75000.0        23479.8    13083.1   14202.1
2.70   55000.0        92010.7    49851.[illegible]   44966.5
2.70   65000.0        50784.7    30915.2   27863.0
2.70   75000.0        36390.5    19060.9   16907.3
3.00   55000.0       106202.1    74519.2   52076.3
3.00   65000.0        65786.1    43731.2   32275.2
3.00   75000.0        40100.5    26912.0   19525.6
9.00
 .40                   5715.5     4743.0    4233.2
 .40                   7945.3     5496.5    5017.7
 .40                  10697.3     6238.3    6036.4
 .40                  13773.8     6935.8    7592.8
 .40                  17318.2     7617.4    9064.9
 .40                  21735.1     8181.2   11476.3
 .40                  25033.9     8441.6   13466.4
 .40                  28483.7     8704.1   15732.7
```

TABLE B1.- CONTINUED.

.40	29214.2	8697.6	16553.2
.40	39698.8	8697.6	25883.0
.40	48329.7	8697.6	36011.2
.40	54858.1	8697.6	45504.2
.40	60516.7	8697.6	54844.4
.40	65675.6	8697.6	63999.2
.60	5192.6	5674.4	2651.1
.60	7258.1	6547.7	3343.4
.60	9775.5	7406.7	4228.7
.60	12655.8	8204.2	5467.4
.60	15887.8	8980.6	6995.7
.60	20080.1	9592.7	9370.1
.60	23107.3	9834.3	11281.2
.60	25975.5	10180.0	13282.5
.60	26516.2	10172.9	13979.7
.60	34620.9	10172.9	21526.1
.60	41456.0	10172.9	29711.6
.60	46727.1	10172.9	37371.2
.60	51345.4	10172.9	44907.3
.60	55484.8	10172.9	52293.3
.80	8216.9	9705.7	2684.6
.80	11329.9	11021.9	3720.2
.80	14706.6	12266.6	5053.7
.80	18795.7	13459.9	6899.1
.80	23894.0	14473.9	9688.7
.80	27289.1	14922.9	11862.9
.80	30603.6	15382.7	14063.1
.80	31120.3	15371.1	14773.1
.80	40306.5	15371.1	23314.9
.80	48112.1	15371.1	32587.8
.80	54137.9	15371.1	41286.5
.80	59406.4	15371.1	49845.1
.80	64188.7	15371.1	58233.9
1.00	5914.3	6387.7	1324.1
1.00	8185.8	7161.9	2192.2
1.00	10541.5	7898.4	3225.2
1.00	12828.6	8541.8	4377.4
1.00	15491.8	9119.9	5922.2
1.00	17276.5	9371.5	7139.9
1.00	18894.5	9544.1	8451.7
1.00	19312.9	9529.4	9064.3
1.00	24058.3	9529.4	13689.6
1.00	28218.1	9529.4	18696.2
1.00	31480.0	9529.4	23370.0
1.00	34350.5	9529.4	27967.9
1.00	35966.2	9529.4	32473.7
1.40	8135.8	8906.5	1030.9
1.40	10437.8	9945.3	1886.9
1.40	12835.6	10923.3	2953.9
1.40	15591.9	11826.1	4387.1
1.40	17250.4	12199.2	5434.8
1.40	18855.0	12562.2	6484.8
1.40	19223.6	12545.3	7045.3
1.40	23750.0	12545.3	11382.0

C - 2

TABLE B1. - CONCLUDED.

1.40	27740.6	12545.3	16081.5
1.40	30926.4	12545.3	20497.8
1.40	33739.8	12545.3	24842.6
1.40	36281.2	12545.3	29100.7
2.00	20012.4	19835.7	2301.1
2.00	21372.6	19780.2	3380.2
2.00	21905.3	19757.6	3829.0
2.00	22227.2	19733.0	4325.2
2.00	27370.4	19733.0	9966.7
2.00	31958.4	19733.0	14228.5
2.00	35675.0	19733.0	19145.0
2.00	38941.7	19733.0	23982.5
2.00	41943.5	19733.0	28724.6
2.40	20329.9	21221.5	1455.7
2.40	25041.0	21221.5	5686.8
2.40	29247.4	21221.5	10296.2
2.40	32699.6	21221.5	14737.2
2.40	35760.1	21221.5	19107.1
2.40	38526.2	21221.5	23391.4
2.62	30737.7	28070.7	5142.0
2.62	35874.3	28070.7	10721.8
2.62	40123.5	28070.7	16132.8
2.62	43885.3	28070.7	21457.6
2.62	47299.2	28070.7	26678.9
2.70	33026.4	30915.2	4814.4
2.70	38526.5	30915.2	10775.3
2.70	43093.7	30915.2	16569.5
2.70	47130.8	30915.2	22271.5
2.70	50784.7	30915.2	27863.0
9.0			

TABLE C1. - OUTPUT LISTING FOR SIZED AIRCRAFT (TAPE6).

```
                        1  SIZING AND PERFORMANCE RESULTS     (  9.41 AM  ;  MAR  28  1985 )

                        JP FUEL
                                             ( IN WING AND BODY )

                          SUPERSONIC TRANSPORT, JP-FUEL
                         TURBOJET ENGINE FOR SUPERSONIC TRANSPORT, JP-FUEL
              RANGE,      4012.2 NM     WG,    643633.0 LB     ENDURANCE,   3.13 HRS

              W/S,  82.00 PSF     T/W,  .320     PASSENGERS,  292     M,CR,  2.62

             S,REF,   7849.18 SQ FT     THRUST/ENG, SL,  51490.64 LB

         BTU/PAS/NM,  3839.0     PASS MILES/GAL,   32.35   SEATS,  292   SEATS,AB,    5   PAS LEVELS,    1

     PAYLOAD,    61028. LBS     (  292 PAS        48180. LBS, PAS       12848. LBS, BAGGAGE           0. LBS, CARGO    )

                   TECHNOLOGY IMPROVEMENTS (IN PERCENT)
              (APPLIED FROM M=   0.00 TO M=   2.62 WHERE APPROPRIATE)

                            NONE


     NOTE--MAIN CRUISE LEG OCCURS AT BEST AVAILABLE BREGUET FACTOR

                              WEIGHT FRACTIONS
          WDRY/WG      WOP/WG      WEMP/WG      WSEO/WG      WPPS/WG      WSTR/WG      WLG/WG
          WFUS/WG      WWNG/WG     WCAN/WG       WHT/WG      WVT/WG       WEN/WG      WPL/WG
            WB           WWW        WWWM         WFT

           .54529       .45047       .42450       .09022       .07206       .26222       .03801
           .07626       .11485      0.00000       .00517       .00721       .06184       .09482
          5.03703      4.26927      0.00000      0.00000

     WING VARIABLES,   T/C,    2.820 PERCENT     SWEEP,C/4, 47.45     SPAN,    122.274 FT

     ASPECT RATIO (AREA)     1.905 (REFERENCE)          1.727 (TOTAL)          1.727 (TRAPEZOIDAL)

     AREAS, (SQ FT)          REF.,    7849.18     TOTAL,    8657.61     WETTED, EXP.,  14925.28

     FUSELAGE VARIABLES
                            FN=  27.320     LENGTH=  315.00 FT     RADIUS,MAX=   5.765 FT

     TAIL VOLUME COEFFICIENTS...KTAIL    .056 CANARD   0.000
```

TABLE C1. - CONTINUED.

```
VOLUMES,CU.FT.---WING,TOTAL,     16972.25734     EXPOSED,     12877.26771
                 WING FUEL,       5060.72711     WING FUEL,MAX,      5060.72711
                 BODY FUEL,        735.40622     BODY FUEL,MAX,      1588.33507

FUEL DENSITY   6.750 LB/GAL

FUEL DISTRIBUTION          WF,LBS            WF/WG

        WING           255533.19160         .39702
        WING,MAX       255533.19160         .39702
        BODY            37133.14227         .05769
        BODY,MAX        80200.39853         .12461

     TAKEOFF CONDITIONS

DAY TEMP,DEG C.     0.0

FLAP DEFL,DEG  20.0    ALPHA,GR,DEG  -4.0    ALPHA,TO,DEG   7.8    CL,TO  .6148    CDTO  .1180    L/D,TO     5.211

V,ROT  177.14 KN    V,TO  193.40 KN    CLIMB GRADIENT, %   5.8

TAKEOFF FIELD LENGTH          9663. FT    TAXI DRAG/WG          .02000    TAXI TIME       10.00000 MIN

     APPROACH CONDITIONS

FLAP DEFL,DEG  20.0    ALPHA,DEG   9.5    CL  .5975    CD  .1336    L/D     4.471

V,APP  159.43 KN    WEIGHT  399198.4 LB

THRUST DEFLECTION,DEG    TAKEOFF   0.00    MISSION   0.00

DAY TEMP., MISSION, DEG. C        0.00000

MINIMUM THRUST MARGINS,PERCENT

     CLIMB         14.51 AT M= 2.620

          SUBSONIC        155.15 AT M=  .375
          TRANSONIC        50.17 AT M= 1.400
          SUPERSONIC        14.51 AT M= 2.620

     CRUISE          9.13 AT M= 2.620

MIN RATE OF CLIMB DURING CRUISE        1642.54 FT/MIN

RANGES,NM

R,ASCENT,TOT=       472.32523       R,DESCENT,TOT=       273.16358       R,CRUISE=     3266.72720
R,SSC,OB=        0.00000            R.SSC,IB=         0.00000            R,TOTAL=     4012.21602
R,ASCENT=      472.32523            R,DESCENT=      273.16358
```

TABLE C1. - CONTINUED.

```
TRIP TIMES,MIN

T,ASCENT,TOT=        31.24044        T,DESCENT,TOT=        26.35896        T,CRUISE=      130.40195
T,SSC,OB=          0.00000           T,SSC,IB=          0.00000            T,TOTAL=      188.00135
T,ASCENT=          31.24044          T,DESCENT=         26.35896

FUEL FRACTIONS,UF/UG

ASCENT,TOT,            .10360        DESCENT,TOT,            .00541        CRUISE,          .26034
SSC,OB,          0.00000             SSC,IB,          0.00000              TRIP,           .37977
ASCENT,           .10360             DESCENT,           .00541             MISSION,           .45471
TAKEOFF,           .00572            TAXI,           .00471                MAX. FUEL,           .52162
RESERVES,           .07494

FUEL, (LB)

    TOTAL,        292666.3     TRIP (BLOCK),         244434.6     RESERVES,        48231.7

                  CRUISE CONDITIONS (START,MID,END )

  M          ALT        CL         CD          L/D       SFC        BRG FCT     T/TMAX     P/D2      J        E,PROP
                     ALPHA,DEG
MAIN CRUISE LEG

 2.620     63211.     .1002     .01168       8.574     1.3663       9522.      .8733      0.00     0.000     0.000
                     0.0000

 2.620     63971.     .1023     .01202       8.510     1.3725       9407.      .8997      0.00     0.000     0.000
                     0.0000

 2.620     67811.     .1017     .01211       8.392     1.3800       9241.      .9163      0.00     0.000     0.000
                     0.0000

                  FUEL RESERVE INFO

TRIP FUEL ALLOWANCE (  7.0 PERCENT OF TRIP FUEL),  UF/UG=         .02625

MISSED APPROACH      UF/UG=          .00198

ALTERNATE AIRPORT ( 260.0 NM,),  UF/UG=  .02806

     M,CR      .827     ALT,CR    30429. TO   30808. FT     L/D,CR       12.978     T/TMAX,CLIMB          .50000

     T/TMAX,CR          .30070     SFC,CR          .91033 LB/HR/LB

HOLD ( 30.0 MIN. AT 25000.0 FT ),   UF/UG=  .01365

     M,         .65000             ALT,    25000.00000 FT              L/D,       13.19636

     T/TMAX,         .25982        SFC,          .88378 LB/H/LB
```

TABLE C1. - CONTINUED.

```
                                          AERODYNAMICS

                             AT ALTITUDES ALONG CLIMB SCHEDULE

    M      ALT,FT    CDU       CDF      CDPST     CDRUF     CDBL      CDAC      CD,ZL   (L/D)MAX   CL,OPT    CD,OPT

  0.00        0.   0.00000   .00680    .00192    .00027    .00057    .00029    .00896  13.29999   .17600    .01323
   .30     1909.   0.00000   .00650    .00098    .00027    .00057    .00029    .00862  13.32705   .17600    .01321
   .60     7286.   0.00000   .00621    .00093    .00027    .00057    .00029    .00828  13.35421   .17600    .01318
   .70    14857.   0.00000   .00622    .00093    .00027    .00367    .00030    .00839  13.32729   .17700    .01328
   .80    22429.   0.00000   .00623    .00093    .00027    .00076    .00031    .00851  13.30078   .17800    .01338
   .95    30806.   0.00000   .00618    .00093    .00027    .00124    .00032    .00895  12.52308   .18400    .01469
  1.05    32417.    .00276   .00606   0.00000    .00064    .00226    .00034    .01206  10.50192   .19000    .01809
  1.10    33222.    .00291   .00600   0.00000    .00064    .00212    .00034    .01201  10.10660   .18867    .01867
  1.20    34833.    .00321   .00588   0.00000    .00064    .00184    .00036    .01192   9.38486   .18600    .01982
  1.40    38055.    .00258   .00563   0.00000    .00034    .00120    .00038    .01015   9.43437   .17200    .01823
  1.60    41278.    .00250   .00544   0.00000    .00033    .00090    .00041    .00957   9.43615   .16000    .01696
  1.80    44500.    .00242   .00523   0.00000    .00032    .00059    .00043    .00899   9.43822   .14800    .01568
  2.00    47722.    .00234   .00505   0.00000    .00030    .00061    .00046    .00876   9.22494   .14000    .01518
  2.20    50944.    .00227   .00487   0.00000    .00029    .00062    .00048    .00853   8.99698   .13200    .01467
  2.40    54167.    .00224   .00471   0.00000    .00028    .00052    .00030    .00804   8.88191   .12343    .01390
  2.62    57711.    .00221   .00453   0.00000    .00026    .00040    .00009    .00749   8.73955   .11400    .01304

  VALUES AT START OF CRUISE
  2.62    60211.    .00221   .00462    .00026    .00040    .00009    .00758   8.68015    .11400    .01313
```

TABLE C1. - CONCLUDED.

```
TAKEOFF DRAG COEFFICIENT INCREMENTS FROM BASELINE VALUES

DELTA CD,           .00053
BASIS FOR ABOVE INCREMENT

CFTTOB,CFETOB,TOCDACB,TOCDBLB,TOCDRFB
                                       .00654     .00073     .00023     .00058     .00025
CFTTO,CFETO,TOCDAC,TOCDBL,TOCDRF
                                       .00781     0.00000    .00029     .00057     .00027

     ***  INPUTS TO TAKEOFF PROGRAM  ***

WG,    643633.00000     W/S,       82.000     T/W,  .320     DELCD,  .00063

T.O. DAY,  0.000     MISSION DAY,  0.000     THRUST DLF.,  0.000

ALPHA,GR. ROLL,       -4.00000     V,ROT,      177.14154     FLP DFL,TO,       20.00000

TAXI FUEL,         3028.78     W,APR,      399198.41     ALPHA,APR,        9.50000     FLP DFL,APR,       20.00000

     ***  ENGINE SIZING INFO  ***

     ENGINE SIZING FACTOR, ESF=         .78042

MAX THRUST VALUES/ENGINE, SEA LEVEL STATIC

       0.0 DEG. DAY
T,SLS,DECK,     65978.00000     T,SLS,RESIZE,    51490.64000


     ***  INPUTS FOR DOC-ROI PROGRAM  ***

RNGE=    4012.2     WGROSS=  643633.0     FUELBL=  244434.6

BEW=  273221.1     WTENG=    39802.1     VCJ=  205962.6

TBLOCK=    3.300     TCRUISE=    2.173     NSEATS=  292

NOPAS=  292     NCREW=    3     NENGS=    4

XMCR=   2.62     WCARGO=      0.0

TOW=  .3200     WOS=  82.00
```

TABLE C2. - SUMMARY OUTPUT LISTING (TAPE6).

```
 SUMMARY OUTPUT FOR        SUPERSONIC TRANSPORT, JF-FUEL
                                                                                                                  W/WG

  3. GROSS UEIGHT, LBS                  643633.00000        36. CLIMB FUEL, LBS                       66680.48304      .10360
  2. RANGE, NM                            4012.21602        37. CRUISE FUEL, LBS                     167560.65872      .26034
  3. ENDURANCE, HRS                          3.13336        38. DESCENT FUEL, LBS                      3484.59775      .00541
  4. PASSENGERS                            292.00000        39. BLOCK FUEL, LBS                      244434.59158      .37977
  5. CRUISE MACH NUMBER                      2.62000        40. RESERVE FUEL LBS                      48231.74229      .07494
  6. PASS MILES/GALLON                      32.35469        41. TOTAL FUEL, LBS                      292666.33387      .45471

  7. UING LOADING, PSF                      82.00000        42. UING U'., LBS                         73923.24031      .11485
  8. THRUST TO UEIGHT RATIO                   .32000        43. HORIZONTAL TAIL UT.                    3327.66703      .00517
  9. REFERENCE AREA,SQ FT                 7849.18293        44. VERTICAL TAIL UT.                      4639.11985      .00721
 10. THRUST/ENG, SLS                     51490.64000        45. FUSELAGE UT.                          49082.02529      .07626
 11. ASPECT RATIO                            1.90479        46. LANDING GEAR UT.                      24466.12182      .03801
 12. UING SPAN, FT                         122.27443        47. NACELLE UT.                           13336.58335      .02072
 13. SUEEP C/4, DEG                         47.45099        48. TOTAL STRUCTURE UT.                  168774.75766      .26222
 14. UING THICKNESS RATIO, %                 2.82000
 15. FUSELAGE LENGTH, FT                   315.00000        49. ENGINE UT.                            39802.09455      .06184
 16. FUSELAGE RADIUS, MAX                    5.76500        50. THRUST REVERSER UT.                       0.00000     0.00000
 17. FUSELAGE FINENESS RATIO                27.32003        51. MISC. SYSTEM UT.                       1780.90000      .00277
                                                            52. PLUMBING SYSTEM UT.                    4796.91872      .00745
 18. DELTA TEMP, TO, DEG. C                  0.00000        53. TOTAL PROPULSION SYSTEM UT.           46379.01327      .07206
 19. DELTA TEMP, MISSION, DEG. C             0.00000
 20. TAKEOFF FIELD LENGTH, FT             9662.89886        54. FLIGHT CONTROLS UT.                    8430.87516      .01310
 21. TAKEOFF SPEED, K                      193.39812        55. AUXILIARY POUER UT.                       0.00000     0.00000
 22  APPROACH SPEED, K                     159.42626        56. INSTRUMENTS                            3134.56794      .09487
 23. MIN RATE OF CLIMB, CRUISE            1642.53538        57. HYDRAULICS                             5757.08346      .00894
                                                            58. ELECTRICAL                             4754.59582      .00739
 24. MAX L/D, CRUISE                         8.68015        59. AVONICS                                2491.79311      .00387
 25. AVERAGE L/D, CRUISE                     8.49225        60. FURN. AND EQUIPMENT                   25111.00000      .03901
 26. AVERAGE SFC.CRUISE                      1.37292        61. AIR CONDITIONING                       8200.00900      .01274
 27. AVERAGE BREGUET FACTOR, CRUISE       9390.0[illegible]12        62. ANTI-ICING                              187.45689      .00029
 28. AVERAGE ANGLE OF ATTACK, DEG            0.0[illegible]00        63. TOTAL SYSTEM AND EQUIPMENT UT.        58067.37239      .09022

 29. CLIMB RANGE, NM                       472.32523        64. EMPTY UT.                            273221.14332      .42450
 30. CRUISE RANGE, NM                     3266.72720
 31. DESCENT RANGE, NM                     273.16358        65. OPERATING ITEMS                       16717.52281      .02597
                                                            66. OPERATING EMPTY UT.                  289938.66613      .45047
 32. CLIMB TIME, MIN                        31.24044
 33. CRUISE TIME, MIN                      130.40195        67. PASSENGER UT.                         48180.00000      .07486
 34. DESCENT TIME, MIN                      26.35896        68. BAGGAGE UT.                           12848.00000      .01996
 35. BLOCK TIME, MIN                       188.00135        69. CARGO UT.                                 0.00000     0.00000

                                                            70. ZERO FUEL UT.                        350966.66613      .54529
   DATA FOR PROP DRIVEN AIRCRAFT

 71. POUER/DSG, DES                          0.00000        81. RPM, ENGINE                             -10.00000
 72. ADVANCE RATIO, DES                      0.00000        82. RPM, PROP                               -10.00000
 73. POUER COEF., DES                      -10.00000        83. PROP TIP SPEED, FPS                       0.00000
 74. PROP THRUST COEF., DES                  0.00000        84. POUER/DSQ, AVE. CRUISE                    0.00000
 75. EFF, PROP, DES                          0.00000        85. ADVANCE RATIO, AVE. CRUISE                0.00000
 76. EFF, OVAL, DES                          0.00000        86. POUER COEF., AVE. CRUISE                  0.00000
 77. POUER TO UEIGHT RATIO                 -10.00000        87. THRUST COEF., AVE. CRUISE                 0.00000
 78. SHAFT HORSEPOUER                      -10.00000        88. EFF., PROP, AVE. CRUISE                   0.00000
 79. PROP DIAMETER, FT                     -10.00000        89. EFF., OVALL, AVE. CRUISE                  0.00000
 80. GEAR RATIO                            -10.00000        90. PROP UT.                                  0.00000     0.00000
                                                            91. GEAR BOX UT.                              0.00000     0.00000
```

TABLE C3. - WEIGHT STATEMENT (TAPE6).

```
     ITEM                  W,LBS                    W/WG

 WING                      73923.                   .1149
 HTAIL                      3328.                   .0052
 VTAIL                      4639.                   .0072
 CANARD                        0.                  0.0000
 FUSELAGE                  49082.                   .0763
 L. GEAR                   24466.                   .0380
 NACELLES                  13337.                   .0207
 TOT. STRUCTURE                      168775.                  .2622

 ENGINES                   39802.                   .0618
 THRUST REV                    0.                  0.0000
 PROPELLER                     0.                  0.0000
 GEAR BOX                      0.                  0.0000
 MISC SYSTEMS               1780.                   .0028
 PLUMBING                   4797.                   .0075
 TANKS                         0.                  0.0000
 INSULATION                    0.                  0.0000
 TOT. PROPULSION                      46379.                  .0721

 SURFACE CONTROLS           8431.                   .0131
 AUXILIARY POWER               0.                  0.0000
 INSTRUMENTS                3135.                   .0049
 HYDRAULICS                 5757.                   .0089
 ELECTRICAL                 4755.                   .0074
 AVONICS                    2492.                   .0039
 FURN. AND EQUIPMENT       25111.                   .0390
 AIR COND                   8200.                   .0127
 ANTI-ICING                  187.                   .0003
 TOT. SYSTEM AND EQ.                  58067.                  .0902

 EMPTY WEIGHT                        273221.                  .4245

 FLIGHT CREW                 675.                   .0010
 CABIN CREW                 1640.                   .0025
 FUEL,UNUS                  1924.                   .0030
 ENGINE OIL                  667.                   .0010
 PASSENGER SERVICE          8852.                   .0138
 CARGO CONTAINERS           2969.                   .0046
 OPREATING ITEMS                      16718.                  .0260

 OPERATING EMPTY WT.                 289939.                  .4505

 PASSENGERS ( 292)         48180.                   .0749
 BAGGAGE                   12848.                   .0200
 CARGO                         0.                  0.0000
 TOTAL PAYLOAD                        61028.                  .0948

 ZERO FUEL WEIGHT                    350967.                  .5453

 MISSION FUEL                        292666.                  .4547

 GROSS WEIGHT                        643633.                 1.0000
```

TABLE C4. - MISSION ANALYSIS RESULTS (TAPE6).

```
1
                                    MISSION ANALYSIS RESULTS FOR

                         W/S=  82.00 PSF   T/W=  .320     IPAS=  292     WG=  643633.0 LB

        M            V,K         ALT,FT       Q,PSF       W,LBS          W/WG        RANGE,NM    TIME,SEC       FPA,DEG
       A/G       ALPHA,DEG         CL           CD          L/D     SFC,LB/H/LB      BF,NM       L,LBS        DRAG,LBS
     T,LBS       TMAX,LBS          T/D        TMAX/D       T/TMAX  FUEL,LB/SEC     FLAP,DEG     FUEL,LB       E,OVALL
      P/D2           J              CP           CT        E,PROP

      0.0000        0.0000       0.0000       0.0000  640604.2235        .9953       0.0000       0.0000       0.0000
       .3215       -4.0000        .1083        .0447       0.0000       1.0117       0.0000       0.0000       0.0000
 205962.5600   205962.5600       0.0000       0.0000       1.0000      57.8826      20.0000    3028.7765       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .0893       59.0472       0.0000      11.8036  639995.3294        .9843        .0853      10.4032       0.0000
       .2933       -4.0000        .1083        .0447       2.4229       1.0383       0.0000   10036.8992    4142.5161
 205234.6477   205234.6477      49.5435      49.5435       1.0000      59.1939      20.0000    3637.6706       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .1785      118.0944       0.0000      47.2142  639343.9949        .9933        .3531      21.2885       0.0000
       .2749       -4.0000        .1083        .0447       2.4229       1.0649       0.0000   40147.5968   16570.0644
 204506.7354   204506.7354      12.3419      12.3419       1.0000      60.4943      20.0000    4289.0051       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .2678      177.1415       0.0000     106.2320  638612.8719        .9922        .8435      33.2484       0.0000
       .2423       -4.0000        .1083        .0447       2.4229       1.0915       0.0000   90332.0929   37282.6448
 203778.8231   203778.8231       5.4658       5.4658       1.0000      61.7840      20.0000    5020.1281       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .2924      193.3981       0.0000     126.6249  638369.4775        .9918       1.0464      37.1757       0.0000
       .1323        7.7602        .6148        .1180       5.2112       1.0988       0.0000  611059.2097  117259.6997
 203578.4178   203578.4178       1.7361       1.7361       1.0000      62.1372      20.0000    5263.5225       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .3105      205.3688      35.1723     142.6386  637992.0180        .9912       1.3829      43.2382       2.3977
       .0773        8.0000        .6014        .1119       5.3746       1.1042     999.6473  673271.8976  125269.1217
 203249.4568   203249.4568       1.6225       1.6225       1.0000      62.3392      20.0000    5640.9920       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000
TOFL=     9662.89886


       .3195      211.2920     109.3249     150.6576  637750.4419        .9909       1.6066      47.1132       3.3468
       .0876        7.1029        .5184        .0916       5.6621       1.1068    1080.9567  613973.0938  108276.7089
 202793.9006   202793.9006       1.8729       1.8729       1.0000      62.3454      20.0000    5882.5581       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .3353      221.5953     237.2328     165.0892  637376.3399        .9903       1.9666      53.1132       3.3468
       .0975        6.1224        .4744        .0798       5.9431       1.1113    1185.1130  614742.4328  103437.4909
 202009.6839   202009.6839       1.9530       1.9530       1.0000      62.3571      20.0000    6256.6601       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .3467      229.1091     326.0280     176.0157  637126.8845        .9899       2.2165      57.1132       3.3468
       .1027        5.3709        .4467        .0709       6.3021       1.1145    1295.4691  617181.4313   97933.0980
 201462.5343   201462.5343       2.0571       2.0571       1.0000      62.3721      20.0000    6506.1155       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000

       .3567      235.6495     400.4337     185.8028  636924.1479        .9896       2.4259      60.3632       3.3468
        1079        4.7708        .4245        .0647       6.5572       1.1174    1382.8329  619[illegible]20.2323   94419.0488
 201002.1684   201002.1684       2.1288       2.1288       1.0000      62.3894      20.0000    6708.8521       0.0000
      0.0000        0.0000       0.0000       0.0000       0.0000
END OF T.O. SEGMENT
```

TABLE C4. - CONTINUED.

```
          M          V,K          ALT,FT        Q,PSF        W,LBS          V/VG        RANGE,NM     TIME,SEC       FPA,DEG
         A/G      ALPHA,DEG         CL            CD           L/D     SFC,LB/H/LB      BF,NM         L,LBS       DRAG,LBS
       T,LBS      TMAX,LBS          T/D        TMAX/D        T/TMAX   FUEL,LB/SEC     FLAP,DEG      FUEL,LB        E,OVALL
        P/D2          J             CP            CT         E,PROP


       .3567     235.6495      400.4337     185.8028   636924.1479         .9896       2.4258       60.3632        3.3468
       .1806       0.0000         .4366        .0589        7.4092        1.1174    1562.8976   636774.3668     85943.2001
 201002.1684  201002.1684        2.3388       2.3388        1.0000       62.3894       0.0000     6708.8521        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .3754     247.7323      700.0000     203.5462   636464.8512         .9889       2.9211       67.7389        5.7051
       .1904       0.0000         .3983        .0489        8.1451        1.1225    1798.0395   636299.4359     78129.6285
 199327.4758  199327.4758        2.5515       2.5515        1.0000       62.1522       0.0000     7168.1488        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .4000     263.5991     1094.3591     227.7946   635910.3970         .9880       3.5563       76.6826        5.8553
       .2002       0.0000         .3555        .0391        9.1015        1.1292    2125.2731   635723.2771     69848.2286
 197138.7700  197138.7700        2.8224       2.8224        1.0000       61.8357       0.0000     7722.6030        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .5000     327.6637     2698.1197     335.6338   633984.5581         .9850       6.1162      107.8557        5.9081
       .2227       0.0000         .2405        .0195       12.2592        1.1519    3488.6367   633696.3065     51691.6363
 192886.6183  192886.6183        3.7315       3.7315        1.0000       61.7207       0.0000     9648.4419        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .5500     359.4166     3500.0000     394.2720   633144.3982         .9837       7.4158      121.4744        5.8188
       .2251       0.0000         .2045        .0156       13.0842        1.1630    4045.8360   632798.6322     48363.5271
 190875.2800  190875.2800        3.9467       3.9467        1.0000       61.6626       0.0000    10488.6018        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .6000     386.8295     7285.7143     407.0992   631142.7935         .9306      12.3821      169.3905        7.1888
       .1462       0.0000         .1974        .0150       13.1972        1.0312    4953.8483   630742.8459     47793.5615
 140054.4826  175068.1033        2.9304       3.6630         .8000       40.1171       0.0000    12490.2065        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .7000     438.7742    14857.1429     412.1775   627238.8657         .9745      22.4416      257.1188        7.0980
       .1361       0.0000         .1937        .0147       13.2214        1.1084    5238.2679   626727.4766     47402.3264
 132774.0572  147526.7302        2.8010       3.1122          9090       40.8787       0.0000    16394.1343        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .8000     486.7297    22428.5714     393.5423   623377.0540         .9685      33.7029      344.7265        6.3405
       .1197       0.0000         .2016        .0154       13.0908        1.1795    5407.4132   622751.6469     47571.6378
 122209.4234  122209.4234        2.5690       2.5690        1.0000       40.0408       0.0000    20255.9460        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

       .9000     530.4990    30000.0000     357.0251   619318.2880         .9622      49.3915      455.7711        4.5513
       .0812       0.0000         .2207        .0180       12.2634        1.1816    5512.2625   618590.1810     50441.0796
 100704.0340  100704.0340        1.9965       1.9965        1.0000       33.0543       0.0000    24314.7120        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

      1.0000     585.3295    31611.1111     409.4874   617373.3690         .9592      58.4688      514.3429        1.0738
       .0757       0.0000         .1918        .0168       11.4151        1.1919    5614.0603   616477.6228     54005.3470
 100756.6296  100756.6296        1.8657       1.8657        1.0000       33.3584       0.0000    26259.6310        0.0000
      0.0000       0.0000        0.0000       0.0000        0.0000

      1.1000     639.3059    33222.2222     459.8367   615285.5229         .9560      68.9986   576.25[illegible]   [illegible].4429
       .0663       0.0000         .1782        .0170        9.9825        1.1994    5330.2557   61422[illegible]   [illegible]7134
 102335.0729  102335.0729        1.6632       1.6632        1.0000       34.0937       0.0000    28347.4771          9000
      0.0000       0.0000        0.0000       0.0000        0.0000
```

TABLE C4. - CONTINUED.

M A/Q T,LBS P/D2	V,K ALPHA,DEG TMAX,LBS J	ALT,FT CL T/D CP	Q,PSF CD TMAX/D CT	W,LBS L/D T/TMAX E.PROP	W/WG SFC,LB/H/LB FUEL,LB/SEC	RANGE,NM BF,NM FLAP,DEG	TIME,SEC L,LBS FUEL,LB	FPA,DEG DRAG,LBS E,OVALL
1.1200 .0650 102624.9970 0.0000	649.9979 0.0000 102624.0970 0.0000	33544.4444 .1665 1.6371 0.0000	469.5857 .0170 1.6371 0.0000	614839.5307 9.7907 1.0000 0.9000	.9553 1.2907 34.2287	71.3364 5309.5651 0.0008	589.3065 613739.4566 8793.4693	1.2998 62686.0309 0.0000
1.1400 .0635 102903.3227 0.0000	660.6553 0.0000 102903.3227 0.0000	33866.6667 .1630 1.6110 0.0000	479.2151 .0170 1.6110 0.0000	614385.5941 9.6004 1.0000 0.0000	.9546 1.2020 34.3594	73.7480 5286.2959 0.0000	602.5432 613249.9897 29247.4059	1.2611 63877.2399 0.0000
1.1600 .0620 103172.3965 0.0000	671.2780 0.0000 103172.3965 0.0000	34188.8889 .1597 1.5848 0.0000	488.7198 .0170 1.5848 0.0000	61392.8223 9.4124 1.0000 0.0000	.9538 1.2033 34.4855	76.2330 5260.8743 0.0000	615.9871 612751.2886 29710.1777	1.2218 65100.2673 0.0000
1.1800 .0605 103430.9817 0.0000	681.8659 0.0000 103430.9817 0.0000	34511.1111 .1566 1.5593 0.0000	498.0953 .0170 1.5593 0.0000	613450.4172 9.2303 1.0000 0.0000	.9531 1.2045 34.6070	78.8029 5235.4678 0.0000	629.6617 612242.5555 30182.5828	1.1824 66329.6076 0.0000
1.2000 .0589 103678.7593 0.0000	692.4190 0.0000 103678.7593 0.0000	34833.3333 .1536 1.5341 0.0000	507.3369 .0170 1.5341 0.0000	612967.5517 9.0516 1.0000 0.0000	.9524 1.2057 34.7237	81.4617 5208.8281 0.0000	643.5910 611723.0038 30665.4483	1.1429 67581.5158 0.0000
1.3000 .0595 104792.9312 0.0000	745.6540 0.0000 104792.9312 0.0000	36444.4444 .1407 1.5311 0.0000	551.4028 .0158 1.5311 0.0000	610526.8378 8.8995 1.0000 0.0000	.9486 1.2132 35.3150	9[illegible].3826 5482.7033 0.0000	713.2890 609089.3119 33106.1622	1.0914 68441.2063 0.0000
1.4000 .0569 103536.0054 0.0000	803.8120 0.0000 103536.0054 0.0000	38055.5556 .1305 1.5017 0.0000	592.0090 .0148 1.5017 0.0000	607[illegible]53.4914 8.7937 1.0000 0.0000	.9446 1.2244 35.2124	111.0787 5783.3067 0.0000	786.2629 606293.3287 35679.5086	.9680 68946.0720 0.0000
1.5000 .0564 103701.2705 0.0000	860.3700 0.0000 103701.2705 0.0000	39666.6667 .1222 1.4911 0.0000	629.1437 .0141 1.4911 9.0000	605352.8681 8.6768 1.0000 0.0000	.9405 1.2349 35.5729	128.0547 6064.1346 0.0000	859.7437 603455.2214 38280.1319	.8950 69548.3960 0.0000
1.6000 .0555 103272.8251 0.0000	917.7280 0.0000 103272.8251 0.0000	41277.7778 .1155 1.4797 0.0000	662.6857 .0134 1.4797 0.0000	602749.0015 8.6053 1.0000 0.0000	.9365 1.2454 35.7281	146.0923 6363.6643 0.0000	932.7831 600593.1885 40883.9985	.8423 69793.8440 0.0000
1.7000 .0544 102338.0430 0.0000	975.0860 0.0000 102338.0430 0.0000	42888.8889 .1130 1.4687 0.0000	692.5816 .0128 1.4687 0.0000	600135.2538 8.5783 1.0000 0.0000	.9324 1.2559 35.7032	163.3312 6686.9194 0.0000	1005.9652 597718.8495 43497.7462	.7897 69677.7205 0.0000
1.8000 .0531 100974.5695 0.0000	1032.4440 0.0000 100974.5695 0.0000	44500.0000 .1054 1.4586 0.0000	71[illegible].[illegible]343 .0123 1.4586 0.0000	597508.6486 8.5922 1.0000 0.0000	.9283 1.2664 35.5211	185.8959 7036.5754 0.0000	1079.7203 594811.4468 46124.3514	.7388 69226.5741 0.0000

TABLE C4. CONTINUED.

```
      M           U,K         ALT,FT        Q,PSF       W,LBS          U/UG       RANGE,NM      TIME,SEC        FPA,DEG
     A/G      ALPHA,DEG        CL           CD          L/D       SFC,LB/H/LB     BF,NM         L,LBS        DRAG,LBS
    T,LBS     TMAX,LBS         T/D        TMAX/D       T/TMAX     FUEL,LB/SEC    ELAP,DEG      FUEL,LB        E,OVALL
    F/D2          J            CP           CT         E,PROP

    1.9000     1089.8820    46111.1111     741.4825  594828.5415       .9242      208.1464     1155.2079         .6828
     .0506        0.0000         .1017        .0129       8.4787      1.2788     7262.2962   591336.8957     69803.0350
  99902.6470   99902.6470       1.4312       1.4312       1.0000     35.4837        0.0000    48804.4585        0.0000
     0.0000       0.0000        0.0000       0.0006       0.0006

    2.0000     1147.1600    47722.2222     760.5424  592041.9199       .9198      232.6070     1233.9383         .6211
     .0477        0.0000         .0986        .0118       8.3892      1.2911     7495.4211   588742.5069     70178.9421
  98428.3574   98428.3574       1.4025       1.4025       1.0000     35.3014        0.0000    51591.0801        0.0000
     0.0000       0.0000        0.0000       0.0000       0.0000

    2.1000     1204.5180    49333.3333     776.3995  589138.8408       .9153      259.5111     1316.3152         .5647
     .0453        0.0000         .0561        .0115       8.3194      1.3050     7726.4156   585519.0749     70380.1850
  97052.5143   97052.5143       1.3790       1.3790       1.0000     35.1809        0.0009    54494.1592        0.0000
     0.0000       0.0005        0.0000       0.0000       0.0000

    2.2000     1261.8760    50944.4444     788.9824  585107.4230       .9106      289.1372     1402.7953         .5129
     .0425        0.0000         .0940        .0114       8.2551      1.3189     7961.3138   582155.1511     70435.5757
  95326.7780   95326.7780       1.3534       1.3534       1.0000     34.9244        0.0009    58525.5770        0.0000
     0.0000       0.0000        0.0000       9.0000       0.0000

    2.3000     1319.2340    52555.5556     798.3072  582931.1999       .9057      321.9148     1494.2230         .4635
     .0398        0.0000         .0923        .0112       8.2544      1.3330     8230.0755   578634.8740     70099.9101
  93311.7288   93311.7288       1.3311       1.3311       1.0000     34.5503        0.0000    60701.8001        0.0000
     0.0000       0.0000        0.0200       0.0000       0.0000

    2.4000     1376.5920    54166.6667     804.7824  579601.5255       .9005      358.2461     1591.2640         .4182
     .0371        0.0000         .0910        .0110       8.2676      1.3471     8516.8459   574958.2053     69542.6830
  91060.7889   91060.7889       1.3094       1.3094       1.0000     34.0748        0.0000    64031.4745        0.0000
     0.0000       0.6000        0.0000       0.0000       0.0000

    2.5000     1433.9500    55777.7778     808.5050  576079.4731       .8950      398.9284     1695.4808         .3735
     .0340        0.0000         .0900        .0108       8.3008      1.3647     8798.4506   571663.1367     58796.515
  88402.5672   88402.5672       1.2850       1.2850       1.0000     33.5124        0.0000    67553.5269        0.0000
     0.0000       0.0000        0.0000       0.0000       0.0000

    2.6000     1491.3080    57388.8889     809.6575  572316.1713       .8892      444.9823     1808.8343         .3299
     .0350        0.0000         .0892        .0107       8.3506      1.3823     9094.7499   566925.9456     67890.4981
  85638.4834   85638.4834       1.2614       1.2614       1.0000     32.8829        0.0000    71316.8287        0.0000
     0.0000       0.0000        0.0000       0.0000       0.0000

    2.6200     1502.7796    57711.1111     809.5957  571536.1225       .8880      454.8670     1832.0044         .3074
     .0384        0.0000         .0891        .0107       8.3323      1.3858     9155.6566   566070.1114     67692.909
  85075.7099   85075.7099       1.2568       1.2568       1.0000     32.7499        0.0000    72096.8775        0.00
     0.0000       0.0000        0.0000       0.0000       0.0000

    2.6200     1502.7796    60211.1111     718.4190  570243.6649       .8860      472.3252     1874.4267        1.3504
     .0168        0.0000         .1002        .0117       8.5745      1.3868     9380.9537   564790.0146     65868.8874
  75423.7775   75423.7775       1.1451       1.1451       1.0000     29.6559        0.0000    73389.3351        0.0000
     0.0000       0.0006        0.0000       0.0000       0.0000
START OF CRUISE

    2.6200     1502.7796    60211.1111     718.4190  570243.6649       .8860      472.3252     1874.4267        1.3504
     0.0000       0.0000         .1002        .0117       8.5745      1.3663     9522.2795   564790.0146     65858.8874
  65868.8874   75423.7775       1.0000       1.1451        .8730     24.9984        0.0000    73389.3351        0.0000
     0.0000       0.0000        0.0000       0.0000       0.0000
```

TABLE C4. - CONCLUDED.

```
        M           U,K          ALT,FT         Q,PSF          W,LBS         U/UG           RANGE,NM     TIME,SEC        FPA,DEG
       A/G       ALPHA,DEG         CL             CD            L/D       SFC LB/H/LB       BF,NM        W,LBS        DRAG,LBS
     T,LBS       TMAX,LBS         T/D          TMAX/D          T/ MAX    FUEL,LB/SEC      FLAP,DEG      FUEL,LB        E,OVALL
      P/D2           J             CP             CT            E,PR ?

     2.6200     1502.7796     62111.1111      656.0687   528363.5519        .8209      1196.7566     3609.8461          .0247
     0.0000        0.0000          .1016         .0115        8.5481       1.3700      9467.2237   623306.5269     61218.5948
 61218.5948    68828.8277         1.0000        1.1243         .8894      23.2967         0.0000   115279.4481         0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000

     2.6200     1502.7796     63971.1111      600.2857   486463.4389        .7558      1976.3135     5477.3220          .0225
     0.0000        0.0000          .1023         .0120        8.5099       1.3725      9407.3502   481811.03[illegible]  56617.4666
 56617.4666    62932.6143         1.0000        1.1115         .8997      21.5862         0.0000   157169.56[illegible]      0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000

     2.6200     1502.7796     65411.1111      560.3837   444573.3260  [illegible]      2820.0278     7498.4910          .0161
     0.0000        0.0000          .1001         .0119        8.4375  1.[illegible]     9332.1245   440321.5515     52186.2364
 52186.2364    58642.7996         1.0000        1.1237         .8899      19.8864         0.0000   199059.6740         0.0000
     0.0000        0.0000         0.000         0.0000        0.0000

     2.6200     1504.8655     67811.1111      499.7632   402683.2130        .6256      3739.0524     9698.5435          .0246
     0.0000        0.0000          .1017         .0121        8.3923       1.3800      9240.6286   398821.3657     47522.0456
 47522.0456    51862.2888         1.0000        1.0913         .9163      18.2162         0.0000   240949.7870         0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000
END OF CRUISE

START OF DESCENT

     2.6200     1504.8655     67811.1111      499.7632   402683.2130        .6256      3739.0524     9698.5435          .0246
     -.1180        0.0000          .1017         .0121        8.3923       0.0000         0.0000   398821.3657     47522.0456
     0.0000    51862.2888         0.0000        1.0913        0.0000       1.3385         0.0000   240949.7870         0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000

     2.0650     1186.8867     64070.9141      371.1567   402497.2013        .6254      3795.4000     9840.3112         -.6260
     -.1129        0.0000          .1374         .0156        8.0075       0.0000         0.0000   400384.1998     45448.0279
     0.0000    46646.0564         0.0000        1.0264        0.0000       1.1290         0.0000   241135.7987         0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000

     1.5100      866.1058     54505.5976      309.0445   402269.8352        .6250      3852.0322    10048.1585         1.5429
     -.1093        0.0000          .1654         .0181        9.1285       0.0000         0.0000   401218.5828     43952.5266
     0.0000    50407.1155         0.000         1. 469        0.0000       1.1578         0.0000   241263.1649         0.0000
     0.0000        0.0000         0.00          0.0000        0.0000

      .9550      547.7689     37887.9297      277.7253   401808.1845        .6243      3915.9088    10373.4425        -2.4977
     -.0822        0.0000          .1843         .0151       12.1697       0.0000         0.0000   401759.6851     33013.1667
     0.0000    76584.7651         0.0000        2.3319        0.0000       1.6806         0.0000  2[illegible]824.5155    0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000

      .4000      260.3333      4000.0000      204.7698   399601.4237        .6209      4006.2343    11177.6246        -3.5381
     -.0842        0.0000          .2486         .0209       11.8752       0.0000         0.0000   399486.2352     33640.2393
     0.0000   182711.9628         0.0000        5.4314        0.0000       3.8076         0.0000   244031.5763         0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000
APPROACH

      .2413      159.4264       370.0000       85.1191   399198.6152        .6202      4012.2160    11280.0000        -5.7229
     -.1387        9.5000          .5975         .1336        4.4715       0.0000         0.0000   399199.0731     89276.6164
     0.0000   202078.1569         0.0000        2.2635        0.0000       4.0555        20.0000   244434.3848         0.0000
     0.0000        0.0000         0.0000        0.0000        0.0000
END OF MISSION PROFILE
```

TABLE C5. - LISTING OF PLOT TAPE (TAPE11).

```
SUPERSONIC TRANSPORT, JP FUEL,  DESIGN POINT
  1   643644.00000    4812.29086      3.13341    292.00000       2.62000      32.35441       82.00000         .32600
        7849.31707   51491.52000      1.90479    122.27547      47.45099       2.82000      315.00000        5.76509
          27.32003       0.00000      0.00000   9662.89238     193.39812     159.42575     1642.70044        8.68017
           8.49227       1.37292   9390.12140      0.00000     472.32097    3266.80546      273.16443       31.24022
         130.40507      26.35908    188.00437  66681.14863  167566.49626    3484.66825   244441.27849    48232.49132
      292673.76981   73924.43878   3327.75233   4639.19914   49092.52859   24466.53956    13336.70715   168777.25576
       39802.83261       0.00000   1780.00000   4796.98230   46379.81491    8431.01925        0.00000     3134.58616
        5757.08996    4754.63057   2491.82292  25111.00000    8200.00000     187.45841    58067.60726   273224.67813
       16717.55206  289942.23619  48180.00000  12848.00000       0.00000  350970.23019        0.00000        0.00000
         -10.00000       0.00000      0.00000      0.00000     -10.00000     -10.00000      -10.00000      -10.00000
         -10.00000     -10.00000      0.00000      0.00000       0.00000       0.00000        0.50000        0.00000
           0.00000       0.00000      0.00000
SUPERSONIC TRANSPORT, JP FUEL, EFFECT OF T/W AT W/S=110 PSF FOR RANGE=4000 NM
  2   643414.49589    3999.54655      3.31663    292.00000       2.62000      30.02766      110.00000         .25000
        5849.22269   40213.40599      1.90418    105.53646      47.46396       2.82000      315.00000        5.76521
          27.31906       0.00000      0.00000  17484.77857     224.88769     180.39160         .18663        8.20316
           8.08639       1.38530   8859.42020      0.00000    1228.68030    2522.86159      248.08466       75.50167
         100.72781      22.76812    198.99769 126408.81893  126489.24472    2495.09880   262545.67290    48506.99506
      311192.66796   70738.64537   2474.92007   3457.07895   49072.02703   24457.81593    10576.53256   160776.11993
       30438.49070       0.00000   1780.00000   3815.91209   36034.40279    8428.01300        0.00000     2836.29074
        6241.50347    4627.89693   2491.20093  25111.00000    8200.00000     163.01644    58028.92152   254909.44427
       16284.38366  271193.82793  48190.00000  12848.00000       0.00000  332221.82793        0.00000        0.00000
         -10.00000       0.00000      0.00000      0.00000     -10.00000     -10.00000      -10.00000      -10.00000
         -10.00000     -10.00000      0.00000      0.00000       0.00000       0.00000        0.00000        0.00000
           0.00000       0.00000      0.00000
  2   645220.66847    3994.58155      3.12296    292.00000       2.62000      30.86555      110.00000         .30000
        5865.64244   48391.55013      1.90418    105.68449      47.46396       2.82000      315.00000        5.76521
          27.31926       0.00000      0.00000  13805.56744     224.82025     182.31330     3153.35732        8.11511
           8.02453       1.35952   8955.70184      0.00000     580.71023    3171.92131      241.95001       38.53340
         126.64217      22.20183    187.37748  78338.12213  166876.47001    2947.03929   255101.41432    49591.11215
      304692.52647   70016.22666   2482.23974   3466.78356   49154.63274   24526.47313    12582.21989   162228.57572
       37209.65789       0.00000   1780.00000   3824.11067   42813.76656    9451.67185        0.00000     2838.99530
        6242.56290    4633.31929   2496.09413  25111.00000    8200.00000     163.23365    58136.97711   263179.22139
       16320.92060  279500.14199  48180.00000  12848.00000       0.00000  340528.14199        0.00000        0.00000
         -10.00000       0.00000      0.00000      0.00000     -10.00000     -10.00000      -10.00000      -10.00000
         -10.00000     -10.00000      0.00000      0.00000       0.00000       0.00000        0.00000        0.00000
           0.00000       0.00000      0.00000
  2   671585.39432    3998.96557      3.05117    292.00000       2.62000      30.06473      110.00000         .35000
        6105.32  7   58763.72200      1.90418    107.92209      47.46396       2.82000      315.00000        5.76521
          27.3           0.00000      0.00000  11604.00656     222.24471     183.06196     5940.57212        8.09467
           8.0.          1.34936   9002.11689      0.00000     366.47220    3391.92947      240.56389       25.62761
         135.42         22.01649    183.07031  62507.16660  188597.63633    3548.30570   282183.91345    52431.70795
      314615.62141   72001.53590   2603.10757   3608.44175   50350.08855   25528.66319    15096.21133   169188.04830
       45937.17663       0.00000   1780.00000   3943.37481   51650.55344    8797.02038        0.00000     2877.91713
        6257.83747    4711.61556   2567.06011  25111.00000    8200.00000     166.36860    58688.81925   279537.42099
       16404.35192  295941.77292  48180.00000  12848.00000       0.00000  356969.77292        0.00000        0.00000
         -10.00000       0.00000      0.00000      0.00000     -10.00000     -10.00000      -10.00000      -10.00000
         -10.00000     -10.00000      0.00000      0.00000       0.00000       0.00000        0.00000        0.00000
           0.00000       0.00000      0.00000
  2   706442.54716    3997.77530      3.01023    292.00000       2.62000      28.82269      110.00000         .40000
        6422.20497   70644.25472      1.90418    110.58482      47.46396       2.82000      315.00000        5.76521
          27.31906       0.00000      0.00000   9954.52923     222.25780     183.56951     9012.35597        8.09949
           8.01312       1.34117   9065.34810      0.00000     238.26775    3490.81719      238.69036       19.41791
         139.37441      21.82128    180.61360  55792.11679  205446.33489    4237.87181   273400.62995    58089.05188
      329489.68183   74774.44439   2765.42100   3795.72993   51902.18028   26853.67192    17942.27592   178333.72343
       56695.64065       0.00000   1780.00000   4099.91795   61975.55860    9253.61025        0.00000     2927.85786
        6277.51199    4812.79778   2659.61616  25111.00000    8200.00000     170.41576     9412.80980   299422.09184
       16502.77349  315924.86533  48180.00000  12848.00000       0.00000  376952.86533        0.00000        0.00000
         -10.00000       0.00000      0.00000      0.00000     -10.00000      10.00000      -10.00000      -10.00000
         -10.00000     -10.00000      0.00000      0.00000       0.00000       0.00000        0.00000        0.00000
           0.00000       0.00000      0.00000
```

TABLE C6. - LISTING OF THUMBPRINT BASIS (TAPE14).

```
      SUPERSONIC TRANSPORT, JP FUEL
W/S OR REFA (PSF OR SQ FT)
    ?
      110.00000     100.00000       90.00000       80.00000       70.00000       60.00000       50.00000
T/W OR TPE  (-- OR LB)
    ?
        .25000        .30000         .35000         .46000         .45000         .50000         .5 000
 'RANGE, ENDURANCE, OR GROSS WEIGHT,   (NM, HOURS, OR LB)'
  643414.4959  637433.6152  639843.5563  655670.3222  715783.7569 -1000000.0000 -1000000.9000
  645220.6685  640572.8968  638853.9955  637625.4515  663367.6176  759303.1370 -1000000.0000
  671585.3943  664147.1246  657867.3202  654384.4591  677562.6980  751402.3310 -1000000.0000
  706442.5472  697562.1748  690580.3160  682331.6900  708055.7952  783209.9009  983088.2576
  754858.3810  740989.2492  728641.9886  717325.0543  752113.3642  833814.7925 1051520.6556
  816380.2266  796773.7007  777923.3079  764214.2675  806232.1905  904090.4880 1154385.3890
  889564.0138  864123.3578  838902.7715  830501.8905  876228.0906  992997.0100 1310932.5066
 'REFERENCE AREA, SQ. FT.'
    5849.2227    6374.9362    7109.3728    8195.8790   10225.5680   14603.8015   19859.9402
    5865.6424    6405.7290    7098.1555    7970.3181    9476.6803   12655.0523   14360.0000
    6105.3213    6641.4712    7198.9702    8179.8057    9679.4671   12523.3722   14360.0000
    6422.2050    6975.6217    7673.1146    8529.1461   10115.0828   13053.4983   19661.7652
    6862.3489    7409.8935    8096.0221    8966.5632   10744.4766   13896.9132   21030.4131
    7421.6384    7967.7370    8643.5923    9552.6783   11517.6027   15058.1748   23087.7078
    8086.9456    8641.2336    9321.1419   10381.2736   12517.5442   16549.9502   26218.6501
 'THRUST PER ENGINE, LB'
   40213.4060   39843.3510   39990.2223   40979.3951   44736.8598   54764.2557   62062.3131
   48391.5501   48042.9673   47912.5497   47821.9989   49752.5713   56947.7353   53850.0000
   58763.7220   58112.8734   57558.1405   57258.6402   59286.7361   65747.7040   62825.0000
   70644.2547   69756.2175   69058.0316   68230.1690   70805.5795   78320.9900   98308.8258
   84921.5679   83361.2905   81972.2237   80699.0686   84612.7535   93804.1642  118296.0738
  102047.5283   99596.7126   97240.4135   95526.7834  100779.0238  113011.3110  144298.1736
  122315.0519  118816.9617  115349.1311  114194.0099  120481.3625  136537.0889  180253.2197
 'SEAT MILES/GAL'
      30.0277      30.7758      30.9315      30.0934      26.9797 -1000000.0000 -1000000.0000
      30.8656      31.5753      32.0567      32.3925      31.3078      27.2180 -1000000.0000
      30.0647      30.8671      31.6212      32.1408      31.4126      28.6564 -1000000.0000
      28.8227      29.6251      30.3419      31.0952      30.4778      27.9886      22.5933
      27.0298      28.0092      28.9216      29.7335      28.8885      26.5842      21.4604
      24.9919      26.0218      27.0951      28.0184      27.1045      24.7009      19.7848
      22.8998      23.9531      25.0706      25.8132      25.0429      22.6196      17.5579
 'TO FIELD LENGTH, FT'
   17484.7786   15850.5807   14231.3244   12802.3295   11333.5066 -1000000.0000 -1000000.0000
   13806.5674   12758.0499   11487.2475   10252.5248    8995.3973    7726.7754 -1000000.0000
   11604.0066   10589.3528    9568.8321    8535.7522    7530.6552    6502.6119 -1000000.0000
    9954.5292     910 6986    8230.1239    7444.6945    6578.2774    5675.2538    4852.8945
    8739.8917    8066.9779    7295.4383    6540.3097    5798.9747    5067.4837    4268.6066
    7866.7063    7159.9556    6537.0686    5873.9839    5206.8213    4519.9942    3960.9272
    7156.0025    6544.5402    5976.2653    5364.3391    4771.5135    4144.9563    3541.2472
 'CLIMB THRUST MARGIN'
        .0711        .0187        .0029        .0028        .0028 -1000000.0000 -1000000.0000
        .1697        .1855        .1350        .0492        .0030        .0031 -1000000.0000
        .3190        .3433        .2742        .2156        .1125        .0142 -1000000.0000
        .4834        .5149        .4519        .3354        .2214        .1827        .0301
        .6569        .6526        .6060        .5044        .3824        .2633        .1712
        .8364        .8320        .6952        .5955        .5505        .4151        .2459
       1.0196       1.0150        .8633        .7323        .6277        .5820        .3863
```

TABLE C6. - CONCLUDED.

```
'CRUISE THRUST MARGIN'
       .0000        .0005        .0005        .0000        .0004 -1000000.0000 -1000000.0000
       .1697        .1737        .0980        .0004        .0003         .0002 -1000000.0000
       .3190        .3206        .2213        .1730        .0589         .0000 -1000000.0000
       .48[illegible]1        .5119        .3961        .2708        .2122         .0930         .0007
       .6[illegible]        .58[illegible]        .5782        .4375        .3140         .2144         .1009
       .8364        .7484        .6169        .5923        .4698         .3306         .2148
      1.0196        .9197        .7742        .3380        .5941         .4734         .3039
'CRUISE RATE OF CLIMB, FT/MIN'
       .1866       8.5936       8.4084        .8507       7.2726 -1000000.9000 -1000000.0000
   3153.3573    3239.7407    1790.1575       7.2261       4.6958        2.7310 -1000000.0000
   5940.5721    5935.3481    4042.6202    3104.3392    1026.2214         .8156 -1000000.0000
   9012.3560    9376.9040    7235.6451    4846.3222    3697.3749     1559.7558       11.5479
  12226.8392   11085.5901   10558.9534    7831.1389    5452.2283     3585.1910     1610.7390
  15518.1919   13894.7588   11250.6495   10579.9298    8130.5818     5504.2684     3388.8934
  18849.4168   17017.7476   14082.1006   11356.2160   10081.3150     7851.9739     4802.3234
'V,LIFTOFF, K'
    224.8877     214.6560     203.9129     191.2472     178.0275 -1000000.0000 -1000000.0000
    224.8203     212.0506     201.3639     190.0438     178.0015      165.1211 -1000000.0000
    222.2447     2 2.1079     201.4036     190.1148     178.1205      165.2176 -1000000.0000
    222.2579     212.1248     201.4633     188.1090     175.9408      163.0897      149.1326
    222.1935     209.7313     199.1129     187.8778     175.9801      163.1811      149.2435
    219.7933     209.7051     199.1299     187.9404     176.0172      163.2704      149.3525
    217.9824     207.8243     197.1442     175.8524     173.9780      161.2835      147.4597
'V,APPROACH, K'
    180.3916     172.8891     164.4927     154.8730     143.8533 -1000000.9000 -1000000.0000
    182.3134     174.6259     166.2759     157.2411     147.3134      136.2308 -1000000.0000
    183.0620     175.3873     167.1346     158.0943     148.4039      137.6804 -1000000.0000
    183.5695     175.8456     167.4974     158.5171     149.0142      138.5930      126.9620
    183.7178     176.0695     167.8068     158.7698     149.3412      139.9327      127.5059
    183.6568     176.0576     167.8[illegible]47     158.9880     149.5980      139.2322      127.9146
    183.5670     175.9596     167. 507     158.9880     149.7138      139.5024      128.1878
'FUEL FRACTIONS'
       .4837        .4767        .4726        .4737        .4818 -1000000.0000 -1000000.0000
       .4722        .4659        .4606        .4561        .4537         .4548 -1000000.0000
       .4685        .4616        .4551        .4504        .4450         .4401 -1000000.0000
       .4664        .4596        .4536        .4480        .4487         .4341         .4292
       .4667        .4593        .4525        .4170        .4389         .4309         .4240
       .4684        .4606        .4533        .4464        .4377         .4294         .4206
       .4703        .4626        .4552         4475        .4377         .4281         .4186
'EXCESS FUEL, LB
 -95891.8684  -58984.8264  -13945.6446   46557.2546  153463.2541 -1000000.0000 -1000000.0000
 -88486.5543  -51733.6994   -6457.1898   51699.2086  143457.6571   341951.7648 -1000000.0000
 -85049.0329  -46133.8923    1292.8409   61407.9313  157261.2974   345864.0275 -1000000.0000
 -81840.6135  -40273.6219   10260.8393   73582.5041  178202.8715   380235.7410   914974.2718
 -78792.3170  -33414.0436   20912.5253   88253.5385  206861.9113   432293.5521  1034082.3433
 -74717.2451  -24688.9596   34312.3736  108671.6620  243347.87 7   506244.2574  1218514.9202
 -68322.8673  -12946.4670   51608.2343  138192.2579  292579.2764   605464.8877  1516309  839
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16. Abstract

The basic processes of a program that performs sizing operations on a baseline aircraft and determines their subsequent effects on aerodynamics, propulsion, weights, and mission performance are described. Input requirements are defined and output listings explained. Results obtained by applying the method to several types of aircraft are discussed.

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