HANDBOOK

FOR

WEIGHT ESTIMATING AND FORECASTING

OF

MANNED SPACE SYSTEMS DURING CONCEPTUAL DESIGN

Volume II

November 1970

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Prepared For

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FOREWORD

This document is submitted in accordance with the reporting requirements of Contract NAS 9-10326 issued by the National Aeronautics and Space Administration Manned Spacecraft Center.

The handbook for Weight Estimating and Forecasting of Manned Space Systems during Conceptual Design consists of Volumes I and II.

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INTRODUCTION

Volume I of the Handbook for Weight Estimating and Forecasting of Manned Space Systems during Conceptual Design contains two manual methods of preliminary weight estimation, plus weight growth data and two methods for forecasting weight growth. The two weight estimation methods in Volume I are recommended for rapid use only during the earliest phases of design when mission knowledge and design parameters are at a minimum.

Volume II contains a detailed point design method of preliminary weight estimation, to be used by either manual or computer means. This method enables greater in-depth weight assessments of designs when the necessary mission knowledge and design parameters are available. Volume II also contains the description of an associated or independent (user's option) space transportation system sizing program which has the capability of altering a point design configuration, as necessary, to assure vehicle weight, size and performance compatibility.

SECTION 1. POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD

The Point Design Detailed Weight Estimation Method is devised for either manual or computer solution. However, because of the large number of inputs required, a manual solution is recommended only for portions of a vehicle; to estimate the weight of a total vehicle, solution by computer is a much more practical approach. When operating by computer, the point design weight estimation program may be connected optionally in series with the sizing program for space transporation systems (refer to Section 2). The computer utilization is explained in the Computer Program Manual, MSC-01260.

To use the Point Design Detailed Weight Estimation Method, the following general types of design information should be available:

Internal and external vehicle structural arrangement drawings.

Types of aerodynamic control surfaces.

Wing variable sweep arrangement.

Body internal pressures.

Landing gear arrangement.

Engine types, locations and thrust ratings.

Containers for the various liquids and gases - sizes shapes, and pressures.

Types and properties of the various liquids and gases, especially propellant.

Input or output power requirements of electro-mechanical equipment.

Crew quantity.

Weight of cargo and passengers.

Mission duration or resupply time interval.

Maximum velocity of vehicle.

Design load factors.

Structural material types, properties and minimum gage requirements.

Weight contingency and/or growth philosophy.

Special features which are beyond the estimation capability of the method.

Five lists containing all the inputs which are accepted by the method are presented at the rear of this section (Tables I thru V). All five lists are used for the solution of vehicle total weight. The lists are divided into groups, a group for each vehicle subsystem. Individual subsystem weights may be estimated by referring to the appropriate list group.

The point design method is not structured to be automatically iterative, but iterations may be performed by using certain estimated values in lieu of either assigned or earlier estimated values. For example, to solve for a first weight estimate the vehicle liftoff weight (GWST) and reentry weight (GWRE) must have assigned values. The first weight estimate produces an estimated liftoff weight (EGWTO) and reentry weight (EGWRE). If GWST $\neq$ EGWTO, and GWRE $\neq$ EGWRE, a second weight estimate may be made after replacing the originally assigned values of GWST and GWRE with the first estimated values of EGWTO and EGWRE. This procedure may be repeated until the vehicle weight inputs match the vehicle weight outputs. There is one very important consideration regarding this iterative procedure, however, and this is: when any estimated output differs by more than $\pm$ 10% with its counterpart assigned input, the validity of the vehicle configuration must be considered questionable. Estimated values of wing loading, thrust/weight, and propellant weight/vehicle weight may not be compatible with the point design, suggesting that a re-configuration of the vehicle may be in order.

The point design computer program provides for the weight estimation of two large integral body propellant tanks (refer to Group 2) or eight large non-integral propellant tanks (refer to Group 5). The use of identical tanks increases this quantity capability accordingly. For conventional large tank designs, the program computes design pressures, considering the gas pressures, accelerated propellant head pressures and hydrostatic test conditions. Occasionally, an unconventional arrangement of tanks may exist which the program cannot handle, therefore the program will accept design pressures as inputs and allow by-passing of its conventional tank design pressure computations. The quantity of small pressure tanks (refer to Group 5A) that may be weight estimated is practically unlimited.

The following are some general comments on the use of the computer program:

1. It is unnecessary to enter zero values of any inputs. When an input is not entered, its value is assumed to be zero.

2. To change the value of an input for a subsequent run, simply enter the new value at the end of the proper list. The last input supercedes any previous inputs for any particular variable.

3. A mis-lettered input will not stop the program from running, so input accuracy is essential for valid results.

4. A few inputs are called for which are not necessary for program functioning (e.g., max. allowable thrust load factor; body wetted area or volume factors). They are called for to be recorded with other essential data, because they are required to generate required input values.

5. A variety of non-weight information, which is computed within the program, but which would be lost otherwise, is printed out (e.g., propellant tank design pressures, areas and volumes).

6. The printout values of all computed weights are truncated to the right of the decimal point. This will explain the occasional difference between a printed total value and the apparent sum of the parts comprising the total.

7. The correlation weight factors used in the point design equation forms, and which are inputs for the computer program, are normalized to unity in the majority of cases. This allows the user the flexibility of simply changing the recommended input value to whatever value he may select.

This section is divided into the major weight groups comprising a total vehicle, from Wing through Thrust Buildup Propellant. For each major weight group, weight estimation equations are presented, followed by a list of pertinent definitions. Preceding the major weight groups is a summary of the gross weight conditions for a vehicle or module

VEHICLE OR MODULE GROSS WEIGHT CONDITIONS

0.0 Takeoff

EGWTØ = WAS + WB + WIEP + WLAR + WTMP + WØC + WTPP + WPCD + WGAN + WINST + WCØMM + WECS + WPERP + WCSCP + WPERS + WPL + WBLLST + WRPASI + WRESP + WINLØS + WTDP + WFTP + WTBUP.

0.1 Burnout

EGWBØ = EGWTØ - WTDP - WFTP - WTBUP + WFTFAP.

0.2 Dry

EGWDRY = EGWBØ - WRPASI - WRESP - WINLØS - WFTFAP.

0.3 Reentry

EGWRE = EGWBØ - WCAR + WCARRE - (CLPRE)WINLØS.

0.4 Landing

EGWLAN = EGWRE - WFTFAP - (1. - CLPRE)WINLØS.

0.5 Empty

EGWEMP = EGWDRY - WPL - WPERS.

DEFINITIONS FOR VEHICLE OR MODULE GROSS WEIGHT CONDITIONS

Variable	Definition	Units
* CLPRE	Proportion of inflight losses consumed prior to reentry	
EGWBØ	Estimated burn out gross weight	LB
EGWDRY	Estimated dry gross weight	LB
EGWEMP	Estimated empty gross weight	LB
EGWLAN	Estimated gross weight at landing	LB
EGWRE	Estimated gross weight at reentry	LB
EGWTØ	Estimated take off gross weight	LB
WAS	Weight of aerodynamic surfaces	LB
WB	Body weight per vehicle	LB
WBLLST	Weight of ballast	LB
WCAR	Weight of cargo, cargo containers, and passengers plus accommodations	LB
* WCARRE	Weight of cargo and passengers during return trip	LB
WCØMM	Weight of communication	LB
WCSCP	Weight of crew station controls and panels	LB
WECS	Weight of environmental control system	LB
WFTFAP	Weight of full thrust fuel for auxiliary propulsion	LB
WFTP	Weight of full thrust propellant	LB
WGAN	Weight of guidance and navigation	LB
WIEP	Weight of induced environment protection	LB
WINLØS	Weight of inflight losses	LB
WINST	Weight of instrumentation	LB
WLAR	Weight of launch, recovery, and docking	LB
WØC	Weight of orientation controls, separation, and ullage	LB
WPCD	Weight of power conversion and distribution	LB
WPERP	Weight of personnel provisions	LB
WPERS	Weight of personnel	LB
WPL	Weight of cargo	LB
WRESP	Weight of reserve propellant and service items	LB
WRPASI	Weight of residual propellant and service items	LB
WTBUP	Weight of thrust buildup propellant	LB
WTDP	Weight of thrust decay propellant	LB

Variable	Definition	Units
WTMP	Weight of main propulsion system	LB
WTPP	Weight of prime power source	LB
	Total contingency weight in vehicle (WCØNT) = sum of contingency weights of groups 1.0 through 22.0	LB
	Total growth weight in vehicle (WGRØW) = sum of growth weights of groups 1.0 through 22.0	LB

* Input

Aerodynamic surfaces weight consists of the weights of wing, horizontal tail (including body elevons) and vertical tail. Weight equations for each of these three major subsystems are presented under 1.1, 1.2 and 1.3, which immediately follow 1.0.

The weight of aerodynamic surfaces is defined as:

1.0 WAS = WWT + WHT + WVT.

WING

The following wing weight equations apply for any practical planform shapes, thickness ratios, and sweepback and dihedral angles. They apply primarily to the conventional cantilevered monowing on a single vehicle body (wing type 1). However, one vehicle sample (STSB-BM is configured with two bodies joined fore and aft by two wings (types 2 and 3), with only the aft wing cantilevered outboard of the two bodies. Equations are included which apply to this unusual design, where the two wings are assumed to share the total vehicle load in proportion to their relative proximities to the vehicle CG.

Structural material properties are considered.

A planform lift distribution is assumed, with the lift per unit of wing area across the body(s) being assumed as one-half the lift per unit of exposed wing area. No relief from the weight of the wing or its contents is assumed.

The derivation of the bending material equation for the cantilevered portion of a wing requires adherence to the reasonable assumption that the wing thickness at the side of the body is greater than the wing thickness at the tip.

The equations account for additional weight incurred by the presence of wing tip fins and variable wing sweep designs.

The wing primary structure weight non-optimum factor is the average quotient of actual or reported weight divided by theoretical weight for 19 vehicle samples. The non-optimum factor is inversely affected by the magnitude of the theoretical primary structure weight per unit of primary structure planform area. This effect is incorporated into the weight equations.

The total wing weight is defined as:

1.1 WWT = WW1 + WW2 + WW3, where

WWi = WPSWi + WSSWi + WVSPi + WTFPi + WLGPWi + WFTPWi + WAEPWi + WCSWi + WSPWi + WCØNWi + WGRØWi, where

i = 1, or 2 and 3, representing wing type. Type 2 and 3 are designating double wing configuration.

1.1.1 Primary Structure

WPSWi = WBMWi + WSMWi + WRWi.

1.1.1.1 Bending Material (spanwise)

WBMWi = BMPWi(ZNØFWi), where

$$\mathrm{BMPW1} = \frac{\mathrm{WSRW(U1)}}{48}\left[\frac{8(\mathrm{BW1-BBW1})^3}{(\cos^2\mathrm{SAW1})(\cos^2\mathrm{DAW1})(\mathrm{TSW1-TTEW1})^4}\cdot\right.$$
$$\Big\{2(\mathrm{CSW1-CTEW1})(\mathrm{TSW1-TTEW1})^3 + 3\Big[3\mathrm{CTEW1}(\mathrm{TSW1-TTEW1}) -$$
$$\mathrm{TTEW1}(\mathrm{CSW1-CTEW1})\Big]\Big[\mathrm{TSW1}(\mathrm{TSW1-4TTEW1}) +$$
$$(\mathrm{TTEW1})^2\left(2\log_e\frac{\mathrm{TSW1}}{\mathrm{TTEW1}} + 3\right)\Big]\Big\} + \frac{6(\mathrm{BBW1})\mathrm{CCTW1}}{\mathrm{TSW1}}\cdot$$
$$\Big\{8(\mathrm{BW1-BBW1})^2(\mathrm{CSW1+2CTEW1}) + 12(\mathrm{BW1-BBW1})\cdot$$
$$(\mathrm{CSW1+CTEW1})\mathrm{BBW1} + (\mathrm{BBW1})^2\Big(\mathrm{CRW1+3CSW1} -$$
$$\left.\frac{4(\mathrm{SW1+SEW1})}{\mathrm{BBW1}}\Big)\Big\}\right], \text{ where}$$

$$\mathrm{WSRW} = \mathrm{DENSWM/UTSWM},$$

$$\mathrm{U1} = 2(\mathrm{ZNAF})\mathrm{GWRE}/(\mathrm{SW1+SEW1}), \text{ and } \mathrm{TSW1} > \mathrm{TTEW1}.$$

$$\mathrm{ZN\emptyset FWi} = \mathrm{CN\emptyset FWi}\ (3.08)\left\{\left[\frac{\mathrm{SEWi}}{\cos\ \mathrm{DAWi}} + \mathrm{CCTWi}(\mathrm{SWi-SEWi})\right]\cdot\right.$$

$$\left\{\mathrm{SEWi-SSSWi-SAILi-SELWi-\tfrac{1}{2}STEFi-SLEFi-\tfrac{1}{2}SSBi}\right\}^{1/3} \div \left\{\mathrm{SEWi}\left[\mathrm{BMPWi+CWTFi\,(TFPPi)}\right]\right\}^{1/3}.$$

$$\begin{aligned}
\mathrm{BMPW2} = {} & \frac{4\ \mathrm{WSRW\,(U2)}}{\mathrm{TSW2}}\left\{\frac{(\mathrm{BW2-2BBW2})^3\,(\mathrm{CSW2})}{2} + \mathrm{CCTW2}\left[\left(\frac{\mathrm{SW2+SEW2}}{\mathrm{2BBW2}} - \right.\right.\right. \\
& \left.\left.\mathrm{CSW2})\,(\mathrm{BBW2})^3\right] + 1.5\ \left(\frac{\mathrm{SW2+SEW2}}{\mathrm{2BBW2}} - \mathrm{CSW2}\right)(\mathrm{BW2-2BBW2})\bullet \\
& \left.(\mathrm{BBW2})^2\right\}, \text{ where}
\end{aligned}$$

$$\mathrm{U2} = 2\,(\mathrm{ZNAF})\,\mathrm{GWRE\,(CGTW3)}/\left[(\mathrm{SW2+SEW2})\,(\mathrm{CGTW2+CGTW3})\right].$$

$$\begin{aligned}
\mathrm{BMPW3} = {} & \mathrm{WSRW\,(U3)}\left\{\frac{(\mathrm{BW3-2BBW3-BCW3})^3}{6\,(\cos^2\mathrm{SAW3})\,(\cos^2\mathrm{DAW3})\,(\mathrm{TSW3-TTEW3})^4}\bullet\right. \\
& \left[2\,(\mathrm{CSW3-CTEW3})\,(\mathrm{TSW3-TTEW3})^3 + 3\left\{3\mathrm{CTEW3\,(TSW3-TTEW3)} - \right.\right. \\
& \left.\mathrm{TTEW3\,(CSW3-CTEW3)}\right\}\left\{\mathrm{TSW3\,(TSW3-4TTEW3)} + \right. \\
& \left.\left.(\mathrm{TTEW3})^2\left(2\ \log_e \frac{\mathrm{TSW3}}{\mathrm{TTEW3}} + 3\right)\right\}\right] + \frac{2\,(\mathrm{CCTW3})\,\mathrm{BBW3}}{\mathrm{TSW3}}\bullet \\
& \left\{(\mathrm{BW3-2BBW3-BCW3})^2\,(\mathrm{CSW3+2CTEW3}) + 2\,(\mathrm{BBW3})^2\,\left(\mathrm{CSW3} - \right.\right. \\
& \left.\left.\frac{\mathrm{SW3+SEW3}}{\mathrm{2BBW3}}\right) + 3\,(\mathrm{BW3-2BBW3-BCW3})\,(\mathrm{CSW3+CTEW3})\,\mathrm{BBW3}\right\} + \\
& \frac{\mathrm{BCW3}}{\mathrm{TSW3}}\left[(\mathrm{BW3-2BBW3-BCW3})^2\ \bullet\ (\mathrm{CSW3+2CTEW3}) + \right. \\
& 6\,(\mathrm{BW3-2BBW3-BCW3})\,(\mathrm{CSW3+CTEW3})\,\mathrm{BBW3} + 6\mathrm{BCW3}\left[\tfrac{1}{4}(\mathrm{BW3} - \right. \\
& \left.\mathrm{2BBW3-BCW3})\,(\mathrm{CSW3+CTEW3}) + \tfrac{1}{2}\mathrm{BBW3}\left(\mathrm{CSW3} - \frac{\mathrm{SW3+SEW3}}{\mathrm{2BBW3}}\right)\right] + \\
& \left.\left.6\,(\mathrm{BBW3})^2\,\left(\mathrm{CSW3} - \frac{\mathrm{SW3+SEW3}}{\mathrm{2BBW3}}\right) + (\mathrm{BCW3})^2\,\mathrm{CSW3}\right]\right\}, \text{ where}
\end{aligned}$$

$$\mathrm{U3} = 2\,(\mathrm{ZNAF})\,\mathrm{GWRE\,(CGTW2)}/\left[(\mathrm{SW3+SEW3})\,(\mathrm{CGTW2+CGTW3})\right], \text{ and}$$

$$\mathrm{TSW3} > \mathrm{TTEW3}.$$

1.1.1.2 Shear Material (spanwise)

$$\mathrm{WSMWi} = \mathrm{SMPWi\,(ZN\text{Ø}FWi)}, \text{ where}$$

$$\begin{aligned}
\mathrm{SMPW1} = {} & \mathrm{WSRW\,(U1)}\left\{\frac{(\mathrm{BW1-BBW1})^2\,(\mathrm{CSW1+2CTEW1})}{(\cos\ \mathrm{SAW1})\,(\cos\ \mathrm{DAW1})} + \tfrac{1}{2}(\mathrm{BBW1})\,\mathrm{CCTW1}\ \bullet\right. \\
& \left.\left[6\,(\mathrm{BW1-BBW1})\,(\mathrm{CSW1+CTEW1}) + \mathrm{BBW1}\left\{(\mathrm{CRW1+2CSW1}) - \frac{3\,(\mathrm{SW1+SEW1})}{\mathrm{BBW1}}\right\}\right]\right\}.
\end{aligned}$$

$$\mathrm{SMPW2} = 3\ \mathrm{WSRW\,(U2)}\left[(\mathrm{BW2-2BBW2})^2\,\mathrm{CSW2+2CCTW2\,(BBW2)}^2\left(\frac{\mathrm{SW2+SEW2}}{\mathrm{2BBW2}} - \mathrm{CSW2}\right)\right].$$

$$SMPW3 = \frac{WSRW(U3)}{8}\left\{\frac{8(BW3-2BBW3-BCW3)^2(CSW3+2CTEW3)}{(\cos SAW3)(\cos DAW3)} + \right.$$

$$12\ CCTW3\ \frac{\left[(BW3-2BBW3-BCW3)(CSW3+CTEW3)\right]^2}{\frac{SEW3+SW3}{2BBW3} - CSW3} +$$

$$48\ CCTW3\left[BBW3 - \frac{(BW3-2BBW3-BCW3)(CSW3+CTEW3)}{2(\frac{SEW3+SW3}{2BBW3} - CSW3)}\right]^2 \cdot$$

$$\left.(\frac{SEW3+SW3}{2BBW3} - CSW3) + 24(BCW3)^2 CSW3\right\}.$$

1.1.1.3 Ribs (between spars)

$$WRWi = CRIBWi(0.06)(WBMWi+WSMWi).$$

1.1.2 Secondary Structure (fixed leading and trailing edges)

$$WSSWi = CSSWi(0.051)\ \frac{SSSWi(Ui)}{\cos DAWi(ZNAF)}\ .$$

1.1.3 Provision for Variable Sweep (wing type 1 only)

$$WVSP = \frac{CVSP(2.27)WSRW(U1)}{\cos SAW1}\ (BW1-BSHW)^2\left[3CTEW1 + (CSW1 - CTEW1)\ \frac{BW1-BSHW}{BW1-BBW1}\right]\frac{CSHW}{TSHW}\ .$$

1.1.4 Provision for Tip Fins (wing types 1 and 3 only)

$$WTFPi = TFPPi(ZN\emptyset FWi)CWTFi, \text{ where}$$

$$TFPPi = \frac{WSRW(Ui)(BWi-BFWi)^2(1-CTFi)}{6(\cos SAWi)(\cos DAWi)\cos(DAWTi-DAWi)} \cdot$$

$$\left[\frac{\left[1-\cos^2(DAWTi-DAWi)\right](BWi-BFWi)}{(\cos SAWi)(\cos DAWi)\cos(DAWTi-DAWi)(TFWi-TTEWi)^4} \cdot\right.$$

$$\left\{2(CFWi-CTEWi)(TFWi-TTEWi)^3 + 3\left[3CTEWi(TFWi-TTEWi) - \right.\right.$$

$$\left.TTEWi(CFWi-CTEWi)\right]\left[TFWi(TFWi-4TTEWi) + (TTEWi)^2 \cdot\right.$$

$$\left.\left.(2\ \log_e \frac{TFWi}{TTEWi} + 3)\right]\right\} + 12\left[1-\cos(DAWTi-DAWi)\right] \cdot$$

$$CFWi + 2CTEWi\left\{\frac{BFWi-ZNB(BBWi) - BCW3}{(\cos SAWi)(\cos DAWi)(TSWi+TFWi)} + \right.$$

$$\left.\left.CCTWi\ \frac{ZNB(BBWi)}{2TSWi} + \frac{BCW3}{2TSWi}\right\}\right] +$$

$$\frac{44(CTFi)WSRW(BVT)^2(CRVT+2CTVT)HB(ZLVEH)^2}{(\cos SAVT)\cos(90-DAVT)SVT(ZLVT)}\ \bullet$$

$$\left[\frac{BWi-ZNB(BBWi) - BCW3}{(\cos SAWi)(\cos DAWi)(TSWi+TTEWi)} + \frac{BCW3}{2TSWi} + \frac{CCIWi(ZNB)BBWi}{2TSWi}\right].$$

1.1.5 Provision for Main Landing Gear on the Wing (wing type 1 only)

$$WLGPW1 = CLGP(0.0015)ZNLD(GWLAND).$$

1.1.6 Provision for Bladder Fuel Tanks in the Wing

$$WFTPWi = \frac{0.5(VBFT)}{TSWi} CFTPWi, \text{ where}$$

$$VBFT = \sum_{K=1}^{K=5} ZNSST(K)\left[VNSST(K)\right].$$

1.1.7 Provision for Air Breathing Engines in or on the Wing

$$WAEPWi = CABEWi(0.0025)ZNAEWi(TABE).$$

1.1.8 Control Surfaces

$$WCSWi = WAILi + WELWi + WSPi + WTEFi + WLEFi + WLESi + WSBi.$$

1.1.8.1 Ailerons

$$WAILi = CAILi(0.055)\frac{SAILi(Ui)}{(\cos DAWi)ZNAF}.$$

1.1.8.2 Elevons

$$WELWi = CELWi(0.055)\frac{SELWi(Ui)}{(\cos DAWi)ZNAF}.$$

1.1.8.3 Spoilers

$$WSPi = CSPi(0.055)\frac{SSPi(Ui)}{(\cos DAWi)ZNAF}.$$

1.1.8.4 Trailing Edge Flaps

$$WTEFi = CTEFi(0.047)\frac{STEFi(Ui)}{(\cos DAWi)ZNAF}.$$

1.1.8.5 Leading Edge Flaps

$$WLEFi = CLEFi(0.055)\frac{SLEFi(Ui)}{(\cos DAWi)ZNAF}.$$

1.1.8.6 Leading Edge Slats

$$WLESi = CLESi(0.055)\ \frac{SLESi(Ui)}{(\cos DAWi)ZNAF} \ .$$

1.1.8.7 Speed Brakes

$$WSBi = CSBi(0.070)\ \frac{SSBi(Ui)}{(\cos DAWi)ZNAF} \ .$$

1.1.18 Special Features

WSPWi = WSPWi.

1.1.19 Contingency

WCØNWi = CCØNWi(WTBWi), where

WTBWi is the sum of all the items preceding 1.1.19.

1.1.20 Growth

WGRØWi = CGRØWi(WCØNWi + WTBWi).

AERODYNAMIC SURFACES AND WING DEFINITIONS

Variable	Definition	Units
* BBW1	Maximum body width at wing intersection, wing type 1	FT
* BBW2	Maximum body width at wing intersection, wing type 2	FT
* BBW3	Maximum body width at wing intersection, wing type 3	FT
* BCW3	Exposed horizontal planform span between bodies, wing type 3	FT
* BFW1	Horizontal planform wing span between bases of upswept wing tips, wing type 1	FT
* BFW3	Horizontal planform wing span between bases of upswept wing tips, wing type 3	FT
BMPW1	Bending material weight parameter, wing type 1	
BMPW2	Bending material weight parameter, wing type 2	
BMPW3	Bending material weight parameter, wing type 3	
* BSHW	Horizontal planform wing span between hinges of variable - sweep wing	FT
* BVT	Vertical planform span of the vertical tail	FT
* BW1	Horizontal planform wing span, wing type 1	FT

Variable	Definition	Units
* BW2	Horizontal planform wing span, wing type 2	FT
* BW3	Horizontal planform wing span, wing type 3	FT
* CABEW1	Weight factor for engines in or on wing, wing type 1	
* CABEW2	Weight factor for engines in or on wing, wing type 2	
* CABEW3	Weight factor for engines in or on wing, wing type 3	
* CAIL1	Weight factor for ailerons, wing type 1	
* CAIL2	Weight factor for ailerons, wing type 2	
* CAIL3	Weight factor for ailerons, wing type 3	
* CCØNW1	Weight factor for contingency, wing type 1	
* CCØNW2	Weight factor for contingency, wing type 2	
* CCØNW3	Weight factor for contingency, wing type 3	
* CCTW1	Weight factor for wing carry-through structure, wing type 1	
* CCTW2	Weight factor for wing carry-through structure, wing type 2	
* CCTW3	Weight factor for wing carry- through structure, wing type 3	
* CELW1	Weight factor for elevons, wing type 1	
* CELW2	Weight factor for elevons, wing type 2	
* CELW3	Weight factor for elevons, wing type 3	
* CFTPW1	Weight factor for fuel tanks in wing, wing type 1	
* CFTPW2	Weight factor for fuel tanks in wing, wing type 2	
* CFTPW3	Weight factor for fuel tanks in wing, wing type 3	
* CFW1	Length of wing chord at base of upswept wing tip, wing type 1	FT
* CFW3	Length of wing chord at base of upswept wing tip, wing type 3	FT
* CGRØW1	Weight factor for growth for wing, wing type 1	
* CGRØW2	Weight factor for growth for wing, wing type 2	
* CGRØW3	Weight factor for growth for wing, wing type 3	
* CGTW2	Longitudinal distance between vehicle C.G. and quarter-chord of wing MAC, wing type 2	FT
* CGTW3	Longitudinal distance between vehicle C.G. and quarter-chord of wing MAC, wing type 3	FT
* CLEF1	Weight factor for wing leading edge flaps, wing type 1	
* CLEF2	Weight factor for wing leading edge flaps, wing type 2	
* CLEF3	Weight factor for wing leading edge flaps, wing type 3	

Variable	Definition	Units
* CLES1	Weight factor for wing leading edge slats, wing type 1	
* CLES2	Weight factor for wing leading edge slats, wing type 2	
* CLES3	Weight factor for wing leading edge slats, wing type 3	
* CLGP	Provision weight factor for landing gear on wing	
* CNØFW1	Weight factor for wing primary structure, wing type 1	
* CNØFW2	Weight factor for wing primary structure, wing type 2	
* CNØFW3	Weight factor for wing primary structure, wing type 3	
* CRIBW1	Weight factor for wing ribs, wing type 1	
* CRIBW2	Weight factor for wing ribs, wing type 2	
* CRIBW3	Weight factor for wing ribs, wing type 3	
* CRVT	Vertical tail chord length at wing or body intersection	FT
* CRW1	Theoretical wing root chord length, wing type 1	FT
* CRW2	Theoretical wing root chord length, wing type 2	FT
* CRW3	Theoretical wing root chord length, wing type 3	FT
* CSB1	Weight factor for speed brakes, wing type 1	
* CSB2	Weight factor for speed brakes, wing type 2	
* CSB3	Weight factor for speed brakes, wing type 3	
* CSHW	Length of wing chord at hinge of variable-sweep wing	FT
* CSP1	Weight factor for spoilers, wing type 1	
* CSP2	Weight factor for spoilers, wing type 2	
* CSP3	Weight factor for spoilers, wing type 3	
* CSSW1	Weight factor for wing secondary structure, wing type 1	
* CSSW2	Weight factor for wing secondary structure, wing type 2	
* CSSW3	Weight factor for wing secondary structure, wing type 3	
* CSW1	Length of wing chord at side of body, wing type 1	FT
* CSW2	Length of wing chord at side of body, wing type 2	FT
* CSW3	Length of wing chord at side of body, wing type 3	FT
* CTEF1	Weight factor for trailing edge flaps, wing type 1	
* CTEF2	Weight factor for trailing edge flaps, wing type 2	
* CTEF3	Weight factor for trailing edge flaps, wing type 3	
* CTEW1	Length of equivalent wing tip chord, wing type 1 = 2. (SEW1)/(BW1 - BBW1) - CSW1	FT

Variable	Definition	Units
* CTEW2	Length of equivalent wing tip chord, wing type 2 = CSW2	FT
* CTEW3	Length of equivalent wing tip chord, wing type 3 = {2. (SØW3)/[BW3 - 2. (BBW3) - BCW3]} - CSW3, where SØW3 = Exposed horizontal planform wing area outboard of bodies	FT
* CTF1	Type factor for wing tip fins, wing type 1	
* CTF3	Type factor for wing tip fins, wing type 3	
* CTVT	Length of vertical tail chord at tip	FT
* CVSP	Weight factor for variable - sweep wing	
* CWTF1	Weight factor for integral wing tip fins or wing-attached conventional fins, wing type 1	
* CWTF3	Weight factor for integral wing tip fins or wing-attached conventional fins, wing type 3	
* DAVT	Vertical tail dihedral angle (measured from horizontal plane)	DEG
* DAW1	Dihedral angle of wing, wing type 1	DEG
* DAW3	Dihedral angle of wing, wing type 3	DEG
* DAWT1	Dihedral angle of integral wing tip segment, wing type 1	DEG
* DAWT3	Dihedral angle of integral wing tip segment, wing type 3	DEG
* DENSWM	Density of wing structural material	LB/CU IN
* GWLAND	Landing grcss weight (an assigned value)	LB
* GWRE	Reentry or atmospheric cruise design gross weight (compatible with ZNAF)	LB
* HB	Maximum height of body	FT
* SAIL1	Horizontal planform area of ailerons, wing type 1	SQ FT
* SAIL2	Horizontal planform area of ailerons, wing type 2	SQ FT
* SAIL3	Horizontal planform area of ailerons, wing type 3	SQ FT
* SAVT	Vertical tail sweepback angle (quarter-chord line)	DEG
* SAW1	Wing sweepback angle (quarter-chord line), wing type 1	DEG
* SAW3	Wing sweepback angle (quarter-chord line), wing type 3	DEG
* SELW1	Horizontal planform area of elevons, wing type 1	SQ FT
* SELW2	Horizontal planform area of elevons, wing type 2	SQ FT
* SELW3	Horizontal planform area of elevons, wing type 3	SQ FT
* SEW1	Exposed horizontal planform area of wing, wing type 1	SQ FT
* SEW2	Exposed horizontal planform area of wing, wing type 2	SQ FT
* SEW3	Exposed horizontal planform area of wing, wing type 3	SQ FT

Variable	Definition	Units
* SLEF1	Horizontal planform area of wing leading edge flaps, wing type 1	SQ FT
* SLEF2	Horizontal planform area of wing leading edge flaps, wing type 2	SQ FT
* SLEF3	Horizontal planform area of wing leading edge flaps, wing type 3	SQ FT
* SLES1	Horizontal planform area of wing leading edge slats, wing type 1	SQ FT
* SLES2	Horizontal planform area of wing leading edge slats, wing type 2	SQ FT
* SLES3	Horizontal planform area of wing leading edge slats, wing type 3	SQ FT
SMPW1	Shear material weight parameter, wing type 1	
SMPW2	Shear material weight parameter, wing type 2	
SMPW3	Shear material weight parameter, wing type 3	
* SSB1	Horizontal planform area of wing speed brakes, wing type 1	SQ FT
* SSB2	Horizontal planform area of wing speed brakes, wing type 2	SQ FT
* SSB3	Horizontal planform area of wing speed brakes, wing type 3	SQ FT
* SSP1	Horizontal planform area of wing spoilers, wing type 1	SQ FT
* SSP2	Horizontal planform area of wing spoilers, wing type 2	SQ FT
* SSP3	Horizontal planform area of wing spoilers, wing type 3	SQ FT
* SSSW1	Horizontal planform area of wing fixed leading and trailing edge structure, wing type 1. If SSSW1 is unknown, it may be estimated as 0.32(SEW1-SAIL1-SELW1-.5STEF1-SLEF1-.5SSB1)	SQ FT
* SSSW2	Horizontal planform area of wing fixed leading and trailing edge structure, wing type 2. If SSSW2 is unknown, it may be estimated as 0.32(SEW2-SAIL2-SELW2-.5STEF2-SLEF2-.5SSB2)	SQ FT
* SSSW3	Horizontal planform area of wing fixed leading and trailing edge structure, wing type 3. If SSSW3 is unknown, it may be estimated as 0.32(SEW3-SAIL3-SELW3-.5STEF3-SLEF3-.5SSB3)	SQ FT
* STEF1	Horizontal planform area of wing trailing edge flaps, wing type 1	SQ FT
* STEF2	Horizontal planform area of wing trailing edge flaps wing type 2	SQ FT
* STEF3	Horizontal planform area of wing trailing edge flaps, wing type 3	SQ FT
* SVT	Vertical planform area of each vertical tail	SQ FT

Variable	Definition	Units
* SW1	Wing theoretical horizontal planform area, wing type 1	SQ FT
* SW2	Wing theoretical horizontal planform area, wing type 2	SQ FT
* SW3	Wing theoretical horizontal planform area, wing type 3	SQ FT
* TABE	Thrust of each air breathing engine (sea level static)	LB
TFPP1	Tip fin weight provision parameter, wing type 1	
TFPP3	Tip fin weight provision parameter, wing type 3	
* TFW1	Maximum wing thickness at base of upswept wing tip, wing type 1	FT
* TFW3	Maximum wing thickness at base of upswept wing tip, wing type 3	FT
* TSHW	Maximum wing thickness at hinge of variable-sweep wing	FT
* TSW1	Maximum wing thickness at side of body, wing type 1	FT
* TSW2	Maximum wing thickness at side of body, wing type 2	FT
* TSW3	Maximum wing thickness at side of body, wing type 3	FT
* TTEW1	Equivalent maximum wing thickness at tip of wing type 1 = [(TSW1+TBW1)(BTBW1-BBW1)+(TBW1+TTW1)(BW1-BTBW1)]/(BW1-BBW1)-TSW1, where TBW1 = Maximum wing thickness at point of change in wing thickness taper, BTBW1 = Horizontal planform wing span between points of change in wing thickness taper, and TTW1 = Maximum thickness at tip of wing	FT
* TTEW2	Equivalent maximum wing thickness at tip of wing type 2 = TSW2	FT
* TTEW3	Equivalent maximum wing thickness at tip of wing type 3 = {(TSW3+TBW3)[BTBW3-2(BBW3)-BCW3]+(TBW3+TTW3)(BW3-BTBW3)}/[BW3-2.(BBW3)-BCW3]-TSW3, where TBW3 = Maximum wing thickness at point of change in wing thickness taper, BTBW3 = Horizontal planform wing span between points of change in wing thickness taper, and TTW3 = Maximum wing thickness at tip of wing	FT
U1	Ultimate unit loading, wing type 1	PSF
U2	Ultimate unit loading, wing type 2	PSF
U3	Ultimate Unit loading, wing type 3	PSF
* UTSWM	Ultimate tensile strength of wing structural material at the critical design temperature	LB/SQ IN
VBFT	Volume of bladder fuel tanks in vehicle	CU FT
VNSST(K)	Volume of each non-self-sealing tank for air breathing engines	CU FT

Variable	Definition	Units
WAEPW1	Weight provision for air breathing engines, wing type 1	LB
WAEPW2	Weight provision for air breathing engines, wing type 2	LB
WAEPW3	Weight provision for air breathing engines, wing type 3	LB
WAIL1	Weight of ailerons, wing type 1	LB
WAIL2	Weight of ailerons, wing type 2	LB
WAIL3	Weight of ailerons, wing type 3	LB
WAS	Weight of all aerodynamic surfaces	LB
WBMW1	Bending material weight, wing type 1	LB
WBMW2	Bending material weight, wing type 2	LB
WBMW3	Bending material weight, wing type 3	LB
WCØNW1	Contingency weight for wing, wing type 1	LB
WCØNW2	Contingency weight for wing, wing type 2	LB
WCØNW3	Contingency weight for wing, wing type 3	LB
WCSW1	Weight of control surfaces, wing type 1	LB
WCSW2	Weight of control surfaces, wing type 2	LB
WCSW3	Weight of control surfaces, wing type 3	LB
WELW1	Weight of elevons, wing type 1	LB
WELW2	Weight of elevons, wing type 2	LB
WELW3	Weight of elevons, wing type 3	LB
WFTPW1	Weight provision for internal fuel tanks, wing type 1	LB
WFTPW2	Weight provision for internal fuel tanks, wing type 2	LB
WFTPW3	Weight provision for internal fuel tanks, wing type 3	LB
WGRØW1	Weight growth for wing, wing type 1	LB
WGRØW2	Weight growth for wing, wing type 2	LB
WGRØW3	Weight growth for wing, wing type 3	LB
WHT	Weight of horizontal tail	LB
WLEF1	Weight of leading edge flaps, wing type 1	LB
WLEF2	Weight of leading edge flaps, wing type 2	LB
WLEF3	Weight of leading edge flaps, wing type 3	LB
WLES1	Weight of leading edge slats, wing type 1	LB
WLES2	Weight of leading edge slats, wing type 2	LB
WLES3	Weight of leading edge slats, wing type 3	LB
WLGPW1	Weight provision for wing mounted main landing gear	LB

Variable	Definition	Units
WPSW1	Weight of primary structure, wing type 1	LB
WPSW2	Weight of primary structure, wing type 2	LB
WPSW3	Weight of primary structure, wing type 3	LB
WRW1	Rib weight, wing type 1	LB
WRW2	Rib weight, wing type 2	LB
WRW3	Rib weight, wing type 3	LB
WSB1	Weight of speed brakes, wing type 1	LB
WSB2	Weight of speed brakes, wing type 2	LB
WSB3	Weight of speed brakes, wing type 3	LB
WSMW1	Shear material weight, wing type 1	LB
WSMW2	Shear material weight, wing type 2	LB
WSMW3	Shear material weight, wing type 3	LB
WSP1	Weight of spoilers, wing type 1	LB
WSP2	Weight of spoilers, wing type 2	LB
WSP3	Weight of spoilers, wing type 3	LB
* WSPW1	Weight of special features, wing type 1	LB
* WSPW2	Weight of special features, wing type 2	LB
* WSPW3	Weight of special features, wing type 3	LB
WSRW	Weight to strength ratio of wing structural material	IN^{-1}
WSSW1	Weight of secondary structure, wing type 1	LB
WSSW2	Weight of secondary structure, wing type 2	LB
WSSW3	Weight of secondary structure, wing type 3	LB
WTBW1	Weight of wing excluding contingency and growth, wing type 1	LB
WTBW2	Weight of wing excluding contingency and growth, wing type 2	LB
WTBW3	Weight of wing excluding contingency and growth, wing type 3	LB
WTEF1	Weight of trailing edge flaps, wing type 1	LB
WTEF2	Weight of trailing edge flaps, wing type 2	LB
WTEF3	Weight of trailing edge flaps, wing type 3	LB
WTFP1	Weight provision for wing tip fin, wing type 1	LB
WTFP3	Weight provision for wing tip fin, wing type 3	LB
WVSP1	Weight provision for variable-sweep wing	LB
WVT	Weight of vertical tail	LB

Variable	Definition	Units
WW1	Wing weight, wing type 1	LB
WW2	Wing weight, wing type 2	LB
WW3	Wing weight. wing type 3	LB
WWT	Total weight of wings on vehicle	LB
* ZLVEH	Overall length of vehicle	FT
* ZLVT	Length of vertical tail arm (longitudinal distance between the vehicle C.G. and the center of pressure of the vertical tail)	FT
* ZNAEW1	Quantity of air breathing engines in or on wing type 1	
* ZNAEW2	Quantity of air breathing engines in or on wing type 2	
* ZNAEW3	Quantity of air breathing engines in or on wing type 3	
* ZNAF	Ultimate flight vertical load factor at GWRE	
* ZNB	Quantity of bodies	
* ZNLD	Ultimate landing vertical load factor	
ZNØFW1	Non-optimum factor for primary structure weight, wing type 1	
ZNØFW2	Non-optimum factor for primary structure weight, wing type 2	
ZNØFW3	Non-optimum factor for primary structure weight, wing type 3	
	Wing structure unit weight (UWW) = WWT/(SW1 + SW2 + SW3)	LB/SQ FT
	Volume of bladder type fuel tanks in wing (VBTW) = VBFT(CFTPW1 + CFTPW2 + CFTPW3)	CU FT
* ZNSST(K)	Quantity of identical non-self-sealing tanks for air breathing engines	

* Input

HORIZONTAL TAIL

The following horizontal tail weight equations apply for any practical cantilevered planform shapes, thickness ratios, and sweepback and dihedral angles. Distinction is made between all-movable and stabilizer-elevator type tails, and structural material properties are considered.

The ultimate design unit load on the horizontal tail is estimated empirically in the equations, but if a more reliable value is available it may be applied by manipulating the value of the ZLHT term in the expression for UH. The total horizontal tail load is assumed to act on the exposed area only, and is assumed further to be uniformly distributed over the exposed planform. No relief from the weight of the horizontal tail or its contents is assumed.

The derivation of the bending material equation requires adherence to the reasonable assumption that the horizontal tail thickness at the side of the body is greater than the thickness at the tip.

The horizontal tail primary structure weight non-optimum factor is the average quotient of actual or reported weight divided by theoretical weight for 15 vehicle samples. The non-optimum factor is inversely affected by the magnitude of the theoretical primary structure weight per unit of primary structure area. This effect is incorporated into the weight equations.

The horizontal tail weight is defined as:

1.2 WHT = WPSHT + WSSHT + WELHT + WSPHT + WCØNHT + WGRØHT + WELB.

1.2.1 Primary Structure

WPSHT = WBMHT + WSMHT + WRHT.

1.2.1.1 Bending Material (spanwise)

WBMHT = BMPHT(ZNOFHT), where

$$BMPHT = \frac{UH(WSRHT)}{48}\left[\frac{8(BHT-BBHT)^3}{(\cos^2 SAHT)\cos^2 DAHT(TSHT-TTHT)^4}\cdot\right.$$

$$\left\{2(CSHT-CTHT)(TSHT-TTHT)^3 + 3\left[3CTHT(TSHT-TTHT) -\right.\right.$$

$$\left.TTHT(CSHT-CTHT)\right]\cdot\left[TSHT(TSHT-4TTHT) + (TTHT)^2(2\log_e\frac{TSHT}{TTHT} + 3)\right]\Bigg\}+$$

$$\left.\frac{48CCTHT(BBHT)}{TSHT}\left\{(BHT-BBHT)^2(CSHT+2CTHT) + 2\ BBHT(SEHT)\right\}\right],\ \text{where}$$

$$UH = \frac{GWRE(ZLVEH)}{ZLHT(SEHT)},\ WSRHT = DENSHT/UTSHTM,\ \text{and}$$

$$TSHT > TTHT.$$

$$ZN\emptyset FHT = \frac{CN\emptyset FHT}{\left(\frac{BMPHT}{SEHT-SSSHT-SELHT}\cdot\frac{SEHT}{\frac{SEHT}{\cos DAHT} + CCTHT(SHT-SEHT)}\right)^{1/3}}.$$

1.2.1.2 Shear Material (spanwise)

$$WSMHT = SMPHT(ZN\emptyset FHT),\ \text{where}$$

$$SMPHT = UH(WSRHT)\left[\frac{(BHT-BBHT)^2(CSHT+2CTHT)}{\cos SAHT(\cos DAHT)} + 3\ CCTHT(BBHT)(SEHT)\right].$$

1.2.1.3 Ribs (between spars)

$$WRHT = CRIBHT(0.06)(WBMHT+WSMHT).$$

1.2.2 Secondary Structure (fixed leading and trailing edges)

$$WSSHT = CWSSHT(0.00191)\frac{UH(SSSHT)}{\cos DAHT}.$$

1.2.3 Elevators

$$WELHT = CELHT(0.0075)\frac{UH(SELHT)}{\cos DAHT},\ \text{or}$$

Body Elevon

$$WELB = CELB(6.0)SELB.$$

1.2.18 Special Features

$$WSPHT = WSPHT.$$

1.2.19 Contingency

WCØNHT = CCØNHT(WBTHT), where

WBTHT is the sum of all the items preceding 1.2.19.

1.2.20 Growth

WGRØHT = CGRØHT(WCØNHT + WBTHT).

HORIZONTAL TAIL DEFINITIONS

Variable	Definition	Units
* BBHT	Maximum body width at junction of body and horizontal tail	FT
* BHT	Horizontal planform span of horizontal tail	FT
BMPHT	Bending material weight parameter of horizontal tail	
* CCØNHT	Weight factor for contingency for horizontal tail	
* CCTHT	Weight factor for carry-through structure for horizontal tail	
* CELB	Weight factor for body elevons	
* CELHT	Weight factor for horizontal tail elevators	
* CGRØHT	Weight factor for growth for horizontal tail	
* CNØFHT	Weignt factor for horizontal tail primary structure	
* CRIBHT	Weight factor for horizontal tail ribs	
* CSHT	Length of horizontal tail chord at side of body	FT
* CTHT	Length of horizontal tail chord at tip	FT
* CWSSHT	Weight factor for horizontal tail secondary structure	
* DAHT	Dihedral angle of the horizontal tail	DEG
* DENSHT	Density of horizontal tail structural material	LB/CU IN
* GWRE	Reentry or atmospheric cruise design gross weight (compatible with ZNAF)	LB
* SAHT	Sweepback angle of horizontal tail (quarter-chord line)	DEG
* SEHT	Exposed horizontal planform area of horizontal tail	SQ FT
* SELHT	Horizontal planform area of elevators	SQ FT
* SHT	Theoretical horizontal planform area of horizontal tail	SQ FT
SMPHT	Shear material weight parameter of horizontal tail	
* SELB	Horizontal planform area of body elevons	SQ FT

Variable	Definition	Units
* SSSHT	Horizontal planform area of secondary structure of horizontal tail. If SSSHT is unknown it may be estimated as 0.6(SEHT - SELHT)	SQ FT
* TSHT	Horizontal tail thickness at side of body	FT
* TTHT	Tip thickness of horizontal tail	FT
UH	Design unit load parameter for horizontal tail	
* UTSHTM	Ultimate tensile strength of horizontal tail structural material at the critical design temperature	LB/SQ IN
WBMHT	Weight of bending material for horizontal tail	LB
WBTHT	Total horizontal tail weight less contingency and growth	LB
WCØNHT	Contingency weight for horizontal tail	LB
WELB	Body elevons weight	LB
WELHT	Horizontal tail elevators weight	LB
WGRØHT	Weight growth for horizontal tail	LB
WHT	Weight of horizontal tail	LB
WPSHT	Weight of primary structure of horizontal tail	LB
WRHT	Weight of ribs of horizontal tail	LB
WSMHT	Weight of shear material of horizontal tail	LB
* WSPHT	Weight of special features for horizontal tail	LB
WSRHT	Weight to strength ratio of horizontal tail structural material	IN^{-1}
WSSHT	Weight of secondary structure of horizontal tail	LB
* ZLHT	Length of horizontal tail arm (longitudinal distance between the vehicle C.G. and the center of pressure of the horizontal tail)	FT
* ZLVEH	Overall length of vehicle	FT
ZNØFHT	Non-optimum factor for primary structure weight of horizontal tail	
	Horizontal tail structure unit weight (UWHT) = WHT/SHT	LB/SQ FT

* Input

The following vertical tail weight equations apply for any practical cantilevered planform shapes, thickness ratios, and sweepback and dihedral angles. A provision for tee-tail effects is included, and structural material properties are considered.

The ultimate design unit load on the vertical tail is estimated empirically in the equations, but if a more reliable value is available it may be applied by manipulating the value of the ZLVT term in the expression for ultimate unit vertical tail load incorporated in the equations. The total vertical tail load is assumed to be uniformly distributed over the planform area, and no relief is assumed from the weight of the vertical tail or its contents.

The derivation of the bending material equation requires adherence to the reasonable assumption that the vertical tail thickness at the base is greater than the thickness at the tip.

The vertical tail primary structure weight non-optimum factor is the average quotient of actual or reported weight divided by theoretical weight for 15 vehicle samples. The non-optimum factor is inversely affected by the magnitude of the theoretical primary structure weight per unit of primary structure planform area. This effect is incorporated into the weight equations.

The vertical tail weight is defined as:

1.3 WVT = WPSVT + WSSVT + WTTP + WDVF + WRUD + WSPVT + WCØNVT + WGRØVT.

1.3.1 Primary Structure

WPSVT = WBMVT + WSMVT + WRVT.

1.3.1.1 Bending Material (spanwise)

WBMVT = BMPVT(ZNØFVT), where

$$BMPVT = \frac{96(WSRVT)HB(BVT)^3(ZLVEH)^2}{2(\cos^2 SAVT)\cos^2(90-DAVT)(TRVT-TTVT)^4 ZLVT(SVT)} \cdot$$

$$\left\{2(CRVT-CTVT)(TRVT-TTVT)^3 + 3\left[3CTVT(TRVT-TTVT) - TTVT(CRVT-CTVT)\right]\left[TRVT(TRVT-4TTVT) + (TTVT)^2\left(2\log_e \frac{TRVT}{TTVT} + 3\right)\right]\right\}, \text{ where}$$

$$WSRVT = DENSVT/UTSVTM, \text{ and } TRVT > TTVT;$$

$$ZN\emptyset FVT = \frac{CN\emptyset FVT(3.66)\left[ZNVT(SVT-SRUD-SSSVT)\right]^{1/3}}{\left[(BMPVT)\cos(90-DAVT)\right]^{1/3}} \cdot$$

1.3.1.2 Shear Material (spanwise)

$$WSMVT = SMPVT(ZN\emptyset FVT), \text{ where}$$

$$SMPVT = \frac{96(WSRVT)HB(BVT)^2(CRVT+2CTVT)(ZLVEH)^2}{(\cos SAVT)\cos(90-DAVT)ZLVT(SVT)} \cdot$$

1.3.1.3 Ribs (between spars)

$$WRVT = CRIBVT(0.06)(WBMVT+WSMVT).$$

1.3.2 Secondary Structure (fixed leading and trailing edges)

$$WSSVT = CWSSVT(0.143)\frac{(SSSVT)HB(ZLVEH)^2}{\cos(90-DAVT)ZLVT(SVT)} \cdot$$

1.3.3 Tee-tail Provision

$$WTTP = TTPP(ZN\emptyset FVT), \text{ where}$$

$$TTPP = \frac{12(GWRE)ZLVEH(WSRVT)BTT}{(ZLHT)(\cos SAVT)} \cdot$$

1.3.4 Dorsal and Ventral Fins

$$WDVF = CWDVF(0.43)SDVF\left[\frac{11\ HB(ZLVEH)^2}{ZLVT(SVT)ZNVT}\right]^{1/3} \cdot$$

1.3.5 Rudders

$$WRUD = \frac{11\ HB(CRBAL)SRUD(ZLVEH)^2}{\cos(90-DAVT)ZLVT(SVT)} \cdot$$

1.3.18 Special Features

$$WSPVT = WSPVT.$$

1.3.19 Contingency

$$WC\emptyset NVT = CC\emptyset NVT(WBTVT), \text{ where}$$

WBTVT is the sum of all the items preceding 1.3.19.

1.3.20 Growth

$$WGR\emptyset VT = CGR\emptyset VT(WC\emptyset NVT+WBTVT).$$

VERTICAL TAIL DEFINITIONS

Variable	Definition	Units
BMPVT	Bending material weight parameter of vertical tail	
* BTT	Vertical planform span of "T" type vertical tail measured from the body intersection to the horizontal tail intersection	FT
* BVT	Vertical planform span of vertical tail	FT
* CCØNVT	Weight factor for contingency for vertical tail	
* CGRØVT	Weight factor for growth for vertical tail	
* CNØFVT	Weight factor for vertical tail primary structure	
* CRBAL	Weight factor for vertical tail rudder	
* CRIBVT	Weight factor for vertical tail ribs	
* CRVT	Vertical tail chord length at body or wing intersection	FT
* CTVT	Chord length at tip of vertical tail	FT
* CWDVF	Weight factor for dorsal and ventral fins	
* CWSSVT	Weight factor for vertical tail secondary structure	
* DAVT	Dihedral angle of vertical tail (measured from horizontal plane)	DEG
* DENSVT	Density of vertical tail structural material	LB/CU IN
* GWRE	Reentry or atmospheric cruise design gross weight (compatible with ZNAF)	LB
* HB	Maximum height of body	FT
* SAVT	Sweepback angle of vertical tail (quarter chord line)	DEG
* SDVF	Vertical planform area of dorsal and ventral fins	SQ FT
SMPVT	Shear material weight parameter of vertical tail	
* SRUD	Vertical planform area of each rudder	SQ FT
* SSSVT	Vertical planform area of vertical tail fixed leading and trailing edge structure. If SSSVT is unknown it may be estimated as 0.55 (SVT - SRUD)	SQ FT
* SVT	Exposed vertical planform area of each vertical tail	SQ FT
* TRVT	Maximum thickness of vertical tail at junction with body or wing	FT
* TTVT	Maximum thickness of vertical tail at tip	FT
* UTSVTM	Ultimate tensile strength of vertical tail structural material at the critical design temperature	LB/SQ IN
WBMVT	Weight of vertical tail bending material	LB
WBTVT	Weight of vertical tail excluding contingency and growth	
TTPP	Tee-tail provision weight parameter	

Variable	Definition	Units
WCØNVT	Contingency weight for vertical tail	LB
WDVF	Weight of dorsal and ventral fins	LB
WGRØVT	Growth weight for vertical tail	LB
WPSVT	Weight of vertical tail primary structure	LB
WRUD	Weight of rudder	LB
WRVT	Weight of vertical tail ribs	LB
WSMVT	Weight of vertical tail shear material	LB
* WSPVT	Weight of special features for vertical tail	LB
WSRVT	Weight to strength ratio of vertical tail structural material	IN^{-1}
WSSVT	Weight of vertical tail secondary structure	LB
WTTP	Weight penalty for "T" type vertical tail	LB
WVT	Weight of vertical tail	LB
* ZLHT	Length of horizontal tail arm (longitudinal distance between the vehicle C.G. and the center of pressure of the horizontal tail	FT
* ZLVEH	Overall length of vehicle	FT
* ZLVT	Length of vertical tail arm (longitudinal distance between the vehicle C.G. and the center of pressure of the vertical tail)	FT
ZNØFVT	Non-optimum factor for primary structure weight of vertical tail	
* ZNVT	Quantity of vertical tails	
	Vertical tail structure unit weight (UWVT) = WVT/ [ZLVT(SVT)]	LB/SQ FT

* Input

BODY

The following weight equations apply primarily to the bodies of spacecraft (winged and unwinged) and space stations, with conventional aircraft being given secondary consideration. The equations limit body configurations to two integral propellant tanks and two non-tank pressure compartments of different dimensions. No limitations are placed on non-pressurized sections.

Structural shape, size and loads, material properties, use of common bulkheads, carry-through structure for wing and tail, and provisions for secondary structure, landing gear, propulsion systems and special features are prime considerations.

Internal gas pressures and accelerated propellant head pressures, coupled with hydrostatic test conditions, are considered as major parameters in the weight equations for integral propellant tanks.

Incorporated within the equations are considerations of optional limitations on the minimum gage of pressurized skins.

The body weight is defined as:

2.0 WB = WPSB + WSSB + WLGPB + WFTPB + WAEPB + WLRPB + WSPB + WCØNB + WGRØB.

2.1 Primary structure

WPSB = WSAF + WBMB + WBASF.

2.1.1 Skin and frames

WSAF = WSAFC1 + WSAFC2 + WSAFFT + WSAFØT + WSAFR.

2.1.1.1 Skin and frames of pressure compartment No. 1

WSAFC1 = CBAR (713) ZNB (WSRB) PPC1 (SWPC1) (DFPC1 + DAPC1) or CBARM (238) ZNB (TMPC1) SWPC1 (DENSBM), whichever is larger, where

WSRB = DENSBM/UTSBM, and

$$\text{SWPC1} = 0.785\ (\text{DFPC1} + \text{DAPC1}) \left[4(\text{ZLWPC1})^2 + (\text{DFPC1} - \text{DAPC1})^2\right]^{\frac{1}{2}}.$$

2.1.1.2 Skin and frames of pressure compartment No. 2

WSAFC2 = CBAR (713) ZNB (WSRB) PPC2 (SWPC2) (DFPC2 + DAPC2) or CBARM (238) ZNB (TMPC2) SWPC2 (DENSBM), whichever is larger, where

$$SWPC2 = 0.785\ (DFPC2 + DAPC2)\ \left[4(ZLWPC2)^2 + (DFPC2 - DAPC2)^2\right]^{\frac{1}{2}}.$$

2.1.1.3 Skin and frames of integral fuel tank

WSAFFT = CBAR (713) CPRØP1 (ZNPT1) WSRIT1 (PBT1) · SBT1 (DFT1 + DAT1) or CBARM (238) CPRØP1 (ZNPT1) · TMT1 (SBT1) DENIT1, whichever is larger, + CBAR · (713) · CPRØP2 (ZNPT2) WSRIT2 (PBT2) SBT2 (DFT2 + DAT2) or CBARM (238) CPRØP2 (ZNPT2) TMT2 (SBT2) DENIT2, whichever is larger, where

WSRIT1 = DENIT1/UTST1, and WSRIT2 = DENIT2/UTST2.

For details of PBT1, SBT1, PBT2 and SBT2, refer to 5.8.1.1.2.

2.1.1.4 Skin and frames of integral oxidizer tank

WSAFØT = CBAR (713) (1 - CPRØP1) ZNPT1 (WSRIT1) PBT1 · (SBT1) (DFT1 + DAT1) or CBARM (238) (1 - CPRØP1) · ZNPT1 (TMT1) SBT1 (DENIT1), whichever is larger, + CBAR (713) (1 - CPRØP2) ZNPT2 (WSRIT2) PBT2 (SBT2) · (DFT2 + DAT2) or CBARM (238) (1 - CPROP2) ZNPT2 · (TMT2) SBT2 (DENIT2), whichever is larger.

For details of PBT1, SBT1, PBT2 and SBT2, refer to 5.8.1.1.2.

2.1.1.5 Skin and frames of unpressurized body

$$WSAFR = CSSV\ (10^6)\ ZNB\ (WSRB)\ SBR + CSAC\ (7{,}330)\ ZNB \cdot (WSRB)\ (SB)^{4/3}\ (VMAX, < 3{,}000)^{1/3},$$ where

SBR = SB - SWPC1 - SWPC2 - CIT1 (SBT1) ZNPT1 - CIT2 (SBT2) ZNPT2.

2.1.2 Longitudinal stringers, longerons, beams and structural floors

$$WBMB = 2/3\ (CBSV)\ ZNB\ (WSRB)\ UDTLF\ (GWST)\ ZLB\ \left(\frac{ZLST}{HB}\right) + CBAC\ (ZNB)\ WSRB\ (ZNAF)\ WBAC\ (ZLB)^2/HB.$$

2.1.3 Bulkheads, integral propellant tank domes, and special frames

$$WBASF = WBLKC1 + WBLKC2 + WDFT + WD\O T + WBASFR.$$

2.1.3.1 Bulkheads of pressure compartment No. 1

$$WBLKC1 = WFBC1 + WIBC1 + WABC1.$$

2.1.3.1.1 Forward bulkhead of pressure compartment No. 1

$$WFBC1 = CBLK\ (1560)\ ZNB\ (WSRB)\ PPC1\ (DFPC1)^3\ [CTFBC1\ (CAFBC1) + 10\ (CKFBC1)]$$ or $$CBLKM\ (331)\ ZNB\ (TMPC1)\ SFBPC1\ (DENSBM),$$

whichever is larger, where

$$SFBPC1 = CAFBC1\ (1.57)\ (DFPC1)^2.$$

2.1.3.1.2 Intermediate bulkheads in pressure compartment No. 1

$$WIBC1 = CBLK\ (1560)\ ZNB\ (ZNIBC1)\ WSRB\ (PPC1)\ (DIBC1)^3 \cdot [CTIBC1\ (CAIBC1) + 10\ (CKIBC1)]$$ or $$CBLKM\ (331) \cdot ZNB\ (ZNIBC1) \cdot TMPC1\ (SIBPC1)\ DENSBM$$ whichever is larger, where

$$SIBPC1 = CAIBC1\ (1.57)\ (DIBC1)^2.$$

2.1.3.1.3 Aft bulkhead of pressure compartment No. 1

$$WABC1 = CBLK\ (1560)\ ZNB\ (WSRB)\ PPC1\ (DAPC1)^3\ [CTABC1\ (CAABC1) + 10\ (CKABC1)]$$ or $$CBLKM\ (331)\ ZNB\ (TMPC1)\ SABPC1\ (DENSBM),$$

whichever is larger, where

$$SABPC1 = CAABC1\ (1.57)\ (DAPC1)^2.$$

2.1.3.2 Bulkheads of pressure compartment No. 2

$$WBLKC2 = WFBC2 + WIBC2 + WABC2.$$

2.1.3.2.1 Forward Bulkhead of pressure compartment No. 2

$$WFBC2 = CBLK\ (1560)\ ZNB\ (WSRB)\ PPC2\ (DFPC2)^3\ [CTFBC2\ (CAFBC2) +$$

10 (CKFBC2)] or CBLKM (331) ZNB (TMPC2) SFBPC2 (DENSBM), whichever is larger, where

$$SFBPC2 = CAFBC2\ (1.57)\ (DFPC2)^2.$$

2.1.3.2.2 Intermediate bulkheads in pressure compartment No. 2

$$WIBC2 = CBLK\ (1560)\ ZNB\ (ZNIBC2)\ WSRB\ (PPC2)\ (DIBC2)^3 \cdot [CTIBC2\ (CAIBC2) + 10\ (CKIBC2)]$$ or $$CBLKM\ (331) \cdot ZNB\ (ZNIBC2)\ TMPC2\ (SIBPC2)\ DENSBM,$$ whichever is larger, where

$$SIBPC2 = CAIBC2\ (1.57)\ (DIBC2)^2.$$

2.1.3.2.3 Aft bulkhead of pressure compartment No. 2

$$WABC2 = CBLK\ (1560)\ ZNB\ (WSRB)\ PPC2\ (DAPC2)^3\ [CTABC2\ (CAABC2) + 10\ (CKABC2)]$$ or $$CBLKM\ (331)\ ZNB\ (TMPC2)\ SABPC2\ (DENSBM),$$ whichever is larger, where

$$SABPC2 = CAABC2\ (1.57)\ (DAPC2)^2.$$

2.1.3.3 Domes of integral fuel tank

$$WDFT = WFDFT + WADFT.$$

2.1.3.3.1 Forward dome of integral fuel tank

$$WFDFT = CBLK\ (1560)\ CPR\emptyset P1\ (ZNPT1)\ WSRIT1\ (PFDT1)\ (DFT1)^3 \cdot [CTFD1\ (CAFD1) + 10\ (CKFD1)]$$ or $$CBLKM\ (331)\ CPR\emptyset P1 \cdot (ZNPT1)\ TMT1\ (SFDT1)\ DENIT1,$$ whichever is larger, + $$CBLK\ (1560)\ CPR\emptyset P2\ (ZNPT2)\ WSRIT2\ (PFDT2)\ (DFT2)^3 \cdot [CTFD2\ (CAFD2) + 10\ (CKFD2)]$$ or $$CBLKM\ (331)\ CPR\emptyset P2 \cdot (ZNPT2)\ TMT2\ (SFDT2)\ DENIT2,$$ whichever is larger.

For details of PFDT1, SFDT1, PFDT2 and SFDT2, refer to 5.8.1.1.1.

2.1.3.3.2 Aft dome of integral fuel tank

$$WADFT = CBLK\ (1560)\ CPR\emptyset P1\ (ZNPT1)\ (1 + CCD1)\ WSRIT1 \cdot (PADT1)\ (DAT1)^3\ [CTAD1\ (CAAD1) + 10\ (CKAD1)]$$ or

CBLKM (331) CPRØP1 (ZNPT1) (1 + CCD1) TMT1 ·

(SADT1) DENIT1, whichever is larger, + CBLK (1560) ·

CPRØP2 (ZNPT2) (1 + CCD2) WSRIT2 (PADT2) $(DAT2)^3$ ·

[CTAD2 (CAAD2) + 10 (CKAD2)] or CBLKM (331) CPRØP2 ·

(ZNPT2) (1 + CCD2) TMT2 (SADT2) DENIT2, whichever is larger.

For details of PADT1, SADT1, PADT2 and SADT2, refer to 5.8.1.1.3.

2.1.3.4 Domes of integral oxidizer tank

WDOT = WFDØT + WADØT.

2.1.3.4.1 Forward dome of integral oxidizer tank

WFDØT = CBLK (1560) (1 - CPRØP1) ZNPT1 (WSRIT1) PFDT1 ·

$(DFT1)^3$ [CTFD1 (CAFD1) + 10 (CKFD1)] or CBLKM ·

(331) (1 - CPRØP1) ZNPT1 (TMT1) SFDT1 (DENIT1),

whichever is larger, + CBLK (1560) (1 - CPRØP2) ·

ZNPT2 (WSRIT2) PFDT2 $(DFT2)^3$ [CTFD2 (CAFD2) +

10 (CKFD2)] or CBLKM (331) (1 - CPROP2) ZNPT2 ·

(TMT2) SFDT2 (DENIT2), whichever is larger.

For details of PFDT1, SFDT1, PFDT2 and SFDT2, refer to 5.8.1.1.1.

2.1.3.4.2 Aft dome of integral oxidizer tank

WADØT = CBLK (1560) (1 - CPRØP1) ZNPT1 (1 + CCD1) WSRIT1 ·

(PADT1) $(DAT1)^3$ [CTAD1 (CAAD1) + 10 (CKAD1)] or

CBLKM (331) (1 - CPRØP1) ZNPT1 (1 + CCD1) TMT1 ·

(SADT1) DENIT1, whichever is larger, + CBLK (1560) ·

(1 - CPRØP2) ZNPT2 (1 + CCD2) WSRIT2 (PADT2) $(DAT2)^3$ ·

[CTAD2 (CAAD2) + 10 (CKAD2)] or CBLKM (331) (1 - CPRØP2) ·

ZNPT2 (1 + CCD2) TMT2 (SADT2) DENIT2, whichever is larger.

For details of PADT1, SADT1, PADT2 and SADT2, refer to 5.8.1.1.3.

2.1.3.5 Bulkheads and special frames of unpressurized body

$$WBASFR = WBAFG + WBCTW1 + WBCTW2 + WBCTW3 + WHTCT.$$

2.1.3.5.1 Bulkheads and special frames of unpressurized body, excluding major carry-through structure for wing and horizontal tail

$$WBAFG = CBASF\ (ZNB)\ VBR, \text{ where}$$

$$VBR = VB - VPC1 - VPC2 - CIT1\ (V\emptyset LT1) - CIT2\ (V\emptyset LT2),$$

$$VPC1 = VFBPC1 + VWPC1 + VABPC1.$$

$$VPC2 = VFBPC2 + VWPC2 + VABPC2.$$

$$VFBPC1 = CVFBC1\ (0.262)\ (DFPC1)^3.$$

$$VWPC1 = 0.262\ (ZLWPC1)\ \left[(DFPC1)^2 + DFPC1\ (DAPC1) + (DAPC1)^2\right].$$

$$VABPC1 = CVABC1\ (0.262)\ (DAPC1)^3.$$

$$VFBPC2 = CVFBC2\ (0.262)\ (DFPC2)^3.$$

$$VWPC2 = 0.262\ (ZLWPC2)\ \left[(DFPC2)^2 + DFPC2\ (DAPC2) + (DAPC2)^2\right].$$

$$VABPC2 = CVABC2\ (0.262)\ (DAPC2)^3.$$

For details of VØLT1 and VØLT2, refer to 5.8.1.2.

2.1.3.5.2 Carry-through structure for wing type 1

$$WBCTW1 = \tfrac{1}{2}\ (1 - CCTW1)\ (1 + CRIBW1)\ ZN\emptyset FW1\ (WSRW)\ U1\ (BBW1) \cdot \left[\frac{1}{4\ TSW1}\Big\{8\ (BW1 - BBW1)^2\ (CSW1 + 2\ CTEW1) + 12\ BBW1\ (BW1 - BBW1)\ (CSW1 + CTEW1) + BBW1\left[BBW1\ (CRW1 + 3\ CSW1) - 4\ (SW1 + SEW1)\right]\Big\} + 6\ (BW1 - BBW1)\ (CSW1 + CTEW1) + BBW1\ (CRW1 + 2CSW1) - 3\ (SW1 + SEW1)\right].$$

For details of ZNOFW1, WSRW and U1, refer to 1.1.1.1.

2.1.3.5.3 Carry-through structure for wing type 2

$$WBCTW2 = (1 - CCTW2)\ (1 + CRIBW2)\ ZNOFW2\ (WSRW)\ U2\ (BBW2) \cdot$$

$$\left(\frac{2\ \mathrm{BBW2}}{\mathrm{TSW2}} + 3\right)\left[\mathrm{SW2} + \mathrm{SEW2} - 2\ \mathrm{BBW2}\ (\mathrm{CSW2})\right].$$

For details of ZNOFW2, WSRW and U2, refer to 1.1.1.1.

2.1.3.5.4 Carry-through structure for wing type 3

$$\begin{aligned}\mathrm{WBCTW3} = {} & (1 - \mathrm{CCTW3})\ (1 + \mathrm{CRIBW3})\ \mathrm{ZN\text{Ø}FW3}\ (\mathrm{WSRW})\ \mathrm{U3}\ (\mathrm{BBW3}) \cdot \\ & \left[\frac{2}{\mathrm{TSW3}}\left\{(\mathrm{BW3} - 2\mathrm{BBW3} - \mathrm{BCW3})^2\ (\mathrm{CSW3} + 2\ \mathrm{CTEW3}) + \right.\right. \\ & \mathrm{BBW3}\ \left[2\mathrm{BBW3}\ (\mathrm{CSW3}) - \mathrm{SW3} - \mathrm{SEW3}\right] + \\ & \left. 3\ \mathrm{BBW3}\ (\mathrm{BW3} - 2\mathrm{BBW3} - \mathrm{BCW3})\ (\mathrm{CSW3} + \mathrm{CTEW3})\right\} + \\ & \frac{3}{\mathrm{SEW3} + \mathrm{SW3} - 2\ \mathrm{BBW3}\ (\mathrm{CSW3})}\left\{\left[(\mathrm{BW3} - 2\ \mathrm{BBW3} - \mathrm{BCW3}) \cdot \right.\right. \\ & \left.(\mathrm{CSW3} + \mathrm{CTEW3})\right]^2 + \left[\mathrm{SEW3} + \mathrm{SW3} - 2\ \mathrm{BBW3}\ (\mathrm{CSW3}) - \right. \\ & \left.\left.\left.(\mathrm{BW3} - 2\ \mathrm{BBW3} - \mathrm{BCW3})\ (\mathrm{CSW3} + \mathrm{CTEW3})\right]^2\right\}\right].\end{aligned}$$

For details of ZNØFW3, WSRW and U3, refer to 1.1.1.1.

2.1.3.5.5 Carry-through structure for horizontal tail

$$\begin{aligned}\mathrm{WHTCT} = {} & (1 - \mathrm{CCTHT})\ (1 + \mathrm{CRIBHT})\ \mathrm{ZN\text{Ø}FHT}\ (\mathrm{WSRHT})\ \mathrm{UH}\ (\mathrm{BBHT}) \cdot \\ & \left\{\frac{1}{\mathrm{TSHT}}\left[(\mathrm{BHT} - \mathrm{BBHT})^2\ (\mathrm{CSHT} + 2\ \mathrm{CTHT}) + \right.\right. \\ & \left.\left. 2\ \mathrm{BBHT}\ (\mathrm{SEHT})\right] + 3\ \mathrm{SEHT}\right\}.\end{aligned}$$

For details of ZNØFHT, WSRHT and UH, refer to 1.2.1.1.

2.2 Secondary structure (external non-structural doors, hatches and panels, fairing, radome, windshield, windows and miscellaneous

$$\mathrm{WSSB} = \mathrm{CSSB}\ (0.4)\ \mathrm{ZNB}\ (\mathrm{SB}).$$

2.3 Landing gear provision

$$\mathrm{WLGPB} = \mathrm{CLGPB}\ (0.0003)\ \mathrm{ZNLD}\ (\mathrm{GWLAND}).$$

2.4 Atmospheric cruise fuel tank provision

$$\mathrm{WFTPB} = (1 - \mathrm{CFTPW1} - \mathrm{CFTPW2} - \mathrm{CFTPW3})\ (6)\ (\mathrm{VBFT})/\mathrm{BB}.$$

For details of VBFT, refer to 1.1.6.

2.5 Airbreathing engine provision

$$\mathrm{WAEPB} = \mathrm{CAEPB}\ (0.005)\ \mathrm{ZNB}\ (\mathrm{ZNABEB})\ \mathrm{TABE}.$$

2.6 Liquid rocket engine provision

WLRPB = CLRPB (0.0001) ZNLRE (TLRE).

2.18 Special features

WSPB = WSPB.

2.19 Contingency

WCØNB = CCØNB (WTBB), where

WTBB is the sum of all the items preceding 2.19

2.20 Growth

WGRØB = CGRØB (WCØNB + WTBB).

BODY DEFINITIONS

Variable	Definition	Units
* ATLF	Maximum allowable ultimate thrust load factor	
* BB	Maximum width of body	FT
* BBHT	Maximum body width at junction of body and horizontal tail	FT
* BHT	Horizontal planform span of horizontal tail	FT
* BBW1	Maximum body width at wing intersection, wing type 1	FT
* BBW2	Maximum body width at wing intersection, wind type 2	FT
* BBW3	Maximum body width at wing intersection, wing type 3	FT
* BCW3	Exposed horizontal planform wing span between bodies, wing type 3	FT
* BW1	Horizontal planform wing span, wing type 1	FT
* BW2	Horizontal planform wing span, wing type 2	FT
* BW3	Horizontal planform wing span, wing type 3	FT
* CAABC1	Wetted area factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DAPC1 and bulkhead shape (refer to Figure 5-2 for value)	
* CAABC2	Wetted area factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DAPC2 and bulkhead shape (refer to Figure 5-2 for value)	
* CAAD(I)	Wetted area factor for aft dome of main propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-2 for value)	
* CAEPB	Weight factor for provision for air breathing engines in or on body	

Variable	Definition	Units
* CAFBC1	Wetted area factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape (refer to Figure 5-2 for value)	
* CAFBC2	Wetted area factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape (refer to Figure 5-2 for value)	
* CAFD(I)	Wetted area factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape (refer to Figure 5-2 for value). When ZLFD(I) = zero, CAFD(I) = zero.	
* CAIBC1	Wetted area factor for intermediate pressure bulkheads in body pressure compartment No. 1, a function of ZLIBC1/DIBC1 and bulkhead shape (refer to Figure 5-2 for value)	
* CAIBC2	Wetted area factor for intermediate pressure bulkheads in body pressure compartment No. 2, a function of ZLIBC2/DIBC2 and bulkhead shape (refer to Figure 5-2 for value)	
* CBAC	Weight factor for stringers and longerons in aircraft bodies only	
* CBAR	Weight factor for body pressure compartment walls or main propellant tank barrels (unrestricted by minimum allowable thickness	
* CBARM	Weight factor for body pressure compartment walls or main propellant tank barrels (restricted by minimum allowable thickness	
* CBASF	Weight factor for body bulkheads and special frames	
* CBLK	Weight factor for body pressure compartment bulkheads or main propellant tank domes (unrestricted by minimum allowable thickness)	
* CBLKM	Weight factor for body pressure compartment bulkheads or main propellant tank domes (restricted by minimum allowable thickness)	
* CBSV	Weight factor for stringers and longerons in space vehicle bodies only	
* CCD(I)	Type factor for aft dome of main propellant tank No. (I)	
* CCØNB	Weight contingency factor for body	
* CCTHT	Factor for carry-through structure for horizontal tail	
* CCTW1	Factor for carry-through structure for wing type 1	
* CCTW2	Factor for carry-through structure for wing type 2	
* CCTW3	Factor for carry-through structure for wing type 3	

Variable	Definition	Units
* CFTPW1	Weight factor for fuel tanks in wing, wing type 1	
* CFTPW2	Weight factor for fuel tanks in wing, wing type 2	
* CFTPW3	Weight factor for fuel tanks in wing, wing type 3	
* CGRØB	Weight growth factor for body	
* CIT1	Factor for identifying main propellant tank No. 1	
* CIT2	Factor for identifying main propellant tank No. 2	
* CKABC1	Kick frame area factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DAPC1 (refer to Figure 5-3 for value)	
* CKABC2	Kick frame area factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DAPC2 (refer to Figure 5-3 for value)	
* CKAD(I)	Kick frame area factor for aft dome of propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-3 for value)	
* CKFBC1	Kick frame area factor for forward bulkhead of body pressure compartment No. 1. A function of ZLFBC1/DFPC1 and bulkhead shape (refer to Figure 5-3 for value)	
* CKFBC2	Kick frame area factor for forward bulkhead of body pressure compartment No. 2. A function of ZLFBC2/DFPC2 and bulkhead shape (refer to Figure 5-3 for value)	
* CKFD(I)	Kick frame area factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape (refer to Figure 5-3 for value). When ZLFD(I) = zero, CKFD(I) = zero.	
* CKIBC1	Kick frame area factor for intermediate pressure bulkheads in body pressure compartment No. 1, a function of ZLIBC1/DIBC1 and bulkhead shape (refer to Figure 5-3 for value)	
* CKIBC2	Kick frame area factor for intermediate pressure bulkheads in body pressure compartment No. 2, a function of ZLIBC2/DIBC2 and bulkhead shape (refer to Figure 5-3 for value)	
* CLGPB	Weight factor for landing gear provision in body	
* CLRPB	Weight factor for liquid rocket engine provision in body	
* CPRØP(K)	Factor for identifying large propellant tanks (fuel or oxidizer container)	

Variable	Definition	Units
* CRIBHT	Weight factor for horizontal tail ribs	
* CRIBW1	Weight factor for wing ribs, wing type 1	
* CRIBW2	Weight factor for wing ribs, wing type 2	
* CRIBW3	Weight factor for wing ribs, wing type 3	
* CRW1	Theoretical wing root chord length, wing type 1	FT
* CRW2	Theoretical wing root chord length, wing type 2	FT
* CRW3	Theoretical wing root chord length, wing type 3	FT
* CSAC	Weight factor for body skin and frames in aircraft only	
* CSB	Body wetted area shape factor	
* CSHT	Length of horizontal tail chord at side of body	FT
* CSSB	Weight factor for body secondary structure	
* CSSV	Weight factor for skin and frames in unpressurized body of space vehicles only	
* CSW1	Length of wing chord at side of body, wing type 1	FT
* CSW2	Length of wing chord at side of body, wing type 2	FT
* CSW3	Length of wing chord at side of body, wing type 3	FT
* CTABC1	Material thickness factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DAPC1 and bulkhead shape (refer to Figure 5-4 for value)	
* CTABC2	Material thickness factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DAPC2 and bulkhead shape (refer to Figure 5-4 for value)	
* CTAD(I)	Material thickness factor for aft dome of main propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-4 for value)	
* CTEW1	Length of equivalent wing tip chord, wing type 1 = 2. (SEW1)/ (BW1 - BBW1) - CSW1.	FT
* CTEW2	Length of equivalent wing tip chord, wing type 2 = CSW2	FT
* CTEW3	Length of equivalent wing tip chord, wing type 3 = 2. (SØW3)/[BW3 - 2. (BBW3) - BCW3] - CSW3, where SØW3 = exposed horizontal planform wing area outboard of bodies.	FT

Variable	Definition	Units
* CTFBC1	Material thickness factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape (refer to Figure 5-4 for value)	
* CTFBC2	Material thickness factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape (refer to Figure 5-4 for value)	
* CTFD(I)	Material thickness factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape (refer to Figure 5-4 value). When ZLFD(I) = zero, CTFD(I) = zero.	
* CTHT	Length of horizontal tail chord at tip	FT
* CTIBC1	Material thickness factor for intermediate pressure bulkheads in body pressure compartment No. 1, a function of ZLIBC1/DIBC1 and bulkhead shape (refer to Figure 5-4 for value)	
* CTIBC2	Material thickness factor for intermediate pressure bulkheads in body pressure compartment No. 2, a function of ZLIBC2/DIBC2 and bulkhead shape (refer to Figure 5-4 for value)	
* CVABC1	Volume factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DAPC1 and bulkhead shape (refer to Figure 5-5 for value)	
* CVABC2	Volume factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DAPC2 and bulkhead shape (refer to Figure 5-5 for value)	
* CVB	Body volume shape factor	
* CVFBC1	Volume factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape (refer to Figure 5-5 for value)	
* CVFBC2	Volume factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape (refer to Figure 5-5 for value)	

Variable	Definition	Units
* DAHT	Dihedral angle of the horizontal tail	DEG
* DAPC1	Diameter at aft end of wall of body pressure compartment No. 1; if aft end of compartment is not circular, an equivalent DAPC1 = (compartment height x compartment width)$^{.5}$	FT
* DAPC2	Diameter at aft end of wall of body pressure compartment No. 2; if aft end of compartment is not circular, a equivalent DAPC2 = (compartment height x compartment width)$^{.5}$	FT
* DAT(I)	Diameter at aft end of barrel of main propellant tank No. (I). If aft end of barrel is not circular, an equivalent DAT(I) = (barrel height x barrel width)$^{.5}$	FT
* DENIT1	Density of structural material of main integral propellant tank No. 1	LB/CU IN
* DENIT2	Density of structural material of main integral propellant tank No. 2	LB/CU IN
* DENSBM	Density of body structural material	LB/CU IN
* DFPC1	Diameter at forward end of wall of body pressure compartment No. 1; if forward end of compartment is not circular, an equivalent DFPC1 = (compartment Height x width)$^{.5}$	FT
* DFPC2	Diameter at forward end of wall of body pressure compartment No. 2; if forward end of compartment is not circular, an equivalent DFPC2 = (compartment height x width)$^{.5}$	FT
* DFT(I)	Diameter at forward end of barrel of main propellant tank No. (I); if forward end of barrel is not circular, an equivalent DFT(I) = (barrel height x barrel width)$^{.5}$	FT
* DIBC1	Average diameter of intermediate pressure bulkheads in body pressure compartment No. 1	FT
* DIBC2	Average diameter of intermediate pressure bulkheads in body pressure compartment No. 2	FT
* GWLAND	Landing gross weight (an assigned value)	LB

Variable	Definition	Units
* GWST	Total vehicle stage weight at initiation of full thrust (at launch or in flight) (an assigned value)	LB
* GWST1	Total weight of stage 1 at launch (an assigned value)	LB
* HB	Maximum height of body	FT
* PADT(I)	Ultimate design pressure for aft dome of main propellant tank No. (I)	PSIG
* PBT(I)	Ultimate design pressure for barrel of main propellant tank No. (I)	PSIG
* PFDT(I)	Ultimate design pressure for forward dome of main propellant tank No. (I)	PSIG
* PPC1	Ultimate design pressure for body pressure compartment No. 1	PSIG
* PPC2	Ultimate design pressure for body pressure compartment No. 2	PSIG
SABPC1	Wetted area of aft bulkhead of body pressure compartment No. 1	SQ FT
SABPC2	Wetted area of aft bulkhead of body pressure compartment No. 2	SQ FT
SADT(I)	Wetted area of aft dome of main propellant tank No. (I)	SQ FT
* SB	Wetted area per structural body; if an assigned value is not available, SB may be estimated as CSB(ZLB)(HB+BB)	SQ FT
SBR	Wetted area per body of unpressurized sections	SQ FT
SBT(I)	Wetted area of barrel of main propellant tank No. (I)	SQ FT
* SEHT	Exposed horizontal planform area of horizontal tail	SQ FT
* SEW1	Exposed horizontal planform area of wing, wing type 1	SQ FT
* SEW2	Exposed horizontal planform area of wing, wing type 2	SQ FT
* SEW3	Exposed horizontal planform area of wing, wing type 3	SQ FT
SFBPC1	Wetted area of forward bulkhead of body pressure compartment No. 1	SQ FT

Variable	Definition	Units
SFBPC2	Wetted area of forward bulkhead of body pressure compartment No. 2	SQ FT
SFDT(I)	Wetted area of forward dome of main propellant tank No. (I)	SQ FT
SIBPC1	Average area per intermediate pressure bulkhead in body pressure compartment No. 1	SQ FT
SIBPC2	Average area per intermediate pressure bulkhead in body pressure compartment No. 2	SQ FT
* SW1	Wing theoretical horizontal planform area, wing type 1	SQ FT
* SW2	Wing theoretical horizontal planform area, wing type 2	SQ FT
* SW3	Wing theoretical horizontal planform area, wing type 3	SQ FT
SWPC1	Wetted area of wall of body pressure compartment No. 1	SQ FT
SWPC2	Wetted area of wall of body pressure compartment No. 2	SQ FT
* TABE	Thrust of each air breathing engine (sea level static)	LB
* TLRE	Thrust of each liquid rocket engine (sea level or vacuum rating compatible with operating regime)	LB
* TLRE1	Thrust of each main liquid rocket engine operating during stage 1 (vacuum rating)	LB
* TMPC1	Minimum allowable material thickness of wall or bulkheads of body pressure compartment No. 1	IN
* TMPC2	Minimum allowable material thickness of wall or bulkheads of body pressure compartment No. 2	IN
* TMT(I)	Minimum allowable material thickness of barrel or domes of main propellant tank No. (I)	IN
* TSHT	Maximum horizontal tail thickness at side of body	FT
* TSW1	Maximum wing thickness at side of body, wing type 1	FT
* TSW2	Maximum wing thickness at side of body, wing type 2	FT
* TSW3	Maximum wing thickness at side of body, wing type 3	FT
U1	Ultimate unit loading, wing type 1	PSF
U2	Ultimate unit loading, wing type 2	PSF
U3	Ultimate unit loading, wing type 3	PSF

Variable	Definition	Units
* UDTLF	Ultimate design thrust load factor = 1.5 ZNLRE • (TLRE)/GWST for stage 1 only, = 1.5 ZNLRE1 • (TLRE1)/ (GWST1-WUP1) for stage 2 only, or = ATLF, if smaller than either, but not equal to zero.	
UH	Design unit load parameter for horizontal tail	
* UTSBM	Ultimate tensile strength of the body structural material at the critical design temperature	LB/SQ IN
* UTST(I)	Ultimate tensile strength of the structural material of main propellant tank No. (I) at the critical design temperature	LB/SQ IN
VABPC1	Aft bulkhead volume in body pressure compartment No. 1	CU FT
VABPC2	Aft bulkhead volume in body pressure compartment No. 2	CU FT
* VB	Volume per structural body;if an assigned value is not available, VB may be estimated as CVB(ZLB)HB(BB).	CU FT
VBFT	Volume of bladder fuel tanks in vehicle	CU FT
VBR	Unpressurized volume per structural body	CU FT
VFBPC1	Forward bulkhead volume in body pressure compartment No. 1	CU FT
VFBPC2	Forward bulkhead volume in body pressure compartment No. 2	CU FT
* VMAX	Maximum design velocity of vehicle	FT/SEC
VØLT(I)	Volume of main propellant tank No. (I)	CU FT
VPC1	Volume of body pressure compartment No. 1	CU FT
VPC2	Volume of body pressure compartment No. 2	CU FT
VWPC1	Barrel volume in body pressure compartment No. 1	CU FT
VWPC2	Barrel volume in body pressure compartment No. 2	CU FT
WABC1	Weight of aft bulkhead of body pressure compartment No. 1	LB
WABC2	Weight of aft bulkhead of body pressure compartment No. 2	LB
WADFT	Aft dome weight of integral fuel tank	LB
WADØT	Aft dome weight of integral oxidizer tank	LB
WAEPB	Air breathing engine provision weight in body, per vehicle	LB
WB	Total body weight, per vehicle	LB

Variable	Definition	Units
* WBAC	Weight of body and contents, when ZNAF applies, for aircraft only	LB
WBAFG	Weight of bulkheads and special frames in unpressurized body, excluding major carry-through structure for wing and horizontal tail	LB
WBASF	Weight of bulkheads, integral propellant tank domes, and special frames	LB
WBASFR	Weight of bulkheads and special frames in unpressurized body	LB
WBCTW1	Body carry-through structure weight for wing type 1	LB
WBCTW2	Body carry-through structure weight for wing type 2	LB
WBCTW3	Body carry-through structure weight for wing type 3	LB
WBLKC1	Weight of bulkheads in body pressure compartment No. 1	LB
WBLKC2	Weight of bulkheads in body pressure compartment No. 2	LB
WBMB	Weight of longitudinal stringers, longerons, beams and structural floors	LB
WCØNB	Contingency weight for body, per vehicle	LB
WDFT	Weight of domes of integral fuel tank	LB
WDØT	Weight of domes of integral oxidizer tank	LB
WFBC1	Weight of forward bulkhead in body compartment No. 1	LB
WFBC2	Weight of forward bulkhead in body compartment No. 2	LB
WFDFT	Forward dome weight of integral fuel tank	LB
WFDØT	Forward dome weight of integral oxidizer tank	LB
WFTPB	Air breathing engine fuel tank provision weight in body, per vehicle	LB
WGRØB	Growth weight for body, per vehicle	LB
WHTCT	Body carry-through structure weight for horizontal tail	LB
WIBC1	Weight of all intermediate bulkheads in body pressure compartment No. 1	LB
WIBC2	Weight of all intermediate bulkheads in body pressure compartment No. 2	LB
WLGPB	Body landing gear provision weight, per vehicle	LB
WLRPB	Liquid rocket engine provision weight in body, per vehicle	LB
WPSB	Body primary structure weight, per vehicle	LB

Variable	Definition	Units
WSAF	Total skin and frames weight in body, per vehicle	LB
WSAFC1	Skin and frames weight in body pressure compartment No. 1, per vehicle	LB
WSAFC2	Skin and frames weight in body pressure compartment No. 2, per vehicle	LB
WSAFFT	Skin and frames weight in body integral fuel tank, per vehicle	LB
WSAFØT	Skin and frames weight in body integral oxidizer tank, per vehicle	LB
WSAFR	Skin and frames weight in unpressurized body, per vehicle	LB
* WSPB	Special features weight of body, per vehicle	LB
WSRB	Weight to strength ratio of body structural material	IN-1
WSRHT	Weight to strength ratio of horizontal tail structural material	IN-1
WSRIT1	Weight to strength ratio of structural material of main integral propellant tank No. 1	IN-1
WSRIT2	Weight to strength ratio of structural material of main integral propellant tank No. 2	IN-1
WSRW	Weight to strength ratio of wing structural material	IN-1
WSSB	Body secondary structure weight, per vehicle	LB
WTBB	Body weight excluding contingency and growth	LB
* WUP1	Usable propellant weight for stage 1 operation (an assigned value)	LB
* ZLABC1	Convex height of aft bulkhead of body pressure compartment No. 1	FT
* ZLABC2	Convex height of aft bulkhead of body pressure compartment No. 2	FT
* ZLAD(I)	Convex height of aft dome of main propellant tank No. (I)	FT
* ZLB	Overall structural length of body	FT
* ZLCD(I)	Concave height of aft dome of main propellant tank No. (I), in the case of a common dome. E.g., ZLCD1 is to be used instead of ZLFD2.	FT
* ZLFBC1	Convex height of forward bulkhead of body pressure compartment No. 1	FT

Variable	Definition	Units
* ZLFBC2	Convex height of forward bulkhead of body pressure compartment No. 2	FT
* ZLFD(I)	Convex height of forward dome of main propellant tank No. (I); when a forward dome is common to the forward adjoining tank, it shall be considered as part of the fwd adjoining tank.	FT
* ZLIBC1	Average convex or concave height of intermediate pressure bulkheads in body compartment No. 1	FT
* ZLIBC2	Average convex or concave height of intermediate pressure bulkheads in body compartment No. 2	FT
* ZLST	Overall length of vehicle stage	FT
* ZLWPC1	Length of wall of body pressure compartment No. 1	FT
* ZLWPC2	Length of wall of body pressure compartment No. 2	FT
* ZNABEB	Quantity of air breathing engines in or on each body	
* ZNAF	Ultimate flight vertical load factor at GWRE	
* ZNB	Quantity of identical bodies per vehicle	
* ZNIBC1	Quantity of intermediate pressure bulkheads per body in body pressure compartment No. 1	
* ZNIBC2	Quantity of intermediate pressure bulkheads per body in body pressure compartment No. 2	
* ZNLD	Ultimate landing vertical load factor	
* ZNLRE	Quantity of liquid rocket engines	
* ZNLRE1	Quantity of main liquid rocket engines operating during stage 1	
ZNØFHT	Horizontal tail non-optimum factor for primary structure weight	
ZNØFW1	Wing non-optimum factor for primary structure weight, wing type 1	
ZNØFW2	Wing non-optimum factor for primary structure weight, wing type 2	
ZNØFW3	Wing non-optimum factor for primary structure weight, wing type 3	
* ZNPT(I)	Quantity of main propellant tanks No. (I), per vehicle	
	Wetted area of aft bulkhead of body pressure compartment No. 1 (AABPC1) = ZNB(SABPC1)	SQ FT
	Wetted area of aft bulkhead of body pressure compartment No. 2 (AABPC2) = ZNB (SABPC2)	SQ FT

Variable	Definition	Units
	Wetted area of aft dome of forward body integral propellant tank (AADIT1) = ZNPT1(SADT1)CIT1	SQ FT
	Wetted area of aft dome of aft body integral propellant tank (AADIT2) = ZNPT2(SADT2)CIT2	SQ FT
	Wetted area of barrel of forward body integral propellant tank (ABINT1) = ZNPT1(SBT1)CIT1	SQ FT
	Wetted area of barrel of aft body integral propellant tank (ABINT2) = ZNPT2(SBT2)CIT2	SQ FT
	Wetted area of unpressurized sections of body (ABRUNP) = ZNB(SBR).	SQ FT
	Wetted area of forward bulkhead of body pressure compartment No. 1 (AFBPC1) = ZNB(SFBPC1)	SQ FT
	Wetted area of forward bulkhead of body pressure compartment No. 2 (AFBPC2) = ZNB(SFBPC2)	SQ FT
	Wetted area of forward dome of forward body integral propellant tank (AFDIT1) = ZNPT1(SFDT1)CIT1	SQ FT
	Wetted area of forward dome of aft body integral propellant tank (AFDIT2) = ZNPT2(SFDT2)CIT2	SQ FT
	Wetted area of intermediate pressure bulkheads in body pressure compartment No. 1 (AIBPC1) = ZNB(ZNIBC1)SIBPC1	SQ FT
	Wetted area of intermediate pressure bulkheads in body pressure compartment No. 2 (AIBPC2) = ZNB(ZNIBC2)SIBPC2	SQ FT
	Wetted area of wall of body pressure compartment No. 1 (AWPC1) = ZNB(SWPC1)	SQ FT
	Wetted area of wall of body pressure compartment No. 2 (AWPC2) = ZNB(SWPC2)	SQ FT
	Ultimate design pressure for aft dome of forward body integral propellant tank (PADIT1) = PADT1(CIT1)	PSIG
	Ultimate design pressure for aft dome of aft body integral propellant tank (PADIT2) = PADT2(CIT2)	PSIG
	Ultimate design pressure for barrel of forward body integral propellant tank (PBIT1) = PBT1(CIT1)	PSIG
	Ultimate design pressure for barrel of aft body integral propellant tank (PBIT2) = PBT2(CIT2)	PSIG
	Ultimate design pressure for forward dome of forward body integral propellant tank (PFDIT1) = PFDT1(CIT1)	PSIG
	Ultimate design pressure for forward dome of aft body integral propellant tank (PFDIT2) = PFDT2(CIT2)	PSIG

Variable	Definition	Units
	Volume of body pressure compartment No. 1 (VBØDP1) = ZNB(VPC1)	CU FT
	Volume of body pressure compartment No. 2 (VBØDP2) = ZNB(VPC2)	CU FT
	Volume of unpressurized sections of body (VBRUNP) = ZNB(VBR)	CU FT
	Volume of bladder type fuel tanks in body (VBTB) = VBFT(1. - CFTPW1 - CFTPW2 - CFTPW3)	CU FT
	Volume of forward body integral propellant tank (VPTIT1) = VOLT1(CIT1)ZNPT1	CU FT
	Volume of aft body integral propellant tank (VPTIT2) = VOLT2(CIT2)ZNPT2	CU FT

*Input

INDUCED ENVIRONMENT PROTECTION

The weight for protection against aerodynamic heating is considered as a function of the square of the maximum vehicle velocity in the earth's atmosphere, the type of protection (radiative or ablative, active or passive), the type of vehicle (booster, orbiter, or sub-orbiter, operational or experimental), and the true planform area of aerodynamic surfaces, the body wetted area of lifting bodies and winged vehicles, and the cross-sectional area of ballistic reentry vehicles. The amount of weight required for protection against aerodynamic heating is very dependent on the degree of optimization achieved by the combination of active and/or passive thermal protection arrangements acting in conjunction with the load-carrying capability of primary structure at non-uniform elevated temperatures, and some amount of internal insulation.

The weight for protection against base heating is considered as a function of the cube root of the total engine thrust and the type of vehicle (booster, orbiter, or vehicle launch escape system).

The weight for thermal, noise, meteorite, and radiation protection on space stations and space modules is considered as a function of the type of mission and the wetted body area.

The total weight of induced environment protection is defined as:

3.0 WIEP = WTP + WNP + WMP + WRP + WSPIEP + WCØNEP + WGRØEP.

3.1 Thermal Protection (Active and Passive)

WTP = WTPW + WTPHT + WTPVT + WTPB + WTPBH.

3.1.1 Wing

$$WTPW = CTPW(10^{-9})(VMAX, \gtrsim 3000)^2 \; SEWT, \text{ where}$$

$$SEWT = SEWT1 + SEW2 + SEWT3.$$

$$\text{SEWT1} = \text{CTF1}\Big[(\text{BW1} - \text{BFW1})(\text{CTEW1} + \text{CFW1})/(2\cos\text{DAWT1}) + (\text{BFW1} - \text{BBW1})(\text{CFW1} + \text{CSW1})/(2\cos\text{DAW1})\Big] + (1 - \text{CTF1})\text{SEW1}/\cos\text{DAW1}.$$

$$\text{SEWT3} = \text{BCW3}(\text{CSW3}) + \text{CTF3}\Big[(\text{BW3} - \text{BFW3})(\text{CTEW3} + \text{CFW3})/(2\cos\text{DAWT3}) + (\text{BFW3} - 2\text{BBW3} - \text{BCW3})(\text{CFW3} + \text{CSW3})/(2\cos\text{DAW3})\Big] + (1 - \text{CTF3})(\text{BW3} - 2\text{BBW3} - \text{BCW3})\bullet(\text{CTEW3} + \text{CSW3})/(2\cos\text{DAW3}).$$

3.1.2 Horizontal Tail

$$\text{WTPHT} = \text{CTPHT}(10^{-9})(\text{VMAX}, \gtrsim 3000)^2\ \text{SEHTT}, \text{ where}$$

$$\text{SEHTT} = \text{SEHT}/\cos\text{DAHT}.$$

3.1.3 Vertical Tail

$$\text{WTPVT} = \text{CTPVT}(10^{-9})(\text{VMAX}, \gtrsim 3000)^2\ \text{SVTT}, \text{ where}$$

$$\text{SVTT} = \text{ZNVT}(\text{SVT})/\cos(90 - \text{DAVT}).$$

3.1.4 Body

$$\text{WTPB} = \text{CTPGB}(10^{-9})(\text{VMAX}, \gtrsim 3000)^2\text{ZNB}(\text{SB}) + \text{CTPBB}(20)10^{-9}(\text{VMAX}, \gtrsim 3000)^2\bullet \text{HB}(\text{BB}) + \text{CTPNRB}(\text{SB}).$$

3.1.5 Base Heating

$$\text{WTPBH} = \text{CTPBH}\left\{\Big[\text{ZNLRE}(\text{TLRE})\Big]^{1/3} + (\text{TSRE})^{1/3}\right\}.$$

3.3 Noise Protection

$$\text{WNP} = \text{CNP}(\text{SB}).$$

3.4 Meteorite Protection

$$\text{WMP} = \text{CMP}(\text{SB}).$$

3.5 Radiation Protection

$$\text{WRP} = \text{CRP}(0.04)\text{SB}.$$

3.18 Special Features

WSPIEP = WSPIEP.

3.19 Contingency

WCØNEP = CCØNEP(WTBIEP), where

WTBIEP = WTP + WNP + WMP + WRP + WSPIEP.

3.20 Growth

WGRØEP = CGRØEP(WTBIEP + WCØNEP).

INDUCED ENVIRONMENT PROTECTION DEFINITIONS

Variable	Definition	Units
* BB	Maximum width of body	FT
* BBW1	Maximum body width at wing intersection, wing type 1	FT
* BBW3	Maximum body width at wing intersection, wing type 3	FT
* BCW3	Exposed horizontal planform wing span between bodies, wing type 3	FT
* BFW1	Horizontal planform wing span between bases of upswept wing tips, wing type 1	FT
* BFW3	Horizontal planform wing span between bases of upswept wing tips, wing type 3	FT
* BW1	Horizontal planform wing span, wing type 1	FT
* BW3	Horizontal planform wing span, wing type 3	FT
* CCØNEP	Weight factor for induced environment protection contingency	
* CFW1	Length of wing chord at base of upswept wing tip, wing type 1	FT
* CFW3	Length of wing chord at base of upswept wing tip, wing type 3	FT
* CGRØEP	Weight factor for induced environment protection growth	
* CMP	Weight factor for meteorite protection	
* CNP	Weight factor for noise protection	
* CRP	Weight factor for radiation protection	
* CSW1	Length of wing chord at side of body, wing type 1	FT
* CSW3	Length of wing chord at side of body, wing type 3	FT
* CSB	Body wetted area shape factor	

Variable	Definition	Units
* CTEW1	Length of equivalent wing tip chord, wing type 1 = 2.(SEW1)/(BW1-BBW1) - CSW1	FT
* CTEW3	Length of equivalent wing tip chord, wing type 3 = 2.(SØW3)/[BW3-(2.)(BBW3) - BCW3] - CSW3, where SØW3 = exposed horizontal planform wing area outboard of bodies	FT
* CTF1	Weight factor for wing tip fins, wing type 1	
* CTF3	Weight factor for wing tip fins, wing type 3	
* CTPBB	Weight factor for body thermal protection - ballistic reentry vehicles only	
* CTPBH	Weight factor for base heating thermal protection	
* CTPGB	Weight factor for body thermal protection - glide reentry vehicles only	
* CTPHT	Weight factor for horizontal tail thermal protection	
* CTPNRB	Weight factor for body thermal protection - non-reentry space vehicles only	
* CTPVT	Weight factor for vertical tail thermal protection	
* CTPW	Weight factor for wing thermal protection (Note: All thermal protection weight factors will have a considerable tolerance because of their dependence on the degree of optimization achieved by the combination of active and/or passive thermal protection, primary structure and internal insulation)	
* DAHT	Dihedral angle of horizontal tail	DEG
* DAVT	Dihedral angle of vertical tail (measured from horizontal plane)	DEG
* DAW1	Dihedral angle of wing, wing type 1	DEG
* DAW3	Dihedral angle of wing, wing type 3	DEG
* DAWT1	Dihedral angle of integral wing tip segment, wing type 1	DEG
* DAWT3	Dihedral angle of integral wing tip segment, wing type 3	DEG
* HB	Maximum height of body	FT
* SB	Wetted area per structural body. If an assigned value is not available, SB may be estimated as CSB(ZLB)(HB + BB)	SQ FT
* SEHT	Exposed horizontal planform area of horizontal tail	SQ FT
SEHTT	True area of horizontal tail (external to body)	SQ FT
* SEW1	Exposed horizontal planform area of wing, wing type 1	SQ FT
* SEW2	Exposed horizontal planform area of wing, wing type 2	SQ FT

Variable	Definition	Units
SEWT	Total true area (external to body) of all wings on the vehicle	SQ FT
SEWT1	True area of wing type 1 (external to body)	SQ FT
SEWT3	True area of wing type 3 (external to body)	SQ FT
* SVT	Vertical planform exposed area of each vertical tail	SQ FT
SVTT	True area of vertical tails	SQ FT
* TLRE	Thrust of each main liquid rocket engine	LB
* TSRE	Total solid rocket motor thrust of vehicle	LB
* VMAX	Maximum design velocity of vehicle	FT/SEC
WCØNEP	Induced environment protection contingency weight	LB
WGRØEP	Induced environment protection growth weight	LB
WIEP	Induced environment protection weight	LB
WMP	Meteorite protection weight	LB
WNP	Noise protection weight	LB
WRP	Radiation protection weight	LB
* WSPIEP	Induced environment protection special features weight	LB
WTBIEP	Induced environment protection weight excluding contingency and growth	
WTP	Thermal protection weight (active and passive)	LB
WTPB	Body thermal protection weight	LB
WTPBH	Base heating thermal protection weight	LB
WTPHT	Horizontal tail thermal protection weight	LB
WTPVT	Vertical tail thermal protection weight	LB
WTPW	Wing thermal protection weight	LB
* ZNB	Quantity of bodies	
* ZNLRE	Quantity of liquid rocket engines	
* ZNVT	Quantity of vertical tails	
	Body thermal protection unit weight of wetted area (UWTPB) = (WTPB + WTPBH)/[ZNB(SB)]	LB/SQ FT
	Horizontal tail thermal protection unit weight of planform area (UWTPHT) = WTPHT/SEHTT	LB/SQ FT
	Vertical tail thermal protection unit weight of planform area (UWTPVT) = WTPVT/SVTT	LB/SQ FT
	Wing thermal protection unit weight of planform area (UWTPW) = WTPW/SEWT	LB/SQ FT
* ZLB	Overall Structural length of body	FT

* Input

LAUNCH, RECOVERY AND DOCKING

The launch, recovery and docking group is concerned with the weight of items essential to the launching, recovery and docking of space vehicles and the horizontal landing of aircraft. The total weight of this group is defined as:

4.0 WLAR = WTØG + WDAD + WLG + WFLØAT + WDØCK + WRAID + WIMPS + WSP4 + WCØN4 + WGRØ4.

4.1 Launch gear

WTØG = WLAS + WHAN + WSEPAR.

4.1.1 Launch Support Structure

WLAS = (0.00055)(CATØP)(GWST).

4.1.3 Handling Fittings

WHAN = (0.34)(CHAN)(GWHAN)$^{1/3}$.

4.1.4 Separation System

WSEPAR = WSEPAR.

4.2 Deployable Aerodynamic Devices

WDAD = WDRCH + WPICH + WMACH + WDGCH + WSTCH + WCØCH.

4.2.1 Drogue Parachute

WDRCH = (0.0064)(CDRCH)(GWLAND).

4.2.2 Pilot Parachute (Vehicle)

WPICH = (0.06)(CPICH)(WMACH).

4.2.3 Main Parachutes

WMACH = (CMACH)(1. + CMCREL)(GWLAND)(VSINK)$^{-2}$.

4.2.4 Drag Parachute

WDGCH = (CDGCH)(GWLAND).

4.2.5 Structural and Release Systems

$$WSTCH = (0.18)(CSTCH)(WDRCH + WPICH + WMACH + WDGCH).$$

4.2.6 Sequencing Controls

$$WC\emptyset CH = WC\emptyset CH.$$

4.3 Landing Gear

$$WLG = WMLG + WNLG + WTLG + W\emptyset LG.$$

4.3.1 Main Gear

$$WMLG = WMLGS + WMLGF + WMLGB + WMLGC.$$

4.3.1.1 Struts

$$WMLGS = (0.0219)(CMLGS)(ZNMLG) \bullet \left[\frac{(GWLAND)(ZLMLGE)(ZNLD-1.5)(ZLBG-ZLGCG)}{(ZNMLG)(ZLBG)}\right]^{0.8}, \text{ or}$$

$$(1.6 \times 10^{-4})\left[(CLMMGS)(GWLAND)(VSINK)^2(ZLMMGS)(GRVR)\right].$$

4.3.1.2 Wheels, Tires, Tubes, Air, Skids and Pads

$$WMLGF = (2.25 \times 10^{-3})(CMLGF)\left[\frac{(GWLAND)(ZLBG-ZLGCG)}{(ZLBG)}\right]^{1.15}, \text{ or}$$

$$(6.2 \times 10^{-5})\left[(CLMMGF)(GWLAND)(VSINK)^2(DIAPAD)(GRVR)\right].$$

4.3.1.3 Brakes

$$WMLGB = (CMLGB)(1.-CNLGB)(GWLAND).$$

4.3.1.4 Controls

$$WMLGC = (CMLGC)(WMLGS + WMLGF + WMLGB)^{0.8}.$$

4.3.2 Nose Gear (also Forward Gear of Bicycle Type)

$$WNLG = WNLGS + WNLGF + WNLGB + WNLGC.$$

4.3.2.1 Struts

$$WNLGS = (0.0272)(CNLGS)(ZNNLG)\left[\frac{(GWLAND)(ZLNLGE)(ZNLD-1.5)(ZLGCG)}{(ZNNLG)(ZLBG)}\right]^{0.8}.$$

4.3.2.2 Wheels, Tires, Tubes, Air, and Skids

$$WNLGF = (3.85 \times 10^{-3})(CNLGF)\left[\frac{(GWLAND)(ZLGCG)}{(ZLBG)}\right]^{1.15}.$$

4.3.2.3 Brakes

$$WNLGB = (CMLGB)(CNLGB)(GWLAND).$$

4.3.2.4 Controls

$$WNLGC = (1.21)(CNLGC)(WNLGS + WNLGF + WNLGB)^{0.8}.$$

4.3.3 Tail Landing Gear (Tail Bumper)

$$WTLG = \frac{(CTLG)(GWLAND)}{ZLMTG}.$$

4.3.4 Outrigger Landing Gear

$$WØLG = (4.37 \times 10^{-3})(CØLG)(ZLØLGE)\left[\frac{(ZNLD)(GWLAND)(BW1)}{(BWØLC)}\right]^{0.75}.$$

4.4 Flotation

$$WFLØAT = (CFLØAT)(GWLAND).$$

4.5 Docking

$$WDØCK = WDØLTH + WDØPØS + WDØTUN$$

4.5.3 Latching Mechanisms

$$WDØLTH = (CDØLTH)(ZNDØCK)(DIDØCK).$$

4.5.4 Repositioning Devices

$$WDØPØS = (CDØPØS)(ZNDØCK)(DIDØCK).$$

4.5.7 Tunnel

$$WDØTUN = (CDØTUN)(ZNDØCK)(DIDØCK)(ZLDØCK).$$

4.6 Recovery Aids

$$WRAID = WRAID.$$

4.7 Impact System

$$WIMPS = (CIMPS)(GWLAND).$$

4.18 Special Features

WSP4 = WSP4.

4.19 Contingency

WCØN4 = (CCØN4)(WTB4), where

WTB4 is the sum of all the items preceding 4.19.

4.20 Growth

WGRØ4 = (CGRØ4)(WCØN4 + WTB4).

LAUNCH, RECOVERY, AND DOCKING DEFINITIONS

Variable	Definition	Units
* BW1	Horizontal planform wing span, wing type 1	FT
* BWØLC	Span of outrigger landing gear attachment points	FT
* CATØP	Weight factor for launch fittings	
* CCØN4	Weight factor for contingency for launch, recovery, and docking	
* CDGCH	Weight factor for drag parachutes	
* CDØLTH	Weight factor for docking latching mechanisms	
* CDØPØS	Weight factor for docking repositioning devices	
* CDØTUN	Weight factor for docking tunnels	
* CDRCH	Weight factor for drogue parachutes	
* CFLØAT	Weight factor for flotation gear	
* CGRØ4	Weight factor for growth for launch, recovery, and docking	
* CHAN	Weight factor for handling fittings	
* CIMPS	Weight factor for impact system	
* CLMMGF	Weight factor for landing gear pads (LM-D type)	
* CLMMGS	Weight factor for landing gear struts (LM-D type)	
* CMACH	Weight factor for main parachutes	
* CMCREL	Weight factor for backup for main parachutes	
* CMLGB	Weight factor for landing gear brakes	
* CMLGC	Weight factor for controls for main landing gear	
* CMLGF	Weight factor for main landing gear wheels, tires, etc. (aircraft type)	

Variable	Definition	Units
* CMLGS	Weight factor for main landing gear struts (aircraft type)	
* CNLGB	Factor for brakes on nose gear (proportion of static weight on nose gear of total weight). On bicycle type, forward gear is considered as nose gear	
* CNLGC	Weight factor for nose landing gear controls	
* CNLGF	Weight factor for nose landing gear wheels, tires, etc.	
* CNLGS	Weight factor for nose landing gear struts	
* CØLG	Weight factor for outrigger landing gear	
* CPICH	Weight factor for vehicle's pilot parachute	
* CSTCH	Weight factor for structural and release provisions for deployable aerodynamic devices	
* CTLG	Weight factor for tail landing gear	
* DIAPAD	Diameter of landing gear pads (LM-D type)	FT
* DIDØCK	Diameter of docking tunnel and port	FT
* GRVR	Gravity ratio for landing gear (LM-D type). Ratio of gravity environment for landing gear operation to that of earth's gravity	
* GWHAN	Design handling gross weight (an assigned value)	LB
* GWLAND	Landing gross weight (an assigned value)	LB
* GWST	Total vehicle stage weight at initiation of full thrust (at launch or in flight) (an assigned value)	LB
* VSINK	Vehicle design sinking velocity at landing. (If sinking velocity is specified for altitude other than sea level, convert to sea level equivalent velocity by multiplying by the square root of the ratio of the air density at the specified altitude to that at sea level)	FT/SEC
* WCØCH	Weight factor for parachute sequencing controls	LB
WCØN4	Weight of contingency for launch, recovery, and docking	LB
WDAD	Weight of deployable aerodynamic devices	LB
WDGCH	Weight of drag parachutes	LB
WDØCK	Weight of docking equipment	LB
WDØLTH	Weight of docking latches	LB
WDØPØS	Weight of docking repositioning devices	LB
WDØTUN	Weight of docking tunnels	LB
WDRCH	Weight of drogue parachutes	LB

Variable	Definition	Units
WFLØAT	Weight of flotation gear	LB
WGRØ4	Weight of growth for launch, recovery, and docking	LB
WHAN	Weight of handling fittings	LB
WIMPS	Weight of impact system	LB
WLAR	Weight of launch, recovery, and docking	LB
WLAS	Weight of launch fittings	LB
WLG	Weight of landing gear	LB
WMACH	Weight of main parachutes	LB
WMLG	Weight of main landing gear	LB
WMLGB	Weight of main landing gear brakes	LB
WMLGC	Weight of main landing gear controls	LB
WMLGF	Weight of main landing gear wheels, tires, etc.	LB
WMLGS	Weight of main landing gear struts	LB
WNLG	Weight of nose landing gear	LB
WNLGB	Weight of nose landing gear brakes	LB
WNLGC	Weight of nose landing gear controls	LB
WNLGF	Weight of nose landing gear wheels, tires, etc.	LB
WNLGS	Weight of nose landing gear struts	LB
WØLG	Weight of outrigger landing gear	LB
WPICH	Weight of vehicle's pilot parachute	LB
* WRAID	Weight of recovery aids	LB
* WSEPAR	Weight of separation provisions	LB
* WSP4	Weight of special features for launch, recovery, and docking	LB
WSTCH	Weight of structural and release provisions for deployable aerodynamic devices	LB
WTB4	Weight of launch, recovery, and docking excluding contingency and growth	LB
WTLG	Weight of tail landing gear or tail bumper	LB
WTØG	Weight of launch gear	LB
* ZLBG	Length between main landing gear and nose landing gear, or length between forward and aft landing gears for bicycle type	FT
* ZLDØCK	Length of each docking tunnel (average if different)	FT

Variable	Definition	Units
* ZLGCG	Length between main landing gear and landing longitudinal center of gravity of vehicle (aft gear is considered the main gear of a bicycle type)	FT
* ZLMLGE	Length of main landing gear fully extended (axle to trunnion)	FT
* ZLMMGS	Length of landing gear (LM-D type) measured from contact point on the pad to the upper fitting on the body	FT
* ZLMTG	Length between main landing gear and tail landing gear	FT
* ZLNLGE	Length of nose landing gear fully extended (axle to trunnion)	FT
* ZLØLGE	Length of outrigger landing gear fully extended (axle to trunnion)	FT
* ZNDØCK	Quantity of docking locations	
* ZNLD	Ultimate design landing vertical load factor	
* ZNMLG	Quantity of main landing gear assemblies	
* ZNNLG	Quantity of nose landing gear assemblies	

* Input

MAIN PROPULSION

This group consists of all main propulsion items, including all non-integral propellant tanks. The weight equations under 5.8.1 and 5.11.1 are for booster type propellant tanks, where accelerated propellant head pressures and hydrostatic test conditions are major considerations. Other parameters also considered are tank shape, size, gas pressure, material properties, and use of common bulkheads. The weight equations are for tank structure and supports, as well as for baffling, insulation and feed line conduit. The last three weight items are also included in this group for booster type integral propellant tanks. Incorporated within the equations are considerations of optional limitations on the minimum gage of the barrels and domes.

Items 5.8.10 and 5.11.9 are liquid rocket propellant tanks that are estimated by using the pressure tank routine (see Group 5A). This routine ignores accelerated head pressures; it analyzes each tank for a uniform pressure condition. The intent of this procedure is for the weight estimation of non-booster type space vehicle propulsion tanks (e.g., SM, LM-D, LM-A), as well as for pressure tanks used for other functions (i.e., RCS fuel storage, breathing O_2 storage, etc.).

This weight group also includes liquid rocket and air breathing engines and accessories, solid propellant propulsion system, propellant distribution, and pressurization systems. The liquid rocket engines and air breathing engines (turbojet) can either be estimated by using known unit engine weights or as a function of thrust.

The total weight of the propulsion group is defined as:

5.0 WTMP = WLREA + WSPS1 + WABES + WTPS + WNIFC + WFS + WPSF +

WNIØC + WØS + WPSØ + WSP5 + WCØN5 + WGRØ5.

5.1 Liquid Rocket Engines and Accessories

$$WLREA = WLRE + WGLRE.$$

5.1.1 Engines and Accessories

$$WLRE = CMLRE(ZNLRE)\left[WULRE, \text{ or } CLRE(TLRE)\right].$$

5.1.2 Gimbals

$$WGLRE = \frac{CGLRE(WLRE)}{CMLRE}.$$

5.2 Solid Propellant Propulsion (Inerts Only)

$$WSPS1 = \frac{WCEL1(CA1 - 1.)(1. - CMF1)}{CMF1(CA1) - CA1 + 1.}, \text{ where}$$

$$CA1 = \exp\left[\frac{DELV1}{CISP1(32.17)CDAG1(\cos CANG1)}\right].$$

5.6 Air Breathing Engines and Accessories (Turbojet)

$$WABES = WABE + WSTAE + WACAE.$$

5.6.1 Engines

$$WABE = (ZNABE)\left[WUABE, \text{ or } 0.2(CABE)TABE\right].$$

5.6.2 Structural Provisions

$$WSTAE = WEMAE + WPYAE + WNAAE + WFWAE + WAIAE + WICAE.$$

5.6.2.1 Engine Mounts

$$WEMAE = 0.0046(CENGM)ZNABE(TABE).$$

5.6.2.2 Engine Pylons

$$WPYAE = (CPLAE)ZLPY(ZNABE)TABE(ZMACP)^{\frac{1}{2}}.$$

5.6.2.3 Engine Nacelles

$$WNAAE = 2.9(CENGN)ZLNAE(ZNNAE)(ZMACP)^{\frac{1}{2}}(BNAAE + HNAAE).$$

5.6.2.4 Firewalls

$$WFWAE = CFWAE(ZNABE)TABE.$$

5.6.2.5 Air Induction Ducts

$$WAIAE = 0.0052(CAIND)ZNABE(TABE)(ZLAID)^{\frac{1}{2}}.$$

5.6.2.6 Air Induction Controls

WICAE = CAIAE(ZNABE)TABE.

5.6.3 Engine Accessories

WACAE = WECAE + WEXAE + WESAE + WEIAE + WØSAE.

5.6.3.1 Engine Controls

WECAE = 0.65(CENGC)ZLENG.

5.6.3.2 Engine Exhausts

WEXAE = 0.0016(CENGE)ZNABE(TABE)ZLEXE.

5.6.3.3 Engine Starters

WESAE = CASAE(ZNABE)TABE.

5.6.3.4 Engine Injection Water System

WEIAE = 0.006(CEIAE)ZNABE(TABE).

5.6.3.5 Engine Oil System

WØSAE = 0.5(CØSAE)WEØAE.

5.7 Purge System for Stage Childown

WTPS = CPS(TLRE)ZNLRE.

5.8 Fuel Containers(Non-integral, Booster Type)

WNIFC = Sum of WNIFT(I) + WNSSI + WPTF, where

(I) can be 1 through 8. (I) will be replaced by i in the following equations to simplify the appearance of the various terms. There are two restrictions regarding the numbering of the booster type propellant tanks: (1) When two or more tanks are joined by common domes, the tanks shall be sequentially numbered from front to rear; (2) In the case of two integral tanks, the maximum quantity provided for, the fwd. one shall be No. 1 and the aft one shall be No. 2.

5.8.1 Non-integral Fuel Tank No. i

$$\text{WNIFTi} = \text{WSNITi} + \text{WBAFi} + \text{WSUPTi} + \text{WINSLi} + \text{WCØNDi}.$$

5.8.1.1 Tank Structure

$$\text{WSNITi} = \text{WFDTi} + \text{WBTi} + \text{WADTi}.$$

5.8.1.1.1 Forward Dome

$$\text{WFDTi} = \text{CBLK}(1560)\text{CPRØPi}(\text{ZNPTi})\text{WSRPTi}(\text{PFDTi})(\text{DFTi})^3 \cdot \left[\text{CTFDi}(\text{CAFDi}) + 10(\text{CKFDi})\right]$$

or

$$\text{CBLKM}(331)\text{CPRØPi}(\text{ZNPTi})\text{TMTi}(\text{SFDTi})\text{DENTi},$$

whichever is larger, where

$$\text{WSRPTi} = \text{DENTi}/\text{UTSTi};$$

$$\text{PFDTi} = \text{PGTi} + \text{PPFDi}, \text{ or } = \text{an assigned value, where}$$

$$\text{PPFDi} = \left[\text{ZLFDi} + \text{ZLCD}(i - 1)\right]\text{DENSW}/144, \text{ when UDTLF} \cdot (\text{DENPi}) < \text{DENSW},$$

$$\text{or } = \text{UDTLF}\left[\text{ZLFDi} + \text{ZLCD}(i - 1) + \text{ZLBTi} + \text{ZLADi}\right]\text{DENPi}/144 - (\text{ZLADi} + \text{ZLBTi})\text{DENSW}/144, \text{ when UDTLF}(\text{DENPi}) \geq \text{DENSW};$$

$$\text{SFDTi} = \text{CAFDi}(1.57)(\text{DFTi})^2.$$

5.8.1.1.2 Barrel

$$\text{WBTi} = \text{CBAR}(713)\text{CPRØPi}(\text{ZNPTi})\text{WSRPTi}(\text{PBTi})\text{SBTi}(\text{DFTi} + \text{DATi})$$

or

$$\text{CBARM}(238)\text{CPRØPi}(\text{ZNPTi})\text{TMTi}(\text{SBTi})\text{DENTi},$$

whichever is larger, where

$$\text{PBTi} = \text{PGTi} + \text{PPBTi}, \text{ or } = \text{an assigned value, where}$$

$$\text{PPBTi} = \left[\text{ZLFDi} + \text{ZLCD}(i - 1) + \tfrac{1}{2}\text{ZLBTi}\right]\text{DENSW}/144, \text{ when UDTLF}(\text{DENPi}) < \text{DENSW}, \text{ or } = \text{UDTLF}\left[\text{ZLFDi} + \text{ZLCD}(i - 1) + \text{ZLBTi} + \text{ZLADi}\right]\text{DENPi}/144 - (\text{ZLADi} + \tfrac{1}{2}\text{ZLBTi})\text{DENSW}/144,$$

when $UDTLF(DENPi) \geq DENSW$;

$$SBTi = 0.785(DFTi + DATi)\left[4(ZLBTi)^2 + (DFTi - DATi)^2\right]^{\frac{1}{2}}.$$

5.8.1.1.3 Aft Dome

$WADTi = CBLK(1560)CPR\emptyset Pi(ZNPTi)(1 + CCDi)WSRPTi(PADTi)(DATi)^3 \cdot \left[CTADi(CAADi) + 10(CKADi)\right]$ or $CBLKM(331)CPR\emptyset Pi(ZNPTi) \cdot (1 + CCDi)TMTi(SADTi)DENTi$, whichever is larger, where

$PADTi = PGTi + PPADi$, or = an assigned value, where

$PPADi = \left[ZLFDi + ZLCD(i - 1) + ZLBTi + ZLADi\right]DENSW/144$, when $UDTLF(DENPi) < DENSW$, or $= UDTLF\left[ZLFDi + ZLCD(i - 1) + ZLBTi + ZLADi\right]DENPi/144$, when $UDTLF(DENPi) \geq DENSW$;

$SADTi = CAADi(1.57)(DATi)^2$.

5.8.1.2 Tank Baffling and Antivortex Webs

$WBAFi = CBAF(0.01)CPR\emptyset Pi(ZNPTi)V\emptyset LTi$, where

$VOLTi = VFDTi + VBTi + VADTi$, where

$VFDTi = CVFDi(0.262)(DFTi)^3$,

$VBTi = 0.262(ZLBTi)\left[(DFTi)^2 + DFTi(DATi) + (DATi)^2\right]$,

$VADTi = CVADi(0.262)(DATi)^3$.

5.8.1.6 Tank Supports

$WSUPTi = CSUPTi(ZNPTi)\left[\frac{UDTLF}{ZNPTi}(WSNITi + WBAFi + WINSLi + WC\emptyset NDi + WPR\emptyset Pi)\right]^{\frac{1}{2}}(0.5)$, where

$WPR\emptyset Pi = (1 - CULL)CPR\emptyset Pi(ZNPTi)DENPi(V\emptyset LTi)$.

5.8.1.7 Tank Insulation

$WINSLi = CINSi(0.45)CPR\emptyset Pi(ZNPTi)SINSi$, where

$SINSi = SFDTi + (1 - CSEGi)SBTi + (1 - CSCDi)SADTi$.

5.8.1.9 Feed Line Conduit (Isolating the Feed Line Routed Through an Aft Tank from a Fwd. Tank)

WCØNDi = CCØN(3.08)CPRØPi(ZNPTi)ZLCØNi(DCØNi).

5.8.9 Air Breathing Engine Fuel Containers

$$\text{WNSSI} = (3.06) \sum_{K=1}^{K=5} \left[\text{VNSST(K)}\right]^{2/3} \left[\text{ZNSST(K)}\right].$$

5.8.10 Rocket Engine Fuel Containers (Non-booster Type)(See Group 5A.)

$$\text{WPTF} = \sum_{K=1}^{K=5} \left[\text{WPT(K)}\right] \left[\text{ZREFT(K)}\right].$$

5.9 Fuel System

WFS = WFSLE + WFSAB.

5.9.1 Liquid Rocket Engine Fuel System

WFSLE = CFSLE(ZNLRE)TLRE.

5.9.2 Air Breathing Engine Fuel System

WFSAB = CFSAB(ZNABE)TABE.

5.10 Pressurization System - Fuel

WPSF = WPSFT + WPSFS.

5.10.1 Containers (See Group 5A.)

$$\text{WPSFT} = \sum_{K=6}^{K=10} \left[\text{WPT(K)}\right] \left[\text{ZPSFT(K)}\right].$$

5.10.2 Lines, Valves, Etc.

$$\text{WPSFS} = \text{CFSFS} \left[\text{ZNLRE (TLRE)}\right]^{\frac{1}{2}}.$$

5.11 Oxidizer Containers (Non-integral, Booster Type)

WNIØC = Sum of WNIØT(I) + WPTØ, where

(I) can be 1 through 8. (I) will be replaced by i in the following equations to simplify the appearance of the various terms. There are two restrictions regarding the numbering of the booster type propellant tanks: (1) when two or more tanks are joined by common domes, the tanks shall be sequentially numbered, from front to rear; (2) In the case of two integral tanks, the maximum quantity provided for, the fwd. one shall be No. 1 and the aft one shall be No. 2.

5.11.1 Non-integral Oxidizer Tank No. i

WNIØTi = WSNITØi + WBAFØi + WSUPTØi + WINSLØi + WCØNDØi.

5.11.1.1. Tank Structure

WSNITØi = WFDTØi + WBTØi + WADTØi.

5.11.1.1.1 Forward Dome

$$\text{WFDTØi} = \text{CBLK}(1560)(1 - \text{CPRØPi})\text{ZNPTi}(\text{WSRPTi})\text{PFDTi}(\text{DFTi})^3 \cdot \left[\text{CTFDi}(\text{CAFDi}) + 10(\text{CKFDi})\right] \text{ or CBLKM}(331)(1 - \text{CPRØPi}) \cdot \text{ZNPTi}(\text{TMTi})\text{SFDTi}(\text{DENTi}), \text{ whichever is larger.}$$

For details of WSRPTi, PFDTi and SFDTi, refer to 5.8.1.1.1

5.11.1.1.2 Barrel

$$\text{WBTØi} = \text{CBAR}(713)(1 - \text{CPRØPi})\text{ZNPTi}(\text{WSRPTi})\text{PBTi}(\text{SETi})(\text{DFTi} + \text{DATi}) \text{ or CBARM}(238)(1 - \text{CPRØPi})\text{ZNPTi}(\text{TMTi})\text{SBTi}(\text{DENTi}), \text{ whichever is larger.}$$

For details of PBTi and SBTi, refer to 5.8.1.1.2.

5.11.1.1.3 Aft Dome

$$WADT\emptyset i = CBLK(1560)(1 - CPR\emptyset Pi)ZNPTi(1 + CCDi)WSRPTi(PADTi) \cdot (DATi)^3\left[CTADi(CAADi) + .10(CKADi)\right] \text{ or } CBLKM(331) \cdot (1 - CPR\emptyset Pi)ZNPTi(1 + CCDi)TMTi(SADTi)DENTi,$$

whichever is larger.

For details of PADTi and SADTi, refer to 5.8.1.1.3.

5.11.1.2 Tank Baffling and Antivortex Webs

$$WBAF\emptyset i = CBAF(0.01(1 - CPR\emptyset Pi)ZNPTi(V\emptyset LTi).$$

For details of VØLTi, refer to 5.8.1.2.

5.11.1.6 Tank Supports

$$WSUPT\emptyset i = CSUPTi(ZNPTi)\left[\frac{UDTLF}{ZNPTi}(WSNIT\emptyset i + WBAF\emptyset i + WINSL\emptyset i + WC\emptyset ND\emptyset i + WPR\emptyset P\emptyset i)\right]^{\frac{1}{2}}(0.5), \text{ where}$$

$$WPR\emptyset P\emptyset i = (1 - CULL)(1 - CPR\emptyset Pi)ZNPTi(DENPi)V\emptyset LTi.$$

5.11.1.7 Tank Insulation

$$WINSL\emptyset i = CINSi(0.45)(1 - CPR\emptyset Pi)ZNPTi(SINSi).$$

For details of SINSi, refer to 5.8.1.7.

5.11.1.9 Feed Line Conduit (Isolating the Feed Line Routed Through an Aft Tank from a Fwd. Tank)

$$WC\emptyset ND\emptyset i = CC\emptyset N(3.08)(1 - CPR\emptyset Pi)ZNPTi(ZLC\emptyset Ni)DC\emptyset Ni.$$

5.11.9 Rocket Engine Oxidizer Containers (Non-booster Type)(See Group 5A.)

$$WPT\emptyset = \sum_{K=11}^{K=15}\left[WPT(K)\right]\left[ZRE\emptyset T(K)\right].$$

5.12 Oxidizer System

$$W\emptyset S = WFSLE(CFS\emptyset S).$$

5.13 Pressurization System - Oxidizer

WPSØ = WPSØT + WPSØS.

5.13.1 Containers (See Group 5A.)

$$WPSØT = \sum_{K=16}^{K=20} \left[WPT(K)\right]\left[ZPSØT(K)\right].$$

5.13.2 Lines, Valves, Etc.

WPSØS = WPSFS(CFSØS).

5.18 Special Features

WSP5 = WSP5.

5.19 Contingency

WCØN5 = CCØN5(WTB5), where

WTB5 is the sum of all the items preceding 5.19.

5.20 Growth

WGRØ5 = CGRØ5(WCØN5 + WTB5).

MAIN PROPULSION DEFINITIONS

Variable	Definition	Units
* ATLF	Maximum allowable ultimate thrust load factor	
* BNAAE	Width of air breathing engine nacelle	FT
CA1	Intermediate variable	
* CAAD(I)	Wetted area factor for aft dome of main propellant tank No.(I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-2 for value)	
* CABE	Weight factor for air breathing engines	
* CAFD(I)	Wetted area factor for forward dome of main propellant Tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape (refer to Figure 5.2 for value). When ZLFD(I) = zero, CAFD(I) = zero	
* CAIAE	Weight factor for air breathing engine air induction control	
* CAIND	Weight factor for air induction ducts	

Variable	Definition	Units
* CANG1	Cant angle of nozzles of solid propellant system	DEG
* CASAE	Weight factor for air breathing engine starters	
* CBAF	Weight factor for main propellant tank baffling and antivortex webs	
* CBAR	Weight factor for body pressure compartment walls or main propellant tank barrels (unrestricted by minimum allowable thickness)	
* CBARM	Weight factor for body pressure compartment walls or main propellant tank barrels (restricted by minimum allowable thickness)	
* CBLK	Weight factor for body pressure compartment bulkheads or main propellant tank domes (unrestricted by minimum allowable thickness)	
* CBLKM	Weight factor for body pressure compartment bulkheads or main propellant tank domes (restricted by minimum allowable thickness)	
* CCD(I)	Type factor for aft dome of main propellant tank No. (I)	
* CCØN	Weight factor for feed line conduit in main propellant tank	
* CCØN5	Weight factor for contingency for main propulsion system	
* CDAG1	Factor to account for drag and gravitational losses for solid propellant propulsion system	
* CEIAE	Weight factor for air breathing engine water injection system	
* CENGC	Weight factor for air breathing engine controls	
* CENGE	Weight factor for air breathing engine exhausts	
* CENGM	Weight factor for air breathing engine mounts	
* CENGN	Weight factor for air breathing engine nacelles	
* CFSAB	Weight factor for fuel distribution system for air breathing engines	
* CFSFS	Weight factor for pressurization system plumbing for liquid rocket fuel	
* CFSLE	Weight factor for fuel distribution system for liquid rocket engines	
* CFSØS	Weight factor for oxidizer system lines, valves, etc.	
* CFWAE	Weight factor for air breathing engine firewalls and fireseals	
* CGLRE	Weight factor for engine gimbals	
* CGRØ5	Weight factor for growth for main propulsion	
* CINS(I)	Insulation weight factor for main propellant tank No. (I)	

Variable	Definition	Units
* CISP1	Specific impulse for solid propellant propulsion	SEC
* CKAD(I)	Kick frame area factor for aft dome of propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-3 for value)	
* CKFD(I)	Kick frame area factor for forward dome of main propellant Tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape (refer to Figure 5-3 for value). When ZLFD(I) = zero, CKFD(I) = zero	
* CLRE	Weight factor for liquid rocket engines	
* CMF1	Weight factor for mass fraction of solid propellant propulsion systems (See Figure 5-1)	
* CMLRE	Weight factor to account for supports and controls for liquid rocket engines	
* CØSAE	Weight factor for air breathing engine oil system	
* CPLAE	Weight factor for air breathing engine pylons	
* CPRØP(I)	Factor for identifying large propellant tanks (fuel or oxidizer container)	
* CPS	Weight factor for engine chilldown	
* CSCD(I)	Aft dome factor for insulation applicability on main propellant tank No. (I)	
* CSEG(I)	Barrel factor for insulation applicability on main propellant tank No. (I)	
* CSUPT(I)	Supports weight factor for main propellant tank (I)	
* CTAD(I)	Material thickness factor for aft dome of main propellant tank No. (I), a function fo ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-4 for value)	
* CTFD(I)	Material thickness factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape (refer to Figure 5-4 for value). When ZLFD(I) = zero, CTFD(I) = zero	
* CULL	Tank ullage factor (e.g., 0.05)	
* CVAD(I)	Volume factor for aft dome of main propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape (refer to Figure 5-5 for value). If value is based on ZLCD(I)/DAT(I), CVAD(I) shall be a negative value	

Variable	Definition	Units
* CVFD(I)	Volume factor for forward dome of main propellant Tank No. (I), a function of ZLFD(I)/DFT(I), ZLCD(I-1.)/DFT(I) or ZLAD(I-1.)/DFT(I), whichever is not zero, and dome shape (refer to Figure 5-5 for value). If value is based on ZLAD(I-1.)/DFT(I), CVFD(I) shall be a negative value	
* DAT(I)	Diameter at aft end of barrel of main propellant Tank No.(I). If aft end of barrel is not circular, an equivalent DAT(I) = (barrel height X barrel width)$^{.5}$ exp.	FT
* DCØN(I)	Diameter of feed line conduit in main propellant tank No.(I). If an assigned value is not available, DCØN(I) may be estimated as 0.0465[ZNLRE(TLRE)/ZNPT(I)]$^{.25}$ exp.	FT
* DELV1	Required net delta velocity for solid propellant propulsion systems	FT/SEC
* DENP(I)	Density of propellant in main propellant tank No. (I)	LB/CU FT
* DENSW	Density of water used for main propellant tank hydrostatic testing	LB/CU FT
* DENT(I)	Density of structural material of main non-integral propellant tank No. (I)	LB/CU IN
* DFT(I)	Diameter at forward end of barrel of main propellant tank No. (I); if forward end of barrel is not circular, an equivalent DFT(I) = (barrel height X barrel width)$^{.5}$ exp.	FT
* GWST	Total vehicle stage weight at initiation of full thrust (at launch or in flight) (an assigned value)	LB
* GWST1	Total weight of stage 1 at launch (an assigned value)	LB
* HNAAE	Height of air breathing engine nacelle	FT
* PADT(I)	Ultimate design pressure for aft dome of main propellant tank No. (I)	PSIG
* PBT(I)	Ultimate design pressure for barrel of main propellant tank No. (I)	PSIG
* PFDT(I)	Ultimate design pressure for forward dome of main propellant tank No. (I)	PSIG
* PGT(I)	Ultimate design gas pressure in fully loaded main propellant tank No. (I)	PSIG
PPAD(I)	Ultimate propellant head pressure at bottom of aft dome of main propellant tank No. (I)	PSIA
PPBT(I)	Ultimate propellant head pressure at mid-length of main propellant tank No. (I)	PSIA
PPFD(I)	Ultimate propellant head pressure at base of forward dome of main propellant tank No. (I)	PSIA
SADT(I)	Wetted area of aft dome of main propellant tank No. (I)	SQ FT

Variable	Definition	Units
SBT(I)	Wetted area of barrel of main propellant tank No. (I)	SQ FT
SFDT(I)	Wetted area of forward dome of main propellant tank No. (I)	SQ FT
SINS(I)	Insulation area for main propellant tank No. (I)	SQ FT
* TABE	Thrust of each air breathing engine	LB
* TLRE	Thrust of each liquid rocket engine	LB
* TLRE1	Thrust per main liquid rocket engine operating during stage 1 (vacuum rating)	LB
* TMT(I)	Minimum allowable material thickness of barrel or domes of main propellant tank No. (I)	IN
* UDTLF	Ultimate design thrust load factor = 1.5 ZNLRE(TLRE)/GWST for stage 1 only, = 1.5 ZNLRE1(TLRE1)/(GWST1-WUP1) for stage 2 only, or = ATLF if smaller than either, but not equal to zero	
* UTST(I)	Ultimate tensile strength of structural material of main propellant tank No. (I), at the critical design temperature	LB/SQ IN
VADT(I)	Aft dome volume of main propellant tank No. (I)	CU FT
VBT(I)	Barrel volume of main propellant tank No. (I)	CU FT
VFDT(I)	Forward dome volume of main propellant tank No. (I)	CU FT
* VNSST(K)	Volume of each non-self-sealing tank for air breathing engines	CU FT
VØLT(I)	Volume of main propellant tank No. (I)	CU FT
WABE	Weight of air breathing engines	LB
WABES	Weight of air breathing engines and accessories	LB
WACAE	Weight of air breathing engine accessories	LB
WADT(I)	Aft dome weight of main non-integral fuel tank No. (I)	LB
WADTØ(I)	Aft dome weight of main non-integral oxidizer tank No. (I)	LB
WAIAE	Weight of air breathing engine air induction ducts	LB
WBAF(I)	Weight of baffling and antivortex webs of main fuel tank No. (I)	LB
WBAFØ(I)	Weight of baffling and antivortex webs of main oxidizer tank No. (I)	LB
WBT(I)	Barrel weight of main non-integral fuel tank No. (I)	LB
WBTØ(I)	Barrel weight of main non-integral oxidizer tank No. (I)	LB
* WCEL1	Weight of vehicle or module at start of acceleration (excludes solid propellant propulsion system)	LB

Variable	Definition	Units
WCØN5	Weight of contingency for main propulsion	LB
WCØND(I)	Weight of feed line conduit in main fuel tank No. (I)	LB
WCØNDØ(I)	Weight of feed line conduit in main oxidizer tank No. (I)	LB
WECAE	Weight of air breathing engine controls	LB
WEIAE	Weight of water injection system for air breathing engines	LB
WEMAE	Weight of air breathing engine mounts	LB
WEØAE	Weight of air breathing engine oil	LB
WESAE	Weight of air breathing engine starters	LB
WEXAE	Weight of air breathing engine exhaust system	LB
WFDT(I)	Forward dome weight of main non-integral fuel tank No. (I)	LB
WFDTØ(I)	Forward dome weight of main non-integral oxidizer tank No. (I)	LB
WFS	Weight of propulsion fuel distribution system	LB
WFSAB	Weight of fuel distribution system for air breathing engines	LB
WFSLE	Weight of fuel distribution system for liquid rocket engines	LB
WFWAE	Weight of air breathing engine firewalls and fireseals	LB
WGLRE	Weight of liquid rocket engine gimbals	LB
WGRØ5	Weight of growth for main propulsion	LB
WICAE	Weight of air breathing engine air induction controls	LB
WINSL(I)	Insulation weight for main fuel fank No. (I)	LB
WINSLØ(I)	Insulation weight for main oxidizer tank No. (I)	LB
WLRE	Weight of liquid rocket engines and accessories (mounts, controls, etc.)	LB
WLREA	Weight of liquid rocket engines, accessories and gimbals	LB
WNAAE	Weight of air breathing engine nacelles	LB
WNIFC	Total weight of main propulsion non-integral fuel containers	LB
WNIFT(I)	Weight of main propulsion non-integral fuel tank No. (I)	LB
WNIØC	Total weight of main propulsion non-integral oxidizer containers	LB
WNIØT(I)	Weight of main propulsion non-integral oxidizer tank No. (I)	LB
WNSSI	Weight of fuel tanks for air breathing engines	LB
WØS	Weight of oxidizer distribution system for liquid rocket engines	LB
WØSAE	Weight of air breathing engine oil system	LB

Variable	Definition	Units
WPRØP(I)	Weight of loaded fuel capacity in main fuel tank No. (I) (booster type)	LB
WPRØPØ(I)	Weight of loaded oxidizer capacity in main oxidizer tank No. (I) (booster type)	LB
WPSF	Weight of pressurization system for liquid rocket fuel tanks	LB
WPSFS	Weight of pressurization system lines, valves, etc. for liquid rocket fuel tanks	LB
WPSFT	Weight of pressurization tanks for liquid rocket fuel tanks	LB
WPSØ	Weight of pressurization system for liquid rocket oxidizer tanks	LB
WPSØS	Weight of pressurization system lines, valves, etc. for liquid rocket oxidizer tanks	LB
WPSØT	Weight of pressurization tanks for liquid rocket oxidizer tanks	LB
WPT(K)	Weight of each tank (other than booster type), each tank estimated by inputs in Group 5A	LB
WPTF	Weight of non-integral fuel tanks for liquid rocket engines (other than booster type)	LB
WPTØ	Weight of non-integral oxidizer tanks for liquid rocket engines (other than booster type)	LB
WPYAE	Weight of air breathing engine pylons	LB
WSNIT(I)	Structural weight of main non-integral fuel tank No. (I)	LB
WSNITØ(I)	Structural weight of main non-integral oxidizer tank No. (I)	LB
* WSP5	Weight of special features for main propulsion	LB
WSPS1	Weight of solid propellant propulsion system (inerts only)	LB
WSRPT(I)	Weight to strength ratio of structural material of main non-integral propellant tank No. (I)	IN^{-1}
WSTAE	Weight of air breathing engine structural provisions	LB
WSUPT(I)	Supports weight for main non-integral fuel tank No. (I)	LB
WSUPTØ(I)	Supports weight for main non-integral oxidizer tank No. (I)	LB
WTB5	Weight of main propulsion excluding contingency and growth	LB
WTMP	Weight of main propulsion system	LB
WTPS	Weight of purge system for engine childown	LB
* WUABE	Known weight of each air breathing engine	LB
* WULRE	Known weight of each liquid rocket engine	LB

Variable	Definition	Units
* WUP1	Usable propellant weight for stage 1 operation (an assigned value)	LB
* ZLAD(I)	Convex height of aft dome of main propellant tank No. (I)	FT
* ZLAID	Average length of air breathing engine air induction ducts (measured from tip of spike or ramp to engine face)	FT
* ZLBT(I)	Length of barrel of main propellant tank No. (I)	FT
* ZLCD(I)	Concave height of aft dome of main propellant tank No. (I), in the case of a common dome. E.g., ZLCD1 is to be used instead of ZLFD2	FT
* ZLCØN(I)	Length of feed line conduit in main propellant tank No. (I)	FT
* ZLENG	Length for air breathing engine control (sum of length from pilot to each engine measured planform through the body)	FT
* ZLEXE	Length of each air breathing engine exhaust (average length if different)	FT
* ZLFD(I)	Convex height of forward dome of main propellant tank No. (I) (when a forward dome is common to the forward adjoining tank, it shall be considered as part of the forward adjoining tank and not part of the aft adjoining tank)	FT
* ZLNAE	Length of air breathing engine nacelle (average length if different)	FT
* ZLPY	Length of air breathing engine pylon (if swept, use structural length)	LB
* ZMACP	Maximum mach number for propulsion nacelles and pylons (air breathing engines)	
* ZNABE	Quantity of air breathing engines	
* ZNLRE	Quantity of liquid rocket engines	
* ZNLRE1	Quantity of main liquid rocket engines operating during stage 1	
* ZNNAE	Quantity of air breathing engine nacelles	
* ZNPT(I)	Quantity of main propellant booster type tanks No. (I), per vehicle	
* ZNSST(K)	Quantity of identical non-self-sealing tanks for air breathing engines	
* ZPSFT(K)	Quantity of identical pressurization tanks for liquid rocket fuel	
* ZPSØT(K)	Quantity of identical pressurization tanks for liquid rocket oxidizer	
* ZREFT(K)	Quantity of identical liquid rocket fuel tanks (other than booster type)	

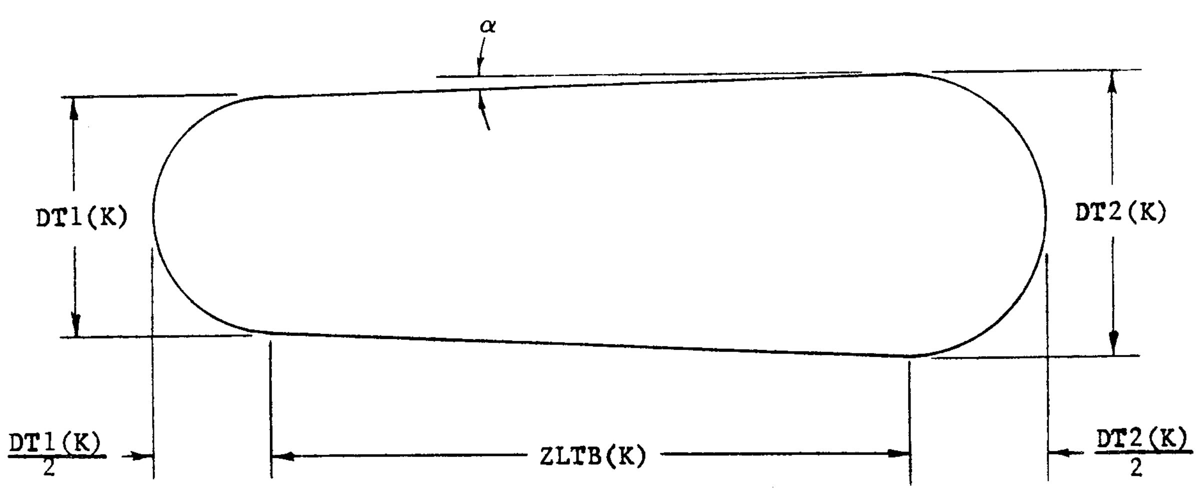
Variable	Definition	Units
* ZREØT(K)	Quantity of identical liquid rocket oxidizer tanks (other than booster type)	
	Wetted area of aft dome of main non-integral propellant tank No. (I) (AADNIT(I)) = ZNPT(I)[1. - CIT(I)] SADT(I)	SQ FT
	Wetted area of barrel of main non-integral propellant tank No. (I) (ABTNIT(I)) = ZNPT(I)[1. - CIT(I)] SBT(I)	SQ FT
	Wetted area of forward dome of main non-integral propellant tank No. (I) AFDNIT(I)) = ZNPT(I)[1. - CIT(I)] SFDT(I)	SQ FT
	Ultimate design pressure for barrel of main non-integral propellant tank No. (I) (PBNIT(I)) = PBT(I)[1. - CIT(I)]	PSIG
	Ultimate design pressure for forward dome of main non-integral propellant tank No. (I) (PFDNIT(I)) = PFDT(I) [1. - CIT(I)]	PSIG
	Ultimate design pressure for aft dome of main non-integral propellant tank No. (I) (PADNIT(I)) = PADT(I) [1. - CIT(I)]	PSIG
	Volume of main non-integral propellant tank No. (I) (VPTNIT(I)) = VØLT(I) [1. - CIT(I)] ZNPT(I)	CU FT

* Input

PRESSURE TANKS

This section contains a theoretical stress analysis method for estimating non-structural pressure tanks, where differential head pressures due to acceleration are negligible. For booster type main propellant tanks, where acceleration head pressures are of major consideration, the method shown under Main Propulsion should be used.

The tanks are of the general shape as shown below.



The heads are assumed to be hemispherically shaped and the taper (α) of the cylindrical section is less than 10°. For straight cylindrical tanks DT1(K) = DT2(K) and for spherical tanks DT1(K) = DT2(K) and ZLTB(K) = 0 (NOTE: Both DT1(K) and DT2(K) should be entered even if they are equal).

As previously stated these tanks are primarily designed for uniform internal pressure, with differential head pressures due to length or height being negligible. The tanks are thin wall types with the skins subjected to membrane stresses only. Since the taper of the cylindrical section is small, a constant skin thickness in the cylindrical section is assumed based on the maximum diameter.

Non-optimum factors have been determined by applying these equations to the actual tank data cataloged in Aerospace Tanks* and other statistical data.

These estimation equations can be used for pressure tanks used for various functions. Subscripts, as shown below, have been assigned to the various functions.

GROUP	FUNCTION	SUBSCRIPTS
5.8	Main Fuel Containers	K=1 to K=5
5.10	Pressurant Containers - Main Fuel	K=6 to K=10
5.11	Main Oxidizer Containers	K=11 to K=15
5.12	Pressurant Containers - Main Oxidizer	K=16 to K=20
6.7	RCS Fuel Containers	K=21 to K=23
6.8	RCS Oxidizer Containers	K=24 to K=26
6.9	Pressurant Container - RCS	K=27 to K=29
7.2	Fuel Cell Reactant Containers	K=30 to K=33
7.6	APU Propellant Containers	K=34 to K=39
12.2	Breathing Gas Containers	K=40 to K=42
14.2	Crew's Water Containers	K=46 to K=48

5A. Pressure Tank

WPT(K) = WSHL(K) + WINS(K) + WTQI(K) + WSUP(K).

5A.1 Structural Shell

$$WSHL(K) = 226.\left[CPSHL(K)\right] DENTM(K)\left\{\left[DT1(K)\right]^2 \cdot THD1(K) + \left[DT2(K)\right]^2 THD2(K) + THB(K) \cdot \left[DT1(K) + DT2(K)\right]\sqrt{ZLTB(K)^2 + \left[\frac{DT2(K)-DT1(K)}{2}\right]^2}\right\},$$ where

* Aerospace Tanks, ITT Research Institute, Jan., 1969.

$$THD1(K) = \frac{3.\left[PRML(K)\right] DT1(K) \left[SFML(K)\right]}{FTUY(K)} .$$

$$THD2(K) = \frac{3.\left[PRML(K)\right] DT2(K) \left[SFML(K)\right]}{FTUY(K)} .$$

$$THB(K) = \frac{6.\left[PRML(K)\right] DT2(K) \left[SFML(K)\right]}{FTUY(K)} .$$

(**NOTE**: If THD1(K), THD2(K), and THB(K) are less than .020 in., they are assigned a nominal minimum gage of .020 in.).

5A.2 Insulation and Cover

Tanks (other than dewar type)

$$WINS(K) = 1.57\left[WINSU(K)\right]\left\{\left[DT1(K)\right]^2 + \left[DT2(K)\right]^2 + \left[DT1(K) + DT2(K)\right]\sqrt{\left[ZLTB(K)\right]^2 + \left[\frac{DT2(K) - DT1(K)}{2.}\right]^2}\right\}.$$

Dewar Type Tanks (Spherical)

$$WINS\ (K) = 13.84\left[CMSC(K)\right]\left[DT1(K)\right]^{3/2} .$$

5A.3 Quantity Indication (Probe type for liquids)

$$WTQI(K) = 1.4\left[CPTQI(K)\right]\left[\frac{DT1(K)}{2.} + \frac{DT2(K)}{2.} + ZLTB(K)\right].$$

5A.4 Tank Supports

$$WSUP(K) = CSUP(K)\left[WSHL(K) + WINS(K) + WTQI(K) + WC\O N(K)\right]^{\frac{1}{2}}, \text{ where}$$

$$WC\O N(K) = 0.2615\left[1. - CULLT(K)\right]DENCL(K)\left\{\left[DT1(K)\right]^3 + \left[DT2(K)\right]^3 + ZLTB(K)\left\{\left[DT1(K)\right]^2 + DT1(K)\left[DT2(K)\right] + \left[DT2(K)\right]^2\right\}\right\}.$$

Variable	Definition	Units
* CMSC(K)	Weight factor for insulation and cover for spherical cryogenic tanks designed for long storage periods (DeWar type)	
* CPSHL(K)	Weight factor for non-optimums of the structural shell	
* CPTQI(K)	Weight factor for probe type quantity indicator for liquids	
* CSUP(K)	Weight factor for tank supports	
* CULLT(K)	Factor for ullage for pressure tanks (unusable portion of tank volume)	
* DENCL(K)	Density of contained liquid or gas	LB/CU FT
* DENTM(K)	Density of tank shell structural material	LB/CU IN
* DT1(K)	Outside diameter of the smaller dome (twice the radius of the dome)	FT
* DT2(K)	Outside diameter of the larger dome (twice the radius of the dome)	FT
* FTUY(K)	The yield or ultimate strength of the tank structural material (see SFML(K))	LB/SQ IN
* PRML(K)	The maximum limit pressure	PSIG
* SFML(K)	Tank design safety factor. Use factor compatible with FTUY(K) such that the ratio of SFML(K) over FTUY(K) is the larger	
THB(K)	Thickness of the structural shell in the cylindrical section	IN
THD1(K)	Thickness of the structural shell of the smaller dome	IN
THD2(K)	Thickness of the structural shell of the larger dome	IN
WCØN(K)	Weight of the contained liquid or gas	LB
WINS(K)	Weight of insulation and cover	LB
* WINSU(K)	Unit weight of insulation and cover of tanks used for storable propellant or cryogenic propellant for short storage periods	LB/SQ FT
WPT(K)	Weight of tank, insulation, quantity indication and supports	LB
WSHL(K)	Weight of structural shell, fittings, and bladder	LB
WSUP(K)	Weight of tank supports	LB
WTQI(K)	Weight of quantity indication for liquids	LB
* ZLTB(K)	Length of cylindrical section of tank (total length less one half of DT1(K) and DT2(K)	FT

* Input

ORIENTATION CONTROLS, SEPARATION AND ULLAGE

The orientation controls, separation and ullage group consists of the weight of aerodynamic surface controls, reaction controls, and separation devices. The RCS thruster's weight can be determined either by using a known or estimated unit weight for each nozzle, or by using the thrust of each nozzle. Nozzle thrust values are required for other purposed, regardless of the method used for RCS thruster weight. Thr RCS propellant and pressurization tank weights are estimated by using the pressure tank routine (see Group 5A.)

This total group weight is defined as:

6.0 $$W\emptyset C = WRCTS + WAC + WSEP + WRCFT + WRC\emptyset T + WRCPR + WRCFS + WRC\emptyset S + WSP6 + WC\emptyset N6 + WGR\emptyset 6.$$

6.2 Thrust System (Auxiliary, RCS)

$$WRCTS = WRCT + WRCTSU.$$

6.2.1 Thrusters

$$WRCT = \sum_{K=1}^{K=6} ZNRCT(K)\left\{WRCU(K),\ \text{or}\ CRCT(K)\left[TRCT(K)\right]^{2/3}\right\}.$$

6.2.2 Thruster Supports

$$WRCTSU = 0.022(CRCTS)TRCTS,\ \text{where}$$

$$TRCTS = \sum_{K=1}^{K=6} ZNRCT(K)\left[TRCT(K)\right].$$

6.3 Aerodynamic Controls

$$WAC = WCAIL + WCELE + WCSP\emptyset + WCTEF + WCLES + WCSB + WCWI + WCPC + WCYC + WCSI + WCTC + WCBLC + WPARKL.$$

6.3.1 Aileron Controls

WCAIL = 0.0007 (SAIL1 + SAIL2 + SAIL3)WULØD, where

$$WUL\emptyset D = \frac{GWRE(ZNAF)}{(SEW1 + SEW2 + SEW3)} .$$

6.3.2 Elevon Controls

WCELE = (0.007)CCELE(SELW1 + SELW2 + SELW3 + SELB)WULØD.

6.3.3 Spoiler Controls

WCSPØ = (0.007)CCSPØ(SSP1 + SSP2 + SSP3)WULØD.

6.3.4 Trailing Edge Flap Controls

WCTEF = (0.003)CCTEF(STEF1 + STEF2 + STEF3)WULØD.

6.3.5 Leading Edge Flap/Slat Controls

WCLES = (0.66)CCLES(WLEF1 + WELF2 + WLEF3 + WLES1 + WLES2 + WLES3).

6.3.6 Speed Brake Controls

WCSB = 0.0032(CCSB)WULØD(SSB1 + SSB2 + SSB3).

6.37 Wing Incidence Controls

WCWI = (2.1×10^{-4})CCWIC(SEW1 + SEW2 + SEW3)WULØD.

6.3.8 Pitch Controls

WCPC = 0.0028(WULOD)[CCPC(SELHT) + CCPCF(SEHT)].

6.3.9 Yaw Controls

WCYC = ZNVT(WULØD)[0.006(CCYC)SRUD + 0.0019(CCYCF)SVT].

6.3.10 Stabilizer Incidence Controls

WCSI = 0.0013(CCSI)SEHT(WULØD).

6.3.11 Trim Controls

WCTC = WCTC.

6.3.12 Boundary Layer Controls

WCBLC = 0.5(CCBLC)(SEW1 + SEW2 + SEW3).

6.3.13 Integral Parking Locks

WPARKL = WPARKL.

6.5 Separation

WSEP = WSEPR + WSEPS.

6.5.1 Separation Rockets (Inerts only)

$$WSEPR = 9.0 \times 10^{-5}\ (CSEPR)WCEL2(DELV2).$$

6.5.2 Separation Springs

$$WSEPS = \frac{1.29 \times 10^{-6}(CSEPS)(DELV2)^2}{\left(\frac{1}{WCEL2} + \frac{1}{WCEL3}\right)}.$$

6.7 RCS Fuel Tanks (See Group 5A.)

$$WRCFT = \sum_{K=21}^{K=23} ZRCFT(K)(WPT(K)).$$

6.8 RCS Oxidizer Tanks (See Group 5A.)

$$WRC\O T = \sum_{K=24}^{K=26} ZRC\O T(K)(WPT(K)).$$

6.9 RCS Pressurization

WRCPR = WRCPT + WRCLV.

6.9.1 RCS Pressurization Tanks (See Group 5A.)

$$WRCPT = \sum_{K=27}^{K=29} ZRCPT(K)(WPT(K)).$$

6.9.2 RCS Pressurization Lines, Valves, Etc.

$$WRCLV = 0.25(CRCLV)(TRCTS)^{2/3}$$

6.10 RCS Fuel Distribution

$$WRCFS = CRCFLV(TRCTS)^{2/3}$$

6.11 RCS Oxidizer Distribution

$$WRC\emptyset S = CRC\emptyset LV(TRCTS)^{2/3}.$$

6.18 Special Features

$$WSP6 = WSP6.$$

6.19 Contingency

$WC\emptyset N6 = CC\emptyset N6(WTB6)$, where

WTB6 is the sum of all the items preceding 6.19.

6.20 Growth

$$WGR\emptyset 6 = CGRO6(WC\emptyset N6 + WTB6).$$

ORIENTATION CONTROLS, SEPARATION, AND ULLAGE DEFINITIONS

Variable	Definition	Units
* CCBLC	Weight factor for boundary layer controls	
* CCELE	Weight factor for elevon controls	
* CCLES	Weight factor for leading edge flap/slat controls	
* CCØN6	Weight factor for contingency for orientation controls, separation, and ullage	
* CCPC	Weight factor for elevator controls	
* CCPCF	Weight factor for all-movable pitch fin controls	
* CCSB	Weight factor for speed brake controls	
* CCSI	Weight factor for adjustable pitch fin incidence controls	
* CCSPØ	Weight factor for spoiler controls	
* CCTEF	Weight factor for trailing edge flap controls	
* CCWIC	Weight factor for wing incidence controls	
* CCYC	Weight factor for rudder type yaw controls	
* CCYCF	Weight factor for all-movable fin type yaw controls	
* CGRØ6	Weight factor for growth for orientation controls, separation, and ullage	
* CRCFLV	Weight factor for RCS fuel distribution system	
* CRCLV	Weight factor for RCS pressurization system lines, valves, etc.	
* CRCØLV	Weight factor for RCS oxidizer distribution system	

Variable	Definition	Units
* CRCT(K)	Weight factor for RCS thrusters	
* CRCTS	Weight factor for RCS thruster supports	
* CSEPR	Weight factor for separation rockets	
* CSEPS	Weight factor for separation springs	
* DELV2	Gross velocity increment for stage or component for separation	FT/SEC
* GWRE	Gross weight at reentry or during atmospheric cruise	LB
* SAIL1	Aileron horizontal planform area, wing type 1	SQ FT
* SAIL2	Aileron horizontal planform area, wing type 2	SQ FT
* SAIL3	Aileron horizontal planform area, wing type 3	SQ FT
* SEHT	Exposed horizontal planform area of horizontal tail	SQ FT
* SELHT	Horizontal planform area of elevators	SQ FT
* SELW1	Horizontal planform area of elevons, wing type 1	SQ FT
* SELW2	Horizontal planform area of elevons, wing type 2	SQ FT
* SELW3	Horizontal planform area of elevons, wing type 3	SQ FT
* SEW1	Exposed horizontal planform area of wing, wing type 1	SQ FT
* SEW2	Exposed horizontal planform area of wing, wing type 2	SQ FT
* SEW3	Exposed horizontal planform area of wing, wing type 3	SQ FT
* SRUD	Vertical planform area of each rudder	SQ FT
* SSB1	Horizontal planform area of wing speed brakes, wing type 1	SQ FT
* SSB2	Horizontal planform area of wing speed brakes, wing type 2	SQ FT
* SSB3	Horizontal planform area of wing speed brakes, wing type 3	SQ FT
* SSP1	Horizontal planform area of spoilers on wing, wing type 1	SQ FT
* SSP2	Horizontal planform area of spoilers on wing, wing type 2	SQ FT
* SSP3	Horizontal planform area of spoilers on wing, wing type 3	SQ FT
* STEF1	Horizontal planform area of wing trailing edge flaps, wing type 1	SQ FT
* STEF2	Horizontal planform area of wing trailing edge flaps, wing type 2	SQ FT
* STEF3	Horizontal planform area of wing trailing edge flaps, wing type 3	SQ FT
* SVT	Vertical planform area of each vertical tail	SQ FT
* TRCT(K)	Thrust of each RCS thruster (vacuum)	LB
TRCTS	Total thrust of all RCS thrusters	LB
* SELB	Horizontal planform area of body elevons	SQ FT

Variable	Definition	Units
WAC	Weight of aerodynamic controls	LB
WCAIL	Weight of aileron controls	LB
WCBLC	Weight of boundary layer controls	LB
WCELE	Weight of elevon controls	LB
* WCEL2	Weight of vehicle or component to be accelerated by separation rockets or springs	LB
* WCEL3	Weight of vehicle or component to react separation springs	LB
WCLES	Weight of wing leading edge flap/slat controls	LB
WCØN6	Weight of contingency for orientation controls, separation, and ullage	LB
WCPC	Weight of elevator/flying stabilizer controls	LB
WCSB	Weight of wing speed brake controls	LB
WCSI	Weight of stabilizer incidence controls	LB
WCSPØ	Weight of spoiler controls	LB
* WCTC	Weight factor for trim controls	LB
WCTEF	Weight of wing trailing edge flap controls	LB
WCYC	Weight of rudder/flying fin controls	LB
WGRØ6	Weight growth for orientation controls, separation, and ullage	LB
WLEF1	Weight of wing leading edge flaps, wing type 1	LB
WLEF2	Weight of wing leading edge flaps, wing type 2	LB
WLEF3	Weight of wing leading edge flaps, wing type 3	LB
WLES1	Weight of wing leading edge slats, wing type 1	LB
WLES2	Weight of wing leading edge slats, wing type 2	LB
WLES3	Weight of wing leading edge slats, wing type 3	LB
WØC	Weight of orientation control, separation, and ullage	LB
* WPARKL	Weight factor for integral parking locks	LB
WPT(K)	Weight of each pressure tank estimated by inputs in Group 5A to be used for RCS fuel tanks, RCS oxidizer tanks, and RCS pressurization tanks	LB
WRCFS	Weight of RCS fuel distribution system	LB
WRCFT	Weight of RCS fuel tanks	LB
WRCLV	Weight of RCS pressurization lines, valves, etc.	LB
WRCØS	Weight of RCS oxidizer distribution system	LB
WCWI	Weight of wing incidence controls	LB

Variable	Definition	Units
WRCØT	Weight of RCS oxidizer tanks	LB
WRCPR	Weight of RCS pressurization system	LB
WRCPT	Weight of RCS pressurization tanks	LB
WRCT	Weight of RCS thrusters	LB
WRCTS	Weight of RCS thrust system	LB
WRCTSU	Weight of RCS thruster supports	LB
* WRCU(K)	Unit weight of identical RCS thrusters	LB
WSEP	Weight of separation system	LB
WSEPR	Weight of separation rockets (inerts only)	LB
WSEPS	Weight of separation springs	LB
* WSP6	Weight of special features for orientation controls, separation, and ullage	LB
WTB6	Weight of orientation controls, separation, and ullage less contingency and growth	LB
WULØD	Wing unit loading	LB/SQ FT
* ZNAF	Ultimate flight vertical load factor	
* ZNRCT(K)	Quantity of identical RCS thrusters	
* ZNVT	Quantity of vertical tails	
* ZRCFT(K)	Quantity of identical RCS fuel tanks (each tank estimated by inputs in Group 5A)	
* ZRCØT(K)	Quantity of identical RCS oxidizer tanks (each tank estimated by inputs in Group 5A)	
* ZRCPT(K)	Quantity of identical RCS pressurization tanks (each tank estimated by inputs in Group 5A)	

* Input

PRIME POWER SOURCE

This weight group includes all prime sources of power (electrical, hydraulic, and pneumatic.) The solar cells weight can be estimated either as a function of output power or effective solar cell area. The equations for solar cell weights should be used with caution since they are based only on 2 samples (Skylab's OWS and ATM.)

The APU weight can be estimated either as a known or estimated unit weight or as a function of rated output power. Rated output power is required regardless of the method used. Tankage weights for APU propellant and fuel cell reactants are estimated by using the pressure tank routine (See Group 5A.)

The weight of this group is defined as:

7.0 WTPP = WPSFC + WPSBT + WPSSC + WPSGG + WSP7 + WCØN7 + WGRØ7.

7.2 Power Source - Fuel Cells

WPSFC = WCELL + WFCTS.

7.2.1 Fuel Cells and Accessories

WCELL = CCELL(138.0)ZNCEL(RPØFC).

7.2.2 Fuel Cell Tanks (See Group 5A.)

$$WFCTS = \sum_{K=30}^{K=33} (WPT(K))\left[ZNFCT(K)\right].$$

7.3 Power Source - Batteries

WPSBT = WSAB + WPSRC.

7.3.1 Batteries and Supports

$$WSAB = \frac{1.05(CPSB)RPØB}{PERDI}$$

7.3.2 Voltage and Recharge Control

WPSRC = 0.187(CVRC)WPSSP.

7.4 Power Source - Solar Cells

WPSSC = WPSSP + WPSDP.

7.4.1 Solar Cell Panels (Solar Cell and Substrate Modules)

WPSSP = CSCSI(2.37)SSC, or 240.0(CSCPØ)RPØSC.

7.4.2 Deployment and Structural Privisions

WPSDP = CSCDP(WPSSP).

7.6 Power Source - Gas Generator

WPSGG = WAPU + WAPUA + WAPUT.

7.6.1 Auxiliary Power Unit (Excludes Electrical Generators, Hydraulic Pumps, Etc.)

$$\text{WAPU} = \text{ZNAPU}\left[\text{CAPU}(70. + 1.22\ \text{APUHP}),\ \text{or WUAPU}\right].$$

7.6.2 APU Accessories (Controls, Propellant Plumbing, Supports)

$$\text{WAPUA} = \text{CAPUA}\left[100.0 + 0.2(\text{ZNAPU})\text{APUHP}\right].$$

7.6.3 APU Propellant Tanks (See Group 5A.)

$$\text{WAPUT} = \sum_{K=34}^{K=39} \text{WPT}(K)\left[\text{ZNAPT}(K)\right].$$

7.18 Special Features

WSP7 = WSP7.

7.19 Contingency

WCØN7 = CCØN7(WTB7), where

WTB7 is the sum of all the items preceding 7.19.

7.20 Growth

WGRØ7 = CGRØ7(WCØN7 + WTB7).

PRIME POWER SOURCE DEFINITIONS

Variable	Definition	Units
* APUHP	Shaft output power of each APU	SHP
* CAPU	Weight factor for APU	
* CAPUA	Weight factor for APU accessories	
* CCELL	Weight factor for Hydrox fuel cells	
* CCØN7	Weight factor for contingency for prime power source	
* CGRØ7	Weight factor for growth for prime power source	
* CPSB	Weight factor for batteries (See Figure 7-1)	
* CSCDP	Weight factor for deployment and structural provisions as a function of solar cell panel weight	
* CSCPØ	Weight factor for solar cell weight as a function of power output	
* CSCSI	Weight factor for solar cell weight as a function of panel total effective area	
* CVRC	Weight factor for voltage and recharge control for solar cell/battery system	
* PERDI	Depletion ratio (ratio of consumed to maximum energy) of secondary storage batteries (such as used in conjunction with solar cell power systems in earth orbit)	
* RPØB	Required total energy output for batteries	KWHR
* RPØFC	Rated power of each fuel cell battery	KW
* RPØSC	Total rated power of solar cell at 55 deg centigrade operating temperature	KW
* SSC	Total effective area of solar cells	SQ FT
WAPU	Weight of auxiliary power unit	LB
WAPUA	Weight of accessories (controls, plumbing, supports) for auxiliary power unit	LB
WAPUT	Weight of propellant and pressurization tanks for auxiliary power system	LB
WSAB	Weight of batteries and supports	LB
WCELL	Weight of fuel cell batteries and accessories	LB
WCØN7	Weight of contingency for prime power source	LB
WFCTS	Weight of fuel cell reactant containers	LB
WGRØ7	Weight of growth for prime power source	LB
WPSBT	Weight of battery power source	LB

Variable	Definition	Units
WPSDP	Weight of deployment and structural provisions for solar Cell array	LB
WPSFC	Weight of fuel cell power source (inerts only)	LB
WPSGG	Weight of gas generator power source (inerts only)	LB
WPSRC	Weight of voltage and recharge controls for storage batteries	LB
WPSSC	Weight of solar cell power source	LB
WPSSP	Weight of solar cells and substrates	LB
WPT(K)	Weight of each pressure tank estimated by inputs in group 5A to be used for estimates of tank for fuel cell reactants and gas generator propellant	LB
* WSP7	Weight of special features for prime power source	LB
WTB7	Weight of prime power source excluding contingency and growth	LB
WTPP	Weight of prime power source	LB
* WUAPU	Weight of known APU	LB
* ZNAPT(K)	Quantity of identical tanks for gas generator propellant system (each tank estimated by inputs in group 5A)	
* ZNAPU	Quantity of auxiliary power units	
* ZNCEL	Quantity of fuel cell batteries	
* ZNFCT(K)	Quantity of identical tanks for fuel cell reactants (each tank estimated by inputs in group 5A)	

* Input

POWER CONVERSION AND DISTRIBUTION

This weight group comprises all of the electrical, hydraulic, and pneumatic conversion and distribution equipment. Since most of the statistical data did not identify wiring for the various functional groups, all the wiring has been included in this weight group.

Electrical power conversion weight can be estimated either as a function of the weights of other systems (prime power, instrumentation, etc.) or if the required equipment is specified, it can be entered as WPCEV. Electrical power distribution is estimated as a function of the weights of other systems (prime power, instrumentation, etc.) and vehicle size. For vehicles that do not contain other systems (like adapters and LES), only the size parameter is used.

The total weight of this group is defined as:

8.0 $$WPCD = WPCE + WPCH + WPDE + WPDH + WSP8 + WC\emptyset N8 + WGR\emptyset 8.$$

8.1 Power Conversion - Electrical (AC & DC)

$$WPCE = CPCE(WTPP + WGAN + WINST + WC\emptyset MM + WCSCP + WPLEP), \text{ or } WPCEV.$$

8.3 Power Conversion - Hydraulic

$$WPCH = 1.7(CPHC)CPF\left[SASS(CSHYD) + 0.1(CLGHYD)WLG\right]^{3/4}, \text{ where}$$

$$SASS = SAIL1 + SAIL2 + SAIL3 + SELW1 + SELW2 + SELW3 + SLEF1 + SLEF2 + SLEF3 + SLES1 + SLES2 + SLES3 + STEF1 + STEF2 + STEF3 + SSP1 + SSP2 + SSP3 + SSB1 + SSB2 + SSB3 + CCPC(SELHT) + CCPCF(SEHT) + ZNVT(CCYC)SRUD + ZNVT(CCYCF)SVT + SELB.$$

8.4 Power Distribution - Electrical (AC & DC)

$$WPDE = (ZLB + BB + HB)\left[CPDE(WTPP + WGAN + WINST + WC\emptyset MM + WCSCP + WPLEP)^{2/3}, \text{ or } 1.5(CPDED)\right].$$

8.6 Power Distribution - Hydraulic

$$WPDH = 0.018(CPHD)CPF(ZLB+BWM)\left[SASS(CSHYD) + 0.1(CLGHYD)WLG\right]^{3/4}.$$

8.18 Special Features

WSP8 = WSP8.

8.19 Contingency

WCØN8 = CCØN8(WTB8), where

WTB8 is the sum of all the items preceding 8.19.

8.20 Growth

WGRØ8 = CGRØ8(WCØN8 + WTB8).

POWER CONVERSION AND DISTRIBUTION DEFINITIONS

Variable	Definition	Units
* BB	Maximum width of body	FT
* BWM	Maximum vehicle lateral dimension	FT
* CCØN8	Weight factor for contingency for power conversion and distribution	
* CCPC	Weight factor for elevator control	
* CCPCF	Weight factor all-movable type pitch control	
* CCYC	Weight factor for rudder type yaw control	
* CCYCF	Weight factor for all-movable type yaw control	
* CGRØ8	Weight factor for growth for power conversion and distribution	
* CLGHYD	Weight factor for hydraulically actuated landing gear	
* CPCE	Weight factor for electrical power conversion	
* CPDE	Weight factor for electrical power distribution	
* CPDED	Weight factor for electrical power distribution for vehicle/module which does not contain electrical equipment (e.g., LES, adapter, etc.)	
* CPF	Weight factor for hydraulic power (see Figure 8-1)	
* CPHC	Weight factor for hydraulic power conversion	
* CPHD	Weight factor for hydraulic power distribution	
* CSHYD	Area of control surfaces hydraulically operated divided by the total area of all control surfaces	

Variable	Definition	Units
* HB	Maximum height of body	FT
* SAIL1	Horizontal planform area of ailerons, wing type 1	SQ FT
* SAIL2	Horizontal planform area of ailerons, wing type 2	SQ FT
* SAIL3	Horizontal planform area of ailerons, wing type 3	SQ FT
SASS	Total area of control surfaces	SQ FT
* SEHT	Exposed horizontal planform of horizontal tail	SQ FT
* SELHT	Horizontal planform area of elevators	SQ FT
* SELW1	Horizontal planform area of elevons, wing type 1	SQ FT
* SELW2	Horizontal planform area of elevons, wing type 2	SQ FT
* SELW3	Horizontal planform area of elevons, wing type 3	SQ FT
* SLEF1	Horizontal planform area of leading edge flaps, wing type 1	SQ FT
* SLEF2	Horizontal planform area of leading edge flaps, wing type 2	SQ FT
* SLEF3	Horizontal planform area of leading edge flaps, wing type 3	SQ FT
* SLES1	Horizontal planform area of leading edge slats, wing type 1	SQ FT
* SLES2	Horizontal planform area of leading edge slats, wing type 2	SQ FT
* SLES3	Horizontal planform area of leading edge slats, wing type 3	SQ FT
* SRUD	Vertical planform area of each rudder	SQ FT
* SSB1	Horizontal planform area of speed brakes, wing type 1	SQ FT
* SSB2	Horizontal planform area of speed brakes, wing type 2	SQ FT
* SSB3	Horizontal planform area of speed brakes, wing type 3	SQ FT
* SSP1	Horizontal planform area of spoilers on wing, wing type 1	SQ FT
* SSP2	Horizontal planform area of spoilers on wing, wing type 2	SQ FT
* SSP3	Horizontal planform area of spoilers on wing, wing type 3	SQ FT
* STEF1	Horizontal planform area of trailing edge flaps, wing type 1	SQ FT
* STEF2	Horizontal planform area of trailing edge flaps, wing type 2	SQ FT
* STEF3	Horizontal planform area of trailing edge flaps, wing type 3	SQ FT
* SVT	Vertical planform area of each vertical tail	SQ FT
WCØMM	Weight of communication	LB
WCØN8	Weight of contingency for power conversion and distribution	LB
WCSCP	Weight of crew station controls and panels	LB
WGAN	Weight of guidance and navigation	LB
WGRØ8	Weight of growth for power conversion and distribution	LB
WINST	Weight of instrumentation	LB
SELB	Horizontal planform area of body elevons	SQ FT

Variable	Definition	Units
WLG	Weight of landing gear	LB
WPCD	Weight of power conversion and distribution	LB
WPCE	Weight of electrical power conversion equipment	LB
* WPCEV	Weight of known electrical power conversion equipment	LB
WPCH	Weight of hydraulic power conversion equipment	LB
WPDE	Weight of electrical power distribution	LB
WPDH	Weight of hydraulic power distribution (inert only, fluid is in section 22)	LB
* WPLEP	Weight of payload which requires electrical power	LB
* WSP8	Weight of special features for power conversion and distribution	LB
WTB8	Weight of power conversion and distribution excluding contingency and growth	LB
WTPP	Weight of prime power source	LB
* ZLB	Length of body	FT
* ZNVT	Quantity of vertical tails	

* Input

GUIDANCE AND NAVIGATION

This weight group encompasses the functions of guidance and navigation. The weight estimation technique employed for this group depends solely on the knowledge of the system and comparable equipment on similar vehicles. If a good definition of the required equipment is not available, use the guidance and navigation weight shoun in Tables IV-2 through IV-10 and supplementary equipment for atmospheric cruising and landing shown in Table IV-11. The guidance and navigation components weight is entered as WGNC. The equation adds 5 percent for structural supports. Circuitry and power supplies are included in power conversion and distribution.

The total weight of Guidance and Navigation is defined as:

9.0 WGAN = WTB9 + WCØN9 + WGRØ9.

9.1 Total, Excluding Contingency and Growth

WTB9 = CCGN(1.05)WGNC.

9.19 Contingency

WCØN9 = CCØN9(WTB9).

9.20 Growth

WGRØ9 = CGRØ9(WCØN9 + WTB9).

GUIDANCE AND NAVIGATION DEFINITIONS

Variable	Definition	Units
* CCGN	Weight factor for guidance and navigation	
* CCØN9	Weight factor for contingency for guidance and navigation	
* CGRØ9	Weight factor for growth for guidance and navigation	
WCØN9	Weight of contingency for guidance and navigation	LB
WGAN	Weight of guidance and navigation	LB
* WGNC	Weight of known guidance and navigation components	LB
WGRØ9	Weight of growth for guidance and navigation	LB
WTB9	Weight of guidance and navigation excluding contingency and growth	LB

* Input

INSTRUMENTATION

Instrumentation weight is estimated either by means of a size parameter plus consideration of vehicle type, by comparison to known similar vehicles, or by summing all the components and applying an appropriate correlation factor. All the wiring and power supplies for instrumentation are included in electrical power conversion and distribution.

The weight of instrumentation is defined as:

10.0 WINST = WTB10 + WSP10 + WCØN10 + WGRØ10.

10.1 Total less Special Features, Contingency, and Growth

WTB10 = CINST(BB + HB + ZLB), or WINCØ.

10.2 Special Features

WSP10 = WSP10.

10.3 Contingency

WCØN10 = CCØN10(WTB10 + WSP10).

10.4 Growth

WGRØ10 = CGRØ10(WTB10 + WSP10 + WCØN10).

INSTRUMENTATION DEFINITIONS

Variable	Definition	Units
* BB	Maximum width of body	FT
* CCØN10	Weight factor for contingency for instrumentation	
* CGRØ10	Weight factor for growth for instrumentation	
* CINST	Weight factor for instrumentation	
* HB	Maximum height of body	FT
WCØN10	Weight of contingency for instrumentation	LB
WGRØ10	Weight of growth for instrumentation	LB
* WINCØ	Weight of known instrumentation system	LB
WINST	Weight of instrumentation	LB
* WSP10	Weight of special features for instrumentation	LB

Variable	Definition	Units
WTB10	Weight of instrumentation excluding special features, contingency, and growth	LB
* ZLB	Length of body	FT

* Input

COMMUNICATION

This weight group encompasses the function of communication. Communication weight can be estimated either by consideration of the various sub-functions, or by knowing the total weight of the system and entering it as WCØMME and ingoring all other inputs.

The total weight of this group is defined as:

11.0 WCØMM = WICØM + WNECØM + WDSC + WTVS + WCTB + WCCS + WCRAN + WSP11 + WCØMME + WCØN11 + WGRØ11.

11.1 Intercommunication

$$WIC\emptyset M = CIC\emptyset M(ZNIC\emptyset M)^{3/2}.$$

11.2 Near Earth Communication

WNECØM = WNECU + WNECA.

11.2.1 Transmitters, Receivers, Transceivers

$$WNECU = CNECU(ZNECU)^{3/2}.$$

11.2.2 Antennas

WNECA = CNECA.

11.3 Deep Space Communication

WDSC = WDSCU + WDSCA.

11.3.1 Transceivers, Amplifiers

WDSCU = CDSCU(ZNDSC).

11.3.2 Antenna

WDSCA = CDSCA.

11.4 TV System

WTVS = WTVC + WTVM + WTVRS.

11.4.1 TV Camera

WTVC = CTVC(ZTVC).

11.4.2 TV Monitor

WTVM = CTVM(ZTVM).

11.4.3 Remote Camera Station

WTVRS = CTVRS(ZTVRS).

11.5 Tracking Beacon

WCTB = CCTB(ZNTB).

11.9 Command System

WCCS = WCCR + WCCP.

11.9.1 Command Receivers

WCCR = CCCR(ZNCCR).

11.9.2 Command Processors

WCCP = WCCP.

11.10 Ranging

WCRAN = WCRAN.

11.18 Special Features

WSP11 = WSP11.

ALTERNATE METHOD - If the weight of the communication is known, this can be entered in lieu of the details.

WCØMME = WCØMME.

11.19 Contingency

WCØN11 = CCØN11(WTB11), where

WTB11 = WICØM + WNECØM + WDSC + WTVS + WCTB + WCCS + WCRAN + WSP11 + WCØMME.

11.20 Growth

WGRØ11 = CGRØ11(WCØN11 + WTB11).

COMMUNICATION DEFINITIONS

Variable	Definition	Units
* CCCR	Weight factor per command receiver	LB
* CCØN11	Weight factor for contingency for communications	LB
* CCTB	Weight factor per tracking beacon	LB
* CDSCA	Weight factor for deep space communication antennas (see Table XVI)	LB
* CDSCU	Weight factor per deep space transceiver and amplifier	LB
* CGRØ11	Weight factor for growth for communications	
* CICØM	Weight factor for intercommunication system	
* CNECA	Weight factor per near earth communication antenna (see Table XVI)	LB
* CNECU	Weight factor for near earth communication transmitters, receivers, and transceivers	
* CTVC	Weight factor per TV camera	LB
* CTVM	Weight factor per TV monitor	LB
* CTVRS	Weight factor per TV remote camera station	LB
* WCCP	Weight factor for command processors (see Table XVI)	LB
WCCR	Weight of command receivers	LB
WCCS	Weight of command system	LB
WCØMM	Weight of communication	LB
* WCØMME	Weight of communication system (if known)	LB
WCØN11	Weight of contingency for communications	LB
* WCRAN	Weight factor for ranging communication system	LB
WCTB	Weight of tracking beacons	LB
WDSC	Weight of deep space communication system	LB
WDSCA	Weight of deep space communication antennas	LB
WDSCU	Weight of deep space transceivers and amplifiers	LB
WGRØ11	Weight of growth for communications	LB
WICØM	Weight of intercommunication system	LB
WNECA	Weight of near earth communication antennas	LB
WNECØM	Weight of near earth communication system	LB
WNECU	Weight of near earth communication transceivers, receivers, and transmitters	LB
* WSP11	Weight of special features for communications	LB
WTB11	Weight of communication excluding contingency and growth	LB
WTVC	Weight of TV cameras	LB

Variable	Definition	Units
WTVM	Weight of TV monitors	LB
WTVRS	Weight of TV remote camera stations	LB
WTVS	Weight of TV system	LB
* ZNCCR	Quantity of command receivers	
* ZNDSC	Quantity of deep space communication units	
* ZNECU	Quantity of near earth communication units	
* ZNICØM	Quantity of intercommunication stations in vehicle or module	
* ZNTB	Quantity of tracking beacons	
* ZTVC	Quantity of TV cameras	
* ZTVM	Quantity of TV monitors	
* ZTVRS	Quantity of TV remote camera stations	

* Input

ENVIRONMENTAL CONTROL SYSTEM

This group includes weights of equipment for internal compartment temperature and pressure control, crew's atmosphere purification, oxygen source, and electronic equipment temperature control. Tanks for oxygen, nitrogen, etc. for atmosphere control can be estimated either by using the pressure tank routine in Group 5A, or as a function of the weight of stored gases. Atmosphere conditioning and distribution is estimated either as a function of the pressurized volume of the module or as a function of the total pressurized volume which is serviced by this system (e.g., Skylab's AM atmosphere conditioning and distribution services the total pressurized volume of the Skylab cluster). The CO_2 removal equipment is either a molecular sieve type, which is time independent, or a lithium hyroxide type, which is time dependent.

The total weight of the environmental control system is defined as:

12.0 WECS = WESCE + WECSP + WCØØL + WSP12 + WCØN12 + WGRØ12.

12.1 ECS - Equipment

$$WECSE = 0.006(CESCE)(WGAN + WINST + WCØMM + WCSCP + WPLEP)^{5/4}.$$

12.2 ECS - Personnel

WECSP = WACS + WPCS + WTC + WCØ2R.

12.2.1 Atmosphere Control System

WACS = WACST + WACSY.

12.2.1.1 Atmosphere Control System Tanks (See Group 5A.)

$$WACST = \sum_{K=40}^{K=42} WPT(K)\ ZACST(K)\ ,\ \text{or}\ \Big\{CSCØX\Big[10.3(ZCSTØ) + 0.29\ (WBLOX)\Big] + CSCN\Big[9.8(ZCSTN) + 0.245(WBLN)\Big] + (CGØX)1.47(WBGØX) + (CGN)1.67(WBGN) + CBGHE(12.5)WBGHE\Big\}.$$

12.2.1.2 Atmosphere Control System Valves, Lines, Etc.

$$WACSY = CASCD\left[13.0(ZNCE + 2.0(WBLØX + WBGØX + WBGN + WBLN + WBGHE)^{\frac{1}{2}}\right].$$

12.2.2 Pressurization Control System

$$WPCS = CPCS(VØLPC).$$

12.2.3 Temperature Control System

$$WTC = WTCS + WTCI.$$

12.2.3.1 Atmosphere Conditioning and Distribution

$$WTCS = (0.166)(CTCS)(VØLPC)^{2/3}, \text{ or } (0.135)(CTCSC)(VØLAC)^{2/3}.$$

12.2.3.2 Insulation (Only if Inside of Pressurized Compartment)

$$WTCI = 0.65(CTCI)(VØLPC)^{2/3}.$$

12.2.5 CO_2 and Odor Removal

$$WCØ2R = 60.0(CMØSI)ZNCE, \text{ or } .095(CLIØH)ZNCE(TIMED).$$

12.3 Coolant System (Excluding Fluids)

$$WCØØL = CCØØL\left[3.2(WGAN + WINST + WCØMM + WPLEP + WELCØ) + 500.(ZNCE)\right].$$

12.18 Special Features

$$WSP12 = WSP12.$$

12.19 Contingency

$WCØN12 = CCØN12(WTB12)$, where

$$WTB12 = WECSE + WECSP + WCØØL + WSP12.$$

12.20 Growth

$$WGRØ12 = CGRØ12(WCØN12 + WTB12).$$

ENVIRONMENTAL CONTROL SYSTEM DEFINITIONS

Variable	Definitions	Units
* CASCD	Weight factor for atmosphere control system lines, valves, etc.	
* CBGHE	Weight factor for gaseous helium storage tanks for atmosphere control	

Variable	Definitions	Units
* CCØN12	Weight factor for contingency for ECS	
* CCØØL	Weight factor for coolant system	
* CESCE	Weight factor for ECS - equipment	
* CGN	Weight factor for gaseous nitrogen storage tanks for atmosphere control	
* CGØX	Weight factor for gaseous oxygen storage tanks for atmosphere control	
* CGRØ12	Weight factor for growth for ECS	
* CLIØH	Weight factor for lithium hydroxide CO_2 removal equipment	
* CMØSI	Weight factor for molecular sieve CO_2 removal equipment	
* CPCS	Weight factor for pressurization control system	
* CSCN	Weight factor for supercritical nitrogen storage tanks for atmosphere control	
* CSCØX	Weight factor for supercritical oxygen storage tanks for atmosphere control	
* CTCI	Weight factor for pressurized compartment internal insulation	
* CTCS	Weight factor for atmosphere conditioning and distribution (used when the system services only the vehicle or module being estimated)	
* CTCSC	Weight factor for atmosphere conditioning and distribution (used when the system services other modules, e.g., Skylab's AM)	
* TIMED	Design duration or resupply interval for crew's systems	HR
* VØLAC	Total volume of the pressurized compartments which are serviced by the atmosphere conditioning and distribution (same as VØLPC for unmodulized vehicles such as Mercury and Gemini)	CU FT
* VØLPC	Volume of the pressurized compartment of the vehicle or module	CU FT
WACS	Weight of atmosphere control system	LB
WACST	Weight of atmosphere control system tanks	LB
WACSY	Weight of atmosphere control system lines, valves, etc.	LB
* WBGHE	Weight of gaseous helium for atmosphere control	LB
* WBGN	Weight of gaseous nitrogen for atmosphere control	LB
* WBGØX	Weight of gaseous oxygen for atmosphere control	LB
* WBLN	Weight of supercritical nitrogen for atmosphere control	LB
* WBLØX	Weight of supercritical oxygen for atmosphere control	LB

Variable	Definition	Units
WCØMM	Weight of communication	LB
WCØN12	Weight of contingency for ECS	LB
WCØØL	Weight of coolant system (excluding fluids)	LB
WCØ2R	Weight of CO_2 and odor removal equipment	LB
WCSCP	Weight of crew station controls and panels	LB
WECS	Weight of ECS	LB
WECSE	Weight of ECS - equipment	LB
WECSP	Weight of ECS - personnel	LB
* WELCØ	Weight of electronic equipment serviced by the coolant system but not contained within the vehicle (such as the electronics contained in the CM which is cooled by the coolant system in the SM)	LB
WGAN	Weight of guidance and navigation	LB
WGRØ12	Weight of growth for ECS	LB
WINST	Weight of instrumentation	LB
WPCS	Weight of pressurization control system	LB
* WPLEP	Weight of payload which requires electrical power	LB
WPT(K)	Weight of each pressure tank estimated by inputs in Group 5A to be used as an alternate method for estimate of tanks for atmosphere control gases.	LB
* WSP12	Weight of special features for ECS	LB
WTB12	Weight of ECS excluding contingency and growth	LB
WTC	Weight of temperature control system	LB
WTCI	Weight of insulation (only if internal to the pressurized compartment)	LB
WTCS	Weight of atmosphere conditioning and distribution (heating and ventilating)	LB
* ZACST(K)	Quantity of identical tanks for atmosphere gases (each tank estimated by inputs in Group 5A)	
* ZCSTN	Quantity of supercritical nitrogen storage tanks used for atmosphere control	
* ZCSTØ	Quantity of supercritical oxygen storage tanks for atmosphere control	
* ZNCE	Quantity of crew for which the ECS and other accomodations are provided	

* Input

PERSONNEL PROVISIONS

This weight group includes the habitable provisions for the crew. Crew's water containers can be estimated either by using the pressure tank routing in Group 5A, or as a function of the capacity of the water storage tanks.

The total personnel provisions weight is defined as:

14.0 $$WPERP = WAFP + WFLSE + WCAHA + WFURN + WINLI + WWAMA + WFØRE + WSTCA + WWTAD + WSP14 + WCØN14 + WGRØ14.$$

14.1 Accomodations for Personnel

$$WAFP = WSEAT + WHAND + WSLEE.$$

14.1.1 Seats

$$WSEAT = ZNC(CSEAT).$$

14.1.2 Handrails

$$WHAND = CHAND(0.2)(VØLPC)^{\frac{1}{2}}.$$

14.13 Sleep Restraints

$$WSLEE = CSLEE(3.5)ZNCE.$$

14.2 Fixed Life Support Equipment

$$WFLSE = WFØCØ + WWACØ + WWADI + WGALL.$$

14.2.1 Food Containers (Non-refrigerated)

$$WFØCØ = CFØCØ(0.1)WFØØD(1. - CPFØD).$$

14.2.2 Water Containers (See Group 5A.)

$$WWACØ = CWACØ(0.25)WWAT, \text{ or } \sum_{K = 46}^{K = 48} ZWACØ(K)\left[WPT(K)\right].$$

14.2.3 Water Distribution and Pressurization System

$$WWADI = CWADI(1.47)(WWAT)^{\frac{1}{2}}.$$

14.2.4 Food Preparation (Non-portable)

$$WGALL = CGALL(30.0)ZNCE.$$

14.3 Cargo Handling

WCAHA = CCAHA(WCARGØ + WCACØ)PCAHA.

14.4 Furnishings

WFURN = WFPC + WPART + WINPA.

14.4.1 Non-structural Floors, Platforms, and Ceilings

WFPC = CFPC(2.5)SFPC.

14.4.2 Partitions and Interior Doors (Non-structural)

WPART = CPART(1.4)SPART.

14.4.3 Interior Paint

$$WINPA = CINPA(0.1)(V\emptyset LPC)^{2/3}.$$

14.6 Interior Lights

WINLI = CINLI(.04)VØLPC.

14.7 Waste Management

WWAMA = CWAMA(0.06)ZNCE(TIMED).

14.9 Food Refrigeration (Includes Refrigerated Food Containers, Heat Transfer System, and Heat Refection System)

WFØRE = CFØRE(1.55)WFØØD(CPFØD).

14.10 Storage Cabinets (Crew Systems)

WSTCA = CSTCA(0.06)ZNCE(TIMED).

14.11 Work Tables, Desks

WWTAD = CWTAD(25.0)ZNCE.

14.18 Special Features

WSP14 = WSP14.

14.19 Contingency

WCØN14 = CCØN14(WTB14), where

WTB14 is the sum of all the items preceding 14.19.

14.20 Growth

WGRØ14 = CGRØ14(WCØN14 + WTB14).

PERSONNEL PROVISIONS DEFINITIONS

Variable	Definitions	Units
* CCAHA	Weight factor for cargo handling	
* CCØN14	Weight factor for contingency for personnel provisions	
* CFØCØ	Weight factor for food containers (non-refrigerated)	
* CFØRE	Weight factor for food refrigeration system	
* CFPC	Weight factor for non-structural flooring, platforms, and ceilings	
* CGALL	Weight factor for food preparation equipment	
* CGRØ14	Weight factor for growth for personnel provisions	
* CHAND	Weight factor for handrails and restraints	
* CINLI	Weight factor for interior lights	
* CINPA	Weight factor for interior paint	
* CPART	Weight factor for non-structural partitions and interior doors	
* CPFØD	Proportion of food (by weight) that requires refrigeration or cold storage	
* CSEAT	Weight factor per crew's seat	LB
* CSLEE	Weight factor for sleeping restraints	
* CSTCA	Weight factor for crew's system storage cabinets	
* CWACØ	Weight factor for crew's water containers	
* CWADI	Weight factor for crew's water distribution and pressurization system	
* CWAMA	Weight factor for waste management	
* CWTAD	Weight factor for work tables and desks	
* PCAHA	Proportion of cargo requiring special handling equipment	

Variable	Definition	Units
* SFPC	Total area of non-structural flooring, platforms, and ceilings	SQ FT
* SPART	Total area of non-structural partitions and interior doors	SQ FT
* TIMED	Design duration or resupply interval for crew's systems	HR
* VØLPC	Volume of the pressurized compartment of the vehicle or module	CU FT
WAFP	Weight of accommodations for personnel	LB
WCAHA	Weight of cargo handling	LB
* WCARGØ	Weight of cargo	LB
WCØN14	Weight of contingency for personnel provisions	LB
WFLSE	Weight of fixed life support equipment	LB
WFØCØ	Weight of non-refrigerated food containers	LB
WFØØD	Weight of food	LB
WFØRE	Weight of food refrigeration system	LB
WFPC	Weight of non-structural flooring, platforms, and ceilings	LB
WFURN	Weight of furnishings	LB
WGALL	Weight of food preparation equipment	LB
WGRØ14	Weight of growth for personnel provisions	LB
WHAND	Weight of handrails and restraints	LB
WINLI	Weight of interior lights	LB
WINPA	Weight of interior paint	LB
WPART	Weight of non-structural partitions and interior doors	LB
WPERP	Total weight of personnel provisions	LB
WPT(K)	Weight of each pressure tank estimated by inputs in Group 5A to be used as an alternate method for estimates of tanks containing crew's water	LB
WSEAT	Weight of crew's seats	LB
WSLEE	Weight of sleeping restraints	LB
* WSP14	Weight of special features of personnel provisions	LB
WSTCA	Weight of crew's system storage cabinets	LB
WTB14	Weight of personnel provisions excluding contingency and growth	LB
WWACØ	Weight of crew's water containers	LB
* WCACØ	Weight of cargo containers	LB

Variable	Definition	Units
WWADI	Weight of crew's water distribution and pressurization system	LB
WWAMA	Weight of waste management	LB
WWAT	Weight of crew's water	LB
WWTAD	Weight of work tables and desks	LB
* ZNC	Quantity of crew at launch and/or reentry	
* ZNCE	Quantity of crew for which the ECS and other accommodations are provided	
* ZWACØ(K)	Quantity of identical crew's water containers	

* Input

CREW STATION CONTROLS AND PANELS

The weight of crew station controls and panels is estimated as a function of the number of flight crew members for aircraft and space vehicles other than space stations. Crew station controls and panels weight for space stations is estimated as a function of total pressurized volume.

The total weight for this group is defined as:

15.0 WCSCP = WTB15 + WSP15 + WCØN15 + WGRØ15.

15.1 Crew Station Controls and Panels

WTB15 = CCSSC(ZNC), or

$$\left[200. + 0.0284(\text{VØLAC})\right] \text{RCSCP.}$$

15.18 Special Features

WSP15 = WSP15.

15.19 Contingency

WCØN15 = CCØN15(WTB15 + WSP15).

15.20 Growth

WGRØ15 = CGRØ15(WTB15 + WSP15 + WCØN15).

CREW STATION CONTROLS AND PANELS DEFINITIONS

Variable	Definition	Units
* CCØN15	Weight factor for contingency for crew station controls and panels	
* CCSSC	Weight factor per crew station controls and panels	LB
* CGRØ15	Weight factor for growth for crew station controls and panels	
* RCSCP	Weight proportion of the crew station controls and panels of the total space station cluster contained within the specified module	
* VØLAC	Total volume of the pressurized compartments which are serviced by the atmosphere conditioning and distribution (same as VØLPC for vehicles such as Mercury and Gemini)	

Variable	Definition	Units
WCØN15	Weight of contingency for crew station controls and panels	LB
WCSCP	Weight of crew station controls and panels	LB
WGRØ15	Weight of growth for crew station controls and panels	LB
* WSP15	Weight of special features for crew station controls and panels	LB
WTB15	Weight of crew station controls and panels excluding special features, contingency, and growth	LB
* ZNC	Quantity of crew at launch and/or reentry	

* Input

PERSONNEL

This weight group includes the crew required to perform the mission and non-fixed items required to support the crew both inside and outside the vehicle, such as personal gear, portable life support items, and crew accessories. Both food and crew's water can be estimated either by knowing the total required amounts, or as a function of daily allowance rates and duration of mission or resupply interval.

The total weight of this group is defined as:

17.0 WPERS = WCRES + WPG + WLS + WACCE + WSP17 + WCØN17 + WGRØ17.

17.1 Crew

WCRES = WCREW + WCWG + WPRST.

17.1.1 Crew

WCREW = ZNC(CCREW).

17.1.2 Constant Wear Garments

WCWG = ZNC(CCWG).

17.1.3 Pressure Suits

WPRST = ZNPS(CPRST).

17.2 Personal Gear

WPG = WPLSS + WPRGA + WCHUT + WHYGE + WCØL + WPRCU.

17.2.1 Portable Life Support Equipment

WPLSS = ZPLSS(CPLSS).

17.2.2 Protective Garments

WPRGA = ZPRGA(CPRGA).

17.2.3 Personal Parachutes

WCHUT = ZCHUT(CCHUT).

17.2.4 Hygienic Equipment

$$WHYGE = CHYGE(8.1 \times 10^{-6})ZNCE(TIMED)^2.$$

17.2.5 Crew Equipment (Personal Clothing Changes)

$$WC\emptyset L = \frac{ZNCE(CC\emptyset L)TIMED}{24.}.$$

17.2.6 Privacy Curtains

$$WPRCU = CPRCU(6.)ZNCE.$$

17.3 Life Support

$$WLS = WF\emptyset\emptyset D + WWAT + WRECR + WEXC + WRC + WSK.$$

17.3.1 Food

$$WF\emptyset\emptyset D = CF\emptyset\emptyset D, \text{ or } \frac{CFPMD(ZNCE)TIMED}{24.}.$$

17.3.2 Water

$$WWAT = CWAT, \text{ or } \frac{CWPMD(ZNCE)TIMED}{22.7}.$$

17.3.3 Recreation Equipment

$$WRECR = CRECR(ZNCE).$$

17.3.4 Exercise Equipment

$$WEXC = CEXC(ZNCE).$$

17.3.5 First Aid

$$WRC = CRC(ZNCE).$$

17.3.6 Survival Kits

$$WSK = CSK(ZNCE).$$

17.4 Accessories

$$WACCE = WMMLB + WMT + WFEXT + WACC\emptyset.$$

17.4.1 Maps, Manuals, Log Books

$$WMMLB = WMMLB.$$

17.4.2 Maintenance Tools

WMT = WMT.

17.4.3 Fire Extinguishers (Portable)

WFEXT = ZFEXT(CFEXT).

17.4.4 Accessory Containers, Retainers, Etc.

WACCØ = WACCØ.

17.18 Special Features

WSP17 = WSP17.

17.19 Contingency

WCØN17 = CCØN17(WTB17), where

WTB17 = WCRES + WPG + WLS + WACCE.

17.20 Growth

WGRØ17 = CGRØ17(WCØN17 + WTB17).

PERSONNEL DEFINITIONS

Variable	Definition	Units
* CCHUT	Weight factor for each personal parachute	LB
* CCØL	Weight factor for crew clothing changes (LB/MAN DAY)	
* CCØN17	Weight factor for contingency for personnel	
* CCREW	Weight factor for each crew (average weight per crew member)	LB
* CCWG	Weight factor for constant wear garment for each crew	LB
* CEXC	Weight factor for exercise equipment per crew	LB
* CFEXT	Weight factor for each portable fire extinguisher	LB
* CFØØD	Weight of food entered as a total amount	LB
* CFPMD	Weight of food allowance (LB/MAN DAY)	
* CGRØ17	Weight factor for growth for personnel	
* CHYGE	Weight factor for hygienic equipment	
* CPLSS	Weight factor for each portable life support system	LB

Variable	Definition	Units
* CPRCU	Weight factor for privacy curtains	
* CPRGA	Weight factor for each protective garment	LB
* CPRST	Weight factor for each pressure suit	LB
* CRC	Weight factor for first aid equipment per crew	LB
* CRECR	Weight factor for recreation equipment per crew	LB
* CSK	Weight factor for survival kits per crew	LB
* CWAT	Weight of crew water entered as a total amount	LB
* CWPMD	Weight of crew water allowance (LB/MAN DAY)	
* TIMED	Design duration or resupply interval for crew's systems	HR
WACCE	Weight of crew's accessories	LB
* WACCØ	Weight factor for accessory containers, retainers, etc.	LB
WCHUT	Weight of personal parachutes	LB
WCØL	Weight of crew's personal clothing changes	LB
WCØN17	Weight of contingency for personnel	LB
WCRES	Weight of crew, constant wear garments, and pressure suits	LB
WCREW	Weight of crew	LB
WCWG	Weight of constant wear garments for crew	LB
WEXC	Weight of exercise equipment	LB
WFEXT	Weight of portable fire extinguishers	LB
WFØØD	Weight of food	LB
WGRØ17	Weight growth for personnel	LB
WHYGE	Weight of personal hygiene equipment	LB
WLS	Weight of life support equipment	LB
* WMMLB	Weight factor for maps, manuals, log book, etc.	LB
* WMT	Weight factor for maintenance tools	LB
WPERS	Total weight cf personnel	LB
WPG	Weight of personal gear	LB
WPLSS	Weight of portable life support systems	LB
WPRCU	Weight of privacy curtains	LB
WPRGA	Weight of protective garments	LB
WPRST	Weight of pressure suits	LB
WRC	Weight of medical and first aid equipment	LB
WRECR	Weight of recreation equipment	LB

Variable	Definition	Units
WSK	Weight of survival kits	LB
* WSP17	Weight of special features for personnel	LB
WTB17	Weight of personnel excluding contingency and growth	LB
WWAT	Weight of crew's water	LB
* ZCHUT	Quantity of personal parachutes	
* ZFEXT	Quantity of portable fire extinguishers	
* ZNC	Quantity of crew at launch and/or reentry	
* ZNCE	Quantity of crew for which the ECS and other accommodations are provided	
* ZNPS	Quantity of pressure suits	
* ZPLSS	Quantity of portable life support systems	
* ZPRGA	Quantity of protective garments	

* Input

CARGO

This group comprises the payload of the vehicle. It includes cargo, passengers, scientific instruments, and experiments, unless provided for in a preceding functional group (e.g., telemetry and recorders for scientific pruposes may be included in the instrumentation group). If the vehicle being estimated is the first stage of a two or more stage vehicle, the weight of stage 2, 3, etc. is entered as cargo.

The total weight of cargo is defined as:

18.0 WPL = WSCIN + WEXP + WCAR + WSP18 + WCØN18 + WGRØ18.

18.1 Scientific Instruments

WSCIN = WSCIN.

18.2 Experiments

WEXP = WEXP.

18.3 Cargo

WCAR = WCACØ + WCARGØ + ZNPAS(WPAS).

18.18 Special Features

WSP18 = WSP18.

18.19 Contingency

WCØN18 = CCØN18(WSCIN + WEXP + WCAR + WSP18).

18.20 Growth

WGRØ18 = CGRØ18 (WSCIN + WEXP + WCAR + WSP18 + WCØN18).

CARGO DEFINITIONS

Variable	Definition	Units
* CCØN18	Weight factor for contingency for cargo	
* CGRØ18	Weight factor for growth for cargo	
* WCACØ	Weight of cargo containers	LB

Variable	Definition	Units
WCAR	Weight of cargo, cargo containers, and passengers **plus** accommodations	LB
* WCARGØ	Weight of cargo	LB
WCØN18	Weight of contingency for cargo	LB
* WEXP	Weight of experiments	LB
WGRØ18	Weight of growth for cargo	LB
* WPAS	Weight of each passenger, including his accommodations	LB
WPL	Weight of cargo	LB
* WSCIN	Weight of scientific instruments	LB
* WSP18	Weight of special features for cargo	LB
* ZNPAS	Quantity of passengers	

* Input

This group consists of the estimated weight allowance for ballast. Allowance should be made for ballast in ballistic reentry bodies, lifting bodies, and launch escape systems.

The total weight of ballast is defined as:

20.0 WBLLST = WTB20 + WSP20 + WCØN20 + WGRØ20.

20.1 Ballast

WTB20 = CBLST1(GWRE), or CBLST2(WLESC).

20.18 Special Features

WSP20 = WSP20.

20.19 Contingency

WCØN20 = CCØN20(WTB20 + WSP20).

20.20 Growth

WGRØ20 = CGRØ20(WTB20 + WSP20 + WCØN20).

BALLAST DEFINITIONS

Variable	Definition	Units
* CBLST1	Weight factor for ballast allowance for ballistic reentry bodies and lifting bodies	
* CBLST2	Weight factor for launch escape towers (e.g., Mercury and Apollo)	
* CCØN20	Weight factor for contingency for ballast	
* CGRØ20	Weight factor for growth for ballast	
* GWRE	Reentry or atmospheric cruise design gross weight	LB
WBLLST	Weight of ballast	LB
WCØN20	Weight of contingency for ballast	LB
WGRØ20	Weight of growth for ballast	LB
* WLESC	Gross weight at launch escape (reentry body plus launch escape tower)	LB
* WSP20	Weight of special features for ballast	LB
WTB20	Weight of ballast excluding special features, contingency, and growth	LB

* Input

RESIDUAL PROPELLANT AND SERVICE ITEMS

The total weight of residual propellant and service items is defined as:

21.0 $$WRPASI = WFPG + WØPG + WFTME1 + WØTME1 + WFØME1 + WØØME1 + WFTAE2 + WFTEP + WØTEP + WSIT + WTPGG + WSP21.$$

21.1 Fuel Pressuring Gas

$$WFPG = \frac{\frac{WFUEL1}{DENF1}(CFPG)(WFUEL1 + WØXID1)}{\frac{WFUEL1}{DENF1} + \frac{WØXID1}{DENØ1}}, \text{ where}$$

$$WFUEL1 = \sum_{I=1}^{I=8} [CPRØP(I)]\, WPRØP(I) + \sum_{K=1}^{K=5} [ZREFT(K)]\, WCØN(K), \text{ and}$$

$$WØXID1 = \sum_{I=1}^{I=8} [1. - CPRØP(I)]\, WPRØPØ(I) + \sum_{K=11}^{K=15} [ZREØT(K)] WCØN(K).$$

21.2 Oxidizer Pressurizing Gas

$$WØPG = \frac{\frac{WØXID1}{DENØ1}(CØPG)(WFUEL1 + WØXID1)}{\frac{WFUEL1}{DENF1} + \frac{WØXID1}{DENØ1}}.$$

21.3 Fuel Trapped - Main Engine

$$WFTME1 = CFTME1(WFUEL1).$$

21.4 Oxidizer Trapped - Main Engine

$$WØTME1 = CØTME1(WØXID1).$$

21.5 Fuel Outage - Main Engine

$$WFØME1 = CFØME1(WFUEL1).$$

21.6 Oxidizer Outage - Main Engine

$$WØØME1 = CØØME1(WØXID1).$$

21.7 Fuel Trapped - Auxiliary Propulsion (Air Breathing Engine System)

$$WFTAE2 = CFTAE2(WFUEL2)^{3/4}, \text{ where}$$

$$WFUEL2 = (DENF2)(7.481) \sum_{K=1}^{K=5} \left[VNSST(K)\right] ZNSST(K).$$

21.11 Fuel Trapped - Electrical Power (Fuel Cells)

WFTEP = CFTEP(WFLEP).

21.12 Oxidizer Trapped - Electrical Power (Fuel Cells)

WØTEP = CØTEP(WØLEP).

21.13 Service Items

WSIT = WPSG + WPNSG + WHYDF + WLUB + WECSF + WTRCSP + WRCSPG +

WFCFL + WCØMG.

21.13.1 Purge System Gas

WPSG = WPSG.

21.13.2 Pneumatic System Gas

WPNSG = WPNSG.

21.13.3 Hydraulic Fluid

WHYDF = 0.44 (WPDH).

21.13.4 Lubricants

WLUB = WEØAE + WEØLRE.

21.13.4.1 Air Breathing Engine Oil

WEØAE = CEØAE(ZNABE).

21.13.4.2 Liquid Rockent Engine Oil

WEØLRE = CEØLRE(ZNLRE).

21.13.5 Environmental Control Fluids (Closed Coolant Loop)

WECSF = CECSF(0.2)WCØØL.

21.13.6 Trapped RCS Propellant

WTRCSP = CRCSP(WRCSF1 + WRCSØ1).

21.13.7 RCS Propellant Pressurizing Gas

WRCSPG = CRCSPG(WRCSF1 + WRCSØ1).

21.13.8 Fuel Cell Fluid (Electrolyte)

WFCFL = 1.3(ZNCEL)RPØFC.

21.13.9 Compartment Gas (Pressurizing Gas Greater Than Ambient at Launch)

WCØMG = (DECØMG - 0.0753)VØLPC.

21.14 Trapped Propellant - Prime Power Source Gas Generator

WTPGG = CTPGG(WPLGG).

21.18 Special Features

WSP21 = WSP21.

RESIDUAL PROPELLANT AND SERVICE ITEMS DEFINITIONS

Variable	Definition	Units
* CECSF	Weight factor for closed circuit coolant loop fluid of ECS	
* CEØAE	Weight factor for engine oil for air breathing engines	LB/ENG
* CEØLRE	Weight factor for engine oil for liquid rocket engines (pump fed only)	LB/ENG
* CFØME1	Weight factor for main propulsion fuel outage	
* CFPG	Weight factor for main propulsion fuel pressurizing gas	
* CFTAE2	Weight factor for trapped fuel of auxiliary propulsion system	
* CFTEP	Weight factor for trapped fuel of electrical power (cryogenic hydrogen)	
* CFTME1	Weight factor for main propulsion trapped fuel	
* CØØME1	Weight factor for main propulsion oxidizer outage	
* CØPG	Weight factor for main propulsion oxidizer pressurizing gas	
* CØTEP	Weight factor for trapped oxidizer of electrical power (cryogenic oxygen)	

Variable	Definition	Units
* CØTME1	Weight factor for main propulsion trapped oxidizer	
* CPRØP(K)	Factor for identifying large propellant tanks (fuel or oxidizer containers)	
* CRCSP	Weight factor for trapped propellant of RCS	
* CRCSPG	Weight factor for RCS propellant pressurizing gas	
* CTPGG	Weight factor for gas generator trapped propellant of prime power source	
* DECØMG	Density of compartment gas at launch	LB/CU FT
* DENF1	Density of main propulsion fuel	LB/CU FT
* DENF2	Density of auxiliary propulsion fuel	LB/GAL
* DENØ1	Density of main propulsion oxidizer	LB/CU FT
* RPØFC	Rated power of each fuel cell battery	KW
* VNSST(K)	Volume of each identical non-self-sealing tank for air breathing engines	CU FT
* VØLPC	Volume of the pressurized crew compartment of the vehicle or module	CU FT
WCØMG	Weight of compartment gas at launch (in excess of ambient conditions)	LB
WCØN(K)	Weight capacity of contained liquid or gas for each tank	LB
WCØØL	Weight of coolant system (excluding fluids)	LB
WECSF	Weight of closed circuit coolant loop fluid of ECS	LB
WEØAE	Weight of air breathing engine oil	LB
WEØLRE	Weight of engine oil for liquid rocket engines	LB
WFCFL	Weight of fuel cell fluid (electrolyte)	LB
* WFLEP	Weight of loaded quantity of fuel for electrical power	LB
WFØME1	Weight of main propulsion fuel outage	LB
WFPG	Weight of main propulsion fuel pressurizing gas	LB
WFTAE2	Weight of trapped fuel of auxiliary propulsion system	LB
WFTEP	Weight of trapped fuel of electrical power (cryogenic hydrogen)	LB
WFTME1	Weight of main propulsion trapped fuel	LB
WFUEL1	Weight of loaded quantity of fuel for main propulsion	LB
WFUEL2	Weight of loaded quantity of auxiliary propulsion fuel	LB
WHYDF	Weight of hydraulic fluid	LB

Variable	Definition	Units
WLUB	Weight of lubricants	LB
* WØLEP	Weight of loaded quantity of oxidizer for electrical power	LB
WØØME1	Weight of main propulsion oxidizer outage	LB
WØPG	Weight of main propulsion oxidizer pressurizing gas	LB
WØTEP	Weight of trapped oxidizer of electrical power (cryogenic oxygen)	LB
WØTME1	Weight of main propulsion trapped oxidizer	LB
WØXID1	Weight of loaded quantity of oxidizer for main propulsion	LB
WPDH	Weight of hydraulic power distribution (inerts only, fluid is in section 21)	LB
* WPLGG	Weight of loaded quantity of gas generator propellant for prime power source	LB
* WPNSG	Weight of trapped pneumatic system gas	LB
WPRØP(K)	Weight of loaded fuel capacity in large fuel tank No. (I) (booster type)	LB
WPRØPØ(I)	Weight of loaded oxidizer capacity in large oxidizer tank No. (I) (booster type)	LB
* WPSG	Weight of trapped purge gas	LB
* WRCSF1	Weight of loaded quantity of RCS fuel	LB
* WRCSØ1	Weight of loaded quantity of RCS oxidizer	LB
WRCSPG	Weight of RCS propellant pressurizing gas	LB
WRPASI	Weight of residual propellants and service items	LB
WSIT	Weight of trapped service items	LB
* WSP21	Weight of special features for residual propellants and service items	
WTPGG	Weight of gas generator trapped propellant for prime power source	LB
WTRCSP	Weight of trapped propellant for RCS	LB
* ZNABE	Quantity of air breathing engines	
* ZNCEL	Quantity of fuel cell batteries	
* ZNLRE	Quantity of liquid rocket engines	
* ZNSST(K)	Quantity of identical non-self-sealing tanks for air breathing engines	
* ZREFT(K)	Quantity of identical liquid rocket fuel tanks	
* ZREØT(K)	Quantity of identical liquid rocket oxidizer tanks	

* Input

RESERVE PROPELLANT & SERVICE ITEMS

The total weight of reserve propellant and service items is defined as:

22.0 WRESP = WFRME1 + WORME1 + WFRCR + WØRCR + WFREP + WFRAE2 + WØREP +

WRSI + WPRGG + WSP22.

22.3 Fuel - Main Engine Reserve

WFRME1 = CFRME1(WFUEL1).

22.4 Oxidizer - Main Engine Reserve

WØRME1 = CØRME1(WØXID1).

22.7 Fuel - RCS Reserve

WFRCR = CFRCR(WRCSF1).

22.8 Oxidizer - RCS Reserve

WØRCR = CØRCR(WRCSØ1).

22.9 Fuel - Electrical Power Reserve

WFREP = CFREP(WFLEP).

22.10 Oxidizer - Electrical Power Reserve

WØREP = CØREP(WØLEP).

22.11 Fuel - Auxiliary Propulsion Reserve

WFRAE2 = CFRAE2(WFUEL2).

22.13 Service Item Reserve

WRSI = WBØX + WBN2 + WRH2Ø + WBGHE.

22.13.2 Metabolic Oxygen Reserve (Usable)

WBØX = WBGØX + WBLØX.

22.13.3 Nitrogen Reserve (Usable)(For Atmosphere Control)

WBN2 = WBGN + WBLN.

22.13.4 Coolant Reserve

WRH2Ø = CRCH2Ø(WCH2Ø).

22.13.8 Helium Reserve (Usable)(For Atmosphere Control)

WBGHE = WBGHE.

22.14 Propellant - Gas Generator Reserve

WPRGG = CPRGG(WPLGG).

22.18 Special Features

WSP22 = WSP22.

RESERVE PROPELLANT AND SERVICE ITEMS DEFINITIONS

Variable	Definition	Units
* CFRAE2	Weight factor for fuel reserve for auxiliary propulsion	
* CFRCR	Weight factor for fuel reserve for RCS	
* CFREP	Weight factor for fuel reserve for electrical power (fuel cells)	
* CFRME1	Weight factor for fuel reserve for main propulsion	
* CØRCR	Weight factor for oxidizer reserve for RCS	
* CØREP	Weight factor for oxidizer reserve for electrical power (fuel cells)	
* CØRME1	Weight factor for oxidizer reserve for main propulsion	
* CPRGG	Weight factor for gas generator propellant reserve for prime power source	
* CRCH2Ø	Weight factor for coolant reserve	
* WBGHE	Weight of loaded quantity of gaseous helium for atmosphere control	LB
* WBGN	Weight of loaded quantity of gaseous nitrogen for atmosphere control	LB
* WBGØX	Weight of loaded quantity of gaseous oxygen for atmoshpere control	LB
* WBLN	Weight of loaded quantity of supercritical stored nitrogen for atmosphere control	LB
* WBLØX	Weight of loaded quantity of supercritical stored oxygen for atmosphere control	LB
WBN2	Weight of loaded quantity of nitrogen for atmosphere control	LB

Variable	Definition	Units
WBØX	Weight of loaded quantity of metabolic oxygen for atmosphere control	LB
* WCH2Ø	Weight of loaded quantity of coolant	LB
* WFLEP	Weight of loaded quantity of fuel for electrical power (fuel cells)	LB
WFRAE2	Weight of fuel reserve for auxiliary propulsion	LB
WFRCR	Weight of fuel reserve for RCS	LB
WFREP	Weight of fuel reserve for electrical power (fuel cells)	LB
WFRME1	Weight of fuel reserve for main propulsion	LB
WFUEL1	Weight of loaded quantity of fuel for main propulsion	LB
WFUEL2	Weight of loaded quantity of auxiliary propulsion fuel	LB
* WØLEP	Weight of loaded quantity of oxidizer for electrical power (fuel cells)	LB
WØRCR	Weight of oxidizer reserve for RCS	LB
WØREP	Weight of oxidizer reserve for electrical power (fuel cells)	LB
WORME1	Weight of oxidizer reserve for main propulsion	LB
WØXID1	Weight of loaded quantity of oxidizer for main propulsion	LB
* WPLGG	Weight of loaded quantity of gas generator propellant for prime power source	LB
WPRGG	Weight of gas generator reserve propellant for prime power source	LB
* WRCSF1	Weight of loaded quantity of RCS fuel	LB
* WRCSØ1	Weight of loaded quantity of RCS oxidizer	LB
WRESP	Weight of reserve propellant and service items	LB
WRH2Ø	Weight of coolant reserve	LB
WRSI	Weight of service items reserve	LB
* WSP22	Weight of special features of reserve propellant and service items	LB

* Input

INFLIGHT LOSSES

The total weight of the inflight losses is defined as:

23.0 WINLØS = WFVEN1 + WØVEN1 + WRCFU + WRCØU + WFUEP + WØUEP + WLØSSI + WUPGG + WSP23.

23.1 Vented Pressurizing Gas - Fuel System (Vented Fuel)

WFVEN1 = WFVEN1.

23.2 Vented Pressurizing Gas - Oxidizer System (Vented Oxidizer)

WØVEN1 = WØVEN1.

23.3 Fuel - RCS

WRCFU = (1. - CFRCR - CRCSP)WRCSF1.

23.4 Oxidizer - RCS

WRCØU = (1. - CØRCR - CRCSP)WRCSØ1.

23.5 Fuel - Electrical Power (Fuel Cells)

WFUEP = (1. - CFTEP - CFREP)WFLEP.

23.6 Oxidizer - Electrical Power (Fuel Cells)

WØUEP = (1. - CØTEP - CØREP)WØLEP.

23.7 Service Items

WLØSSI = WPSGE + WPNSGE + WFRØST + WSEPP + WCUH2Ø.

23.7.3 Purge System Gases

WPSGE = WPSGE.

23.7.4 Pneumatic System Gases

WPNSGE = WPNSGE.

23.7.5 Frost

WFRØST = WFRØST.

23.7.7 Separation System Propellant (Solid Rockets)

WSEPP = (1.35×10^{-4})CSEPR(WCEL2)DELV2.

23.7.10 Coolant Fluids

WCUH2Ø = (1. - CRCH2Ø)WCH2Ø.

23.8 Gas Generator Propellant - Prime Power Source

WUPGG = (1. - CTPGG - CPRGG)WPLGG.

23.18 Special Features

WSP23 = WSP23.

INFLIGHT LOSSES DEFINITIONS

Variable	Definition	Units
* CFRCR	Weight factor for fuel reserve for RCS	
* CFREP	Weight factor for fuel reserve for electrical power (fuel cells)	
* CFTEP	Weight factor for trapped fuel for electrical power (cryogenic hydrogen)	
* CØRCR	Weight factor for oxidizer reserve for RCS	
* CØREP	Weight factor for oxidizer reserve for electrical power (fuel cells)	
* CØTEP	Weight factor for trapped oxidizer for electric power (cryogenic oxygen)	
* CPRGG	Weight factor for gas generator propellant reserve for prime power source	
* CRCH2Ø	Weight factor for coolant reserve	
* CRCSP	Weight factor for trapped propellant for RCS	
* CSEPR	Weight factor for separation rockets	
* CTPGG	Weight factor for trapped gas generator propellant for prime power source	
* DELV2	Gross velocity increment for stage or component for separation	FT/SEC
* WCEL2	Weight of vehicle or component to be accelerated by separation rockets or springs	LB
* WCH2Ø	Weight of loaded quantity of coolant	LB
WCUH2Ø	Weight of nominally consumed coolant	LB
* WFLEP	Weight of loaded quantity of fuel for electrical power (fuel cells)	LB

Variable	Definition	Units
* WFRØST	Weight of frost lost during flight	LB
WFUEP	Weight of nominally consumed fuel for electrical power (fuel cells)	LB
* WFVEN1	Weight of vented fuel for main propulsion	LB
WINLØS	Weight of inflight losses	LB
WLØSSI	Weight of nominally consumed service items	LB
* WØLEP	Weight of loaded quantity of oxidizer for electrical power (fuel cell)	LB
WØUEP	Weight of nominally consumed oxidizer for electrical power (fuel cells)	LB
* WØVEN1	Weight of vented oxidizer for main propulsion	LB
* WPLGG	Weight of loaded quantity of gas generator propellant for prime power source	LB
* WPNSGE	Weight of nominally consumed pneumatic system gases	LB
* WPSGE	Weight of nominally consumed purge system gases	LB
WRCFU	Weight of nominally consumed RCS fuel	LB
WRCØU	Weight of nominally consumed RCS oxidizer	LB
* WRCSF1	Weight of loaded quantity of RCS fuel	LB
* WRCSØ1	Weight of loaded quantity of RCS oxidizer	LB
WSEPP	Weight of solid propellant consumed for separation	LB
* WSP23	Weight of special features for inflight losses	LB
WUPGG	Weight of nominally consumed gas generator propellant for prime power source	LB

* Input

THRUST DECAY PROPELLANT

Total thrust decay propellant is defined as:

24.0 WTDP = WTDF + WTDØ + WSP24.

24.1 Fuel - Main Propulsion

WTDF = CTDF(ZNLRE)TLRE.

24.2 Oxidizer - Main Propulsion

WTDØ = CTDØ(ZNLRE)TLRE.

24.18 Special Features

WSP24 = WSP24.

THRUST DECAY PROPELLANT DEFINITIONS

Variable	Definition	Units
* CTDF	Factor for thrust decay fuel for main propulsion (a function of total thrust)	
* CTDØ	Factor for thrust decay oxidizer for main propulsion (a function of total thrust)	
* TLRE	Thrust of each liquid rocket engine	LB
WTDF	Weight of thrust decay fuel for main propulsion	LB
WTDØ	Weight of thrust decay oxidizer for main propulsion	LB
WTDP	Weight of thrust decay propellant	LB
* WSP24	Weight of special features for thrust decay porpellant	LB
* ZNLRE	Quantity of liquid rocket engines	

* Input

FULL THRUST PROPELLANT

Total full thrust propellant is defined as:

25.0 WFTP = WFTFMP + WFTØMP + WFTFAP + WSPP1 + WSP25.

25.1 Fuel - Main Propulsion

WFTFMP = WFUEL1(1. - CFTME1 - CFRME1 - CFØME1) - (CTDF + CTBUF) •

ZNLRE(TLRE) - WFVEN1 - WRCSF1(CLFU1) - WFPG(CFPGMP).

25.2 Oxidizer - Main Propulsion

WFTØMP = WØXID1(1. - CØTME1 - CØRME1 - CØØME1) - (CTDØ + CTBUØ) •

ZNLRE(TLRE) - WØVEN1 - WRCSØ1(CLØU1) - WØPG(CFPGMP).

25.4 Fuel - Auxiliary Propulsion

WFTFAP = WFUEL2 - WFTAE2 - WFRAE2.

25.5 Solid Propellant

$$\text{WSPP1} = \frac{\text{WSPS1(CMF1)}}{\text{(1. - CMF1)}} .$$

25.18 Special Features

WSP25 = WSP25.

FULL THRUST PROPELLANT DEFINITIONS

Variable	Definition	Units
* CFØME1	Weight factor for main propulsion fuel outage	
* CFPGMP	Factor to be used when vaporized propellants stored in the main propellant tanks are used as pressurant	
* CFRME1	Weight factor for fuel reserve for main propulsion	
* CFTME1	Weight factor for main propulsion trapped fuel	
* CLFU1	Factor to be used when RCS fuel is stored in main propulsion fuel tanks	
* CLØU1	Factor to be used when RCS oxidizer is stored in main propulsion oxidizer tanks	
* CMF1	Weight factor for mass fraction of solid propellant propulsion systems (see Figure 5-1)	
* CØØME1	Weight factor for main propulsion oxidizer outage	

Variable	Definition	Units
* CØRME1	Weight factor for oxidizer reserve for main propulsion	
* CØTME1	Weight factor for main propulsion trapped oxidizer	
* CTBUF	Weight factor for thrust buildup fuel for main propulsion (a function of total thrust)	
* CTBUØ	Weight factor for thrust buildup oxidizer for main propulsion (a function of total thrust)	
* CTDF	Weight factor for thrust decay fuel for main propulsion (a function of total thrust)	
* CTDØ	Weight factor for thrust decay oxidizer for main propulsion (a function of total thrust)	
* TLRE	Thrust of each liquid rocket engine	LB
WFRAE2	Weight of fuel reserve for auxiliary propulsion	LB
WFTAE2	Weight of trapped fuel for auxiliary propulsion system	LB
WFTFAP	Weight of full thrust fuel for auxiliary propulsion	LB
WFTFMP	Weight of full thrust fuel for main propulsion	LB
WFTØMP	Weight of full thrust oxidizer for main propulsion	LB
WFTP	Weight of full thrust propellant	LB
WFUEL1	Weight of loaded quantity of fuel for main propulsion	LB
WFUEL2	Weight of loaded quantity of auxiliary propulsion fuel	LB
* WFVEN1	Weight of vented fuel for main propulsion	LB
* WØVEN1	Weight of vented oxidizer for main propulsion	LB
WØXID1	Weight of loaded quantity of oxidizer for main propulsion	LB
* WRCSF1	Weight of loaded quantity of RCS fuel	LB
* WRCSØ1	Weight of loaded quantity of RCS oxidizer	LB
WSPP1	Weight of full thrust propellant for solid propulsion	LB
WSPS1	Weight of solid propellant propulsion system (inerts only)	LB
* WSP25	Weight of special features for full thrust propellant	LB
* ZNLRE	Quantity of liquid rocket engines	
WFPG	Weight of main propulsion fuel pressurizing gas	LB
WØPG	Weight of main propulsion oxidizer pressurizing gas	LB

* Input

THRUST BUILDUP PROPELLANT

Total thrust buildup propellant is defined as:

26.0 WTBUP = WTBUF + WTBUØ + WSP26.

26.1 Fuel - Main Propulsion

WTBUF = CTBUF(ZNLRE)TLRE.

26.2 Oxidizer - Main Propulsion

WTBUØ = CTBUØ(ZNLRE)TLRE.

26.18 Special Features

WSP26 = WSP26.

THRUST BUILDUP PROPELLANT DEFINITIONS

Variable	Definition	Units
* CTBUF	Factor for thrust buildup fuel for main propulsion (a function of total thrust)	
* CTBUØ	Factor for thrust buildup oxidizer for main propulsion (a function of total thrust)	
* TLRE	Thrust of each liquid rocket engine	LB
* WSP26	Weight of special features for thrust buildup propellant	LB
WTBUF	Weight of thrust buildup fuel for main propulsion	LB
WTBUØ	Weight of thrust buildup oxidizer for main propulsion	LB
WTBUP	Weight of thrust buildup propellant	LB
* ZNLRE	Quantity of liquid rocket engines	

* Input

TABLE I LIST 1 INPUT DEFINITIONS
(Pg. 141-151)

GROUP 1.1 WING INPUTS
(Pg. 141-147)

Variable	Definitions	Units
BBW1	Maximum body width at wing intersection, wing type 1	FT
BBW2	Maximum body width at wing intersection, wing type 2	FT
BBW3	Maximum body width at wing intersection, wing type 3	FT
BCW3	Exposed horizontal planform wing span between bodies, wing type 3	FT
BFW1	Horizontal planform wing span between bases of upswept wing tips, wing type 1	FT
BFW3	Horizontal planform wing span between bases of upswept wing tips, wing type 3	FT
BSHW	Horizontal planform wing span between hinge centers of variable swept wing	FT
BW1	Horizontal planform wing span, wing type 1	FT
BW2	Horizontal planform wing span (including the two body widths), wing type 2	FT
BW3	Horizontal planform wing span, wing type 3	FT
CABEW1	Weight factor for engines in or on wing, wing type 1 = 1. For engines on wing. = 2. For engines in wing.	
CABEW2	Weight factor for engines in or on wing, wing type 2 = 1. For engines on wing. = 2. For engines in wing.	
CABEW3	Weight factor for engines in or on wing, wing type 3 = 1. For engines on wing. = 2. For engines in wing.	
CAIL1	Weight factor for ailerons, wing type 1 = 1.	
CAIL2	Weight factor for ailerons, wing type 2 = 1.	
CAIL3	Weight factor for ailerons, wing type 3 = 1.	
CCØNW1	Weight factor for contingency, wing type 1	
CCØNW2	Weight factor for contingency, wing type 2	
CCØNW3	Weight factor for contingency, wing type 3	
CCTW1	Weight factor for wing carry-thru structure, wing type 1 = 1. If carry-thru structure is part of wing. = 0. If carry-thru structure is part of body.	
CCTW2	Weight factor for wing carry-thru structure, wing type 2 = 1. If carry-thru structure is part of wing. = 0. If carry-thru structure is part of body.	

Variable	Definition	Units
CCTW3	Weight factor for wing carry-thru structure, wing type 3 = 1. If carry-thru structrue is part of wing. = 0. If carry-thru structure is part of body.	
CELW1	Weight factor for elevons, wing type 1 = 1.	
CELW2	Weight factor for elevons, wing type 2 = 1.	
CELW3	Weight factor for elevons, wing type 3 = 1.	
CFTPW1	Weight factor for internal fuel tanks in wing, wing type 1 = 1.	
CFTPW2	Weight factor for internal fuel tanks in wing, wing type 2 = 1.	
CFTPW3	Weight factor for internal fuel tanks in wing, wing type 3 = 1.	
CFW1	Length of wing chord at base of upswept wing tip, wing type 1	FT
CFW3	Length of wing chord at base of upswept wing tip, wing type 3	FT
CGRØW1	Weight factor for growth, wing type 1	
CGRØW2	Weight factor for growth, wing type 2	
CGRØW3	Weight factor for growth, wing type 3	
CGTW2	Longitudinal distance between vehicle CG and 1/4 chord of wing MAC, wing type 2	FT
CGTW3	Longitudinal distance between vehicle CG and 1/4 chord of wing MAC, wing type 3	FT
CLEF1	Weight factor for wing leading edge flaps, wing type 1 = 1.	
CLEF2	Weight factor for wing leading edge flaps, wing type 2 = 1.	
CLEF3	Weight factor for wing leading edge flaps, wing type 3 = 1.	
CLES1	Weight factor for wing leading edge slats, wing type 1 = 1.	
CLES2	Weight factor for wing leading edge slats, wing type 2 = 1.	
CLES3	Weight factor for wing leading edge slats, wing type 3 = 1.	
CLGP	Weight factor if main landing gear is mounted on wing = 1.	

Variable	Definition	Units
CNØFW1	Weight factor for wing box structure non-optimums, wing type 1 = 1.	
CNØFW2	Weight factor for wing box structure non-optimums, wing type 2 = 1.	
CNØFW3	Weight factor for wing box structure non-optimums, wing type 3 = 1.	
CRIBW1	Weight factor for wing ribs, wing type 1 = 1.	
CRIBW2	Weight factor for wing ribs, wing type 2 = 1.	
CRIBW3	Weight factor for wing ribs, wing type 3 = 1.	
CRW1	Theoretical wing root chord length, wing type 1	FT
CRW2	Theoretical wing root chord length, wing type 2	FT
CRW3	Theoretical wing root chord length, wing type 3	FT
CSB1	Weight factor for speed brakes, wing type 1 = 1.	
CSB2	Weight factor for speed brakes, wing type 2 = 1.	
CSB3	Weight factor for speed brakes, wing type 3 = 1.	
CSHW	Length of wing chord at hinge of variable swept wing	FT
CSP1	Weight factor for spoilers, wing type 1 = 1.	
CSP2	Weight factor for spoilers, wing type 2 = 1.	
CSP3	Weight factor for spoilers, wing type 3 = 1.	
CSSW1	Weight factor for wing secondary structure, wing type 1 = 1.	
CSSW2	Weight factor for wing secondary structure, wing type 2 = 1.	
CSSW3	Weight factor for wing secondary structure, wing type 3 = 1.	
CSW1	Length of wing chord at side of body, wing type 1	FT
CSW2	Length of wing chord at side of body, wing type 2	FT
CSW3	Length of wing chord at side of body, wing type 3	FT
CTEF1	Weight factor for trailing edge flaps, wing type 1 = 1.	

Variable	Definition	Units
CTEF2	Weight factor for trailing edge flaps, wing type 2 = 1.	
CTEF3	Weight factor for trailing edge flaps, wing type 3 = 1.	
CTEW1	Length of equivalent wing tip chord, wing type 1 = 2.(SEW1)/(BW1-BBW1) - CSW1.	FT
CTEW2	Length of equivalent wing tip chord, wing type 2 = CSW2.	FT
CTEW3	Length of equivalent wing tip chord, wing type 3 = 2.(SØW3)/[BW3-2.(BBW3)-BCW3] - CSW3, where SØW3 = exposed horizontal planform wing area outboard of bodies.	FT
CTF1	Weight factor for wing tip fins, wing type 1 = 0. For integral wing tip segments. = 1. For wing attached conventional fins.	
CTF3	Weight factor for wing tip fins, wing type 3 = 0. For integral wing tip segments. = 1. For wing attached conventional fins.	
CVSP	Weight factor for variable swept wing = 1.	
CWTF1	Weight factor for integral wing tip fins or wing attached conventional fins, wing type 1 = 1.	
CWTF3	Weight factor for integral wing tip fins or wing attached conventional fins, wing type 3 = 1.	
DAWT1	Dihedral angle of integral wing tip segment, wing type 1	DEG
DAWT3	Dihedral angle of integral wing tip segment, wing type 3	DEG
DAW1	Dihedral angle of wing, wing type 1	DEG
DAW3	Dihedral angle of wing, wing type 3	DEG
DENSWM	Density of wing structural material	LB/CU IN
GWRE	Reentry or atmospheric cruise design gross weight (compatible with ZNAF) (an assigned value)	LB
SAIL1	Horizontal planform area of ailerons, wing type 1	SQ FT
SAIL2	Horizontal planform area of ailerons, wing type 2	SQ FT
SAIL3	Horizontal planform area of ailerons, wing type 3	SQ FT
SAW1	Wing sweepback angle (quarter chord line), wing type 1	DEG
SAW3	Wing sweepback angle (quarter chord line), wing type 3	DEG
SELW1	Horizontal planform area of elevons, wing type 1	SQ FT

Variable	Definition	Units
SELW2	Horizontal planform area of elevons, wing type 2	SQ FT
SELW3	Horizontal planform area of elevons, wing type 3	SQ FT
SEW1	Exposed horizontal planform area of wing, wing type 1	SQ FT
SEW2	Exposed horizontal planform area of wing, wing type 2	SQ FT
SEW3	Exposed horizontal planform area of wing, wing type 3	SQ FT
SLEF1	Horizontal planform area of wing leading edge flaps, wing type 1	SQ FT
SLEF2	Horizontal planform area of wing leading edge flaps, wing type 2	SQ FT
SLEF3	Horizontal planform area of wing leading edge flaps, wing type 3	SQ FT
SLES1	Horizontal planform area of wing leading edge slats, wing type 1	SQ FT
SLES2	Horizontal planform area of wing leading edge slats, wing type 2	SQ FT
SLES3	Horizontal planform area of wing leading edge slats, wing type 3	SQ FT
SSB1	Horizontal planform area of wing speed brakes, wing type 1	SQ FT
SSB2	Horizontal planform area of wing speed brakes, wing type 2	SQ FT
SSB3	Horizontal planform area of wing speed brakes, wing type 3	SQ FT
SSP1	Horizontal planform area of wing spoilers, wing type 1	SQ FT
SSP2	Horizontal planform area of wing spoilers, wing type 2	SQ FT
SSP3	Horizontal planform area of wing spoilers, wing type 3	SQ FT
SSSW1	Horizontal planform area of wing fixed leading and trailing edge structure, wing type 1. If SSSW1 is unknown, a typical value may be estimated as 0.32 • [SEW1-SAIL1-SELW1-.5(STEF1)-SLEF1-.5(SSB1)].	SQ FT
SSSW2	Horizontal planform area of wing fixed leading and trailing edge structure, wing type 2. If SSSW2 is unknown, a typical value may be estimated as 0.32 • [SEW2-SAIL2-SELW2-.5(STEF2)-SLEF2-.5(SSB2)].	SQ FT
SSSW3	Horizontal planform area of wing fixed leading and trailing edge structure, wing type 3. If SSSW3 is unknown, a typical value may be estimated as 0.32 • [SEW3-SAIL3-SELW3-.5(STEF3)-SLEF3-.5(SSB3)].	SQ FT
STEF1	Horizontal planform area of wing trailing edge flaps, wing type 1	SQ FT

Variable	Definition	Units
STEF2	Horizontal planform area of wing trailing edge flaps, wing type 2	SQ FT
STEF3	Horizontal planform area of wing trailing edge flaps, wing type 3	SQ FT
SW1	Wing theoretical horizontal planform area, wing type 1	SQ FT
SW2	Wing theoretical horizontal planform area, wing type 2	SQ FT
SW3	Wing theoretical horizontal planform area, wing type 3	SQ FT
TFW1	Maximum wing thickness at base of upswept wing tip, wing type 1	FT
TFW3	Maximum wing thickness at base of upswept wing tip, wing type 3	FT
TSHW	Maximum wing thickness at hinge of variable swept wing	FT
TSW1	Maximum wing thickness at side of body, wing type 1	FT
TSW2	Maximum wing thickness at side of body, wing type 2	FT
TSW3	Maximum wing thickness at side of body, wing type 3	FT
TTEW1	Equivalent maximum wing thickness at tip of wing type 1 =[(TSW1+TBW1)(BTBW1-BBW1)+(TBW1+TTW1)(BWL-BTBW1)] / (BW1-BBW1)-TSW1, where TBW1 = maximum wing thickness at point of change in wing type 1 thickness taper, BTBW1 = horizontal planform wing span between points of change in wing type 1 thickness taper, TTW1 = maximum wing thickness at tip of wing type 1	FT
TTEW2	Equivalent maximum wing thickness at tip of wing type 2 = TSW2	FT
TTEW3	Equivalent maximum wing thickness at tip of wing type 3 ={(TSW3+TBW3) [BTBW3-2.(BBW3)-BCW3] +(TBW3+TTW3)(BW3-BTBW3)} / [BW3-2.(BBW3)-BCW3 -TSW3], where TBW3 = maximum wing thickness at point of change in wing type 3 thickness taper, BTBW3 = horizontal planform wing span between points of change in wing type 3 thickness taper, TTW3 = maximum wing thickness at tip of wing type 3	FT
TYPEW	Factor for identifying wing type = 1. For wing type 1. = 2. For wing type 2 and 3.	
UTSWM	Ultimate tensile strength of wing structural material at the critical design temperature	LB/SQ IN
WSPW1	Weight of special features of wing, wing type 1	LB
WSPW2	Weight of special features of wing, wing type 2	LB
WSPW3	Weight of special features of wing, wing type 3	LB
ZNAEW1	Number of air breathing engines in or on wing, wing type 1	

Variable	Definition	Units
ZNAEW2	Number of air breathing engines in or on wing, wing type 2	
ZNAEW3	Number of air breathing engines in or on wing, wing type 3	
ZNAF	Ultimate flight vertical load factor at GWRE	

Note: The wing weight may be estimated independently by using the wing inputs plus the following inputs:

Variable	List	Group
BVT	1	1.3
CRVT	1	1.3
CTVT	1	1.3
DAVT	1	1.3
HB	2	2.
SAVT	1	1.3
SVT	1	1.3
TABE	3	5.
ZLVEH	1	1.3
ZLVT	1	1.3
ZNB	2	2.
ZNLD	2	4.
ZNSST(K)	3	5.
VNSST(K)	3	5.
GWLAND	2	4.

GROUP 1.2 HORIZONTAL TAIL INPUTS
(Pg. 148-149)

Variable	Definition	Units
BBHT	Maximum body width at junction of body and horizontal tail	FT
BHT	Horizontal planform span of horizontal tail	FT
CCØNHT	Weight factor for contingency for horizontal tail	
CCTHT	Weight factor for carry-thru structure for horizontal tail = 0. If carry-thru structure is part of body. = 1. If carry-thru structure is part of horizontal tail.	
CELB	Weight factor for body elevons = 1.	
CELHT	Weight factor for horizontal tail elevators = 1.	
CGRØHT	Weight factor for growth for horizontal tail	
CNØFHT	Weight factor for horizontal tail non-optimums = 3.45 For flying horizontal tail. = 2.49 For conventional horizontal tail.	
CRIBHT	Weight factor for horizontal tail ribs = 1.	
CSHT	Length of horizontal tail chord at side of body	FT
CTHT	Length of horizontal tail chord at tip	FT
CWSSHT	Weight factor for horizontal tail secondary structure = 1.	
DAHT	Dihedral angle of the horizontal tail	DEG
DENSHT	Density of horizontal tail structural material	LB/CU IN
SAHT	Horizontal sweepback angle of horizintal tail (quarter chord line)	DEG
SEHT	Exposed horizontal planform area of horizontal tail	SQ FT
SELB	Horizontal planform area of body elevons	SQ FT
SELHT	Horizontal planform area of elevators	SQ FT
SHT	Theoretical horizontal planform area of horizontal tail	SQ FT
SSSHT	Horizontal planform area of secondary structure of horizontal tail. If SSSHT is unknown, it may be estimated as 0.6(SEHT-SELHT).	SQ FT
TSHT	Horizontal tail thickness at side of body	FT
TTHT	Tip thickness of horizontal tail	FT
UTSHTM	Ultimate tensile strength of horizontal tail structural material at the critical design temperature	LB/SQ IN

Variable	Definition	Units
WSPHT	Weight of special features of the horizontal tail	LB
ZLHT	Horizontal tail arm length (longitudinal distance between the vehicle CG and the center of pressure of the horizontal tail).	FT

Note: The horizontal tail weight may be estimated independently by using the horizontal tail inputs plus the following inputs:

Variable	List	Group
GWRE	1	1.1
ZLVEH	1	1.3

GROUP 1.3 VERTICAL TAIL INPUTS
(Pg. 150-151)

Variable	Definition	Units
BTT	Vertical planform span of vertical 'T' type tail measured from the body intersection to the horizontal tail intersection	FT
BVT	Vertical planform span of vertical tail	FT
CCØNVT	Weight factor for contingency for vertical tail	
CGRØVT	Weight factor for growth for vertical tail	
CNØFVT	Weight factor for vertical tail non-optimums = 1.	
CRBAL	Weight factor for vertical tail rudder = 0.043 With balance weights. = 0.027 Without balance weights.	
CRIBVT	Weight factor for vertical tail ribs = 1.	
CRVT	Vertical tail chord length at wing or body intersection	FT
CTVT	Length of vertical tail chord at tip	FT
CWDVF	Weight factor for dorsal and ventral fins = 1.	
CWSSVT	Weight factor for vertical tail secondary structure = 1.	
DAVT	Vertical tail dihedral angle (measured from horizontal plane)	DEG
DENSVT	Density of vertical tail structural material	LB/CU IN
SAVT	Vertical tail sweepback angle at 1/4 chord line	DEG
SDVF	Vertical planform area of dorsal and ventral fins	SQ FT
SRUD	Vertical planform area of rudder per vertical tail	SQ FT
SSSVT	Vertical planform area of vertical tail fixed leading and trailing edge structure. If SSSVT is unknown, it may be estimated as 0.55(SVT-SRUD).	SQ FT
SVT	Vertical planform exposed area of each vertical tail	SQ FT
TRVT	Maximum thickness of vertical tail at junction with body or wing	FT
TTVT	Maximum thickness of vertical tail tip	FT
UTSVTM	Ultimate tensile strength of vertical tail structural material at the critical design temperature	LB/SQ IN
WSPVT	Weight of special features of the vertical tail	LB
ZLVEH	Overall length of vehicle	FT

Variable	Definition	Units
ZLVT	Length of vertical tail arm (longitudinal distance between vehicle CG and center of pressure of the vertical tail)	FT
ZNVT	Quantity of vertical tails	

Note: The vertical tail weight may be estimated independently by using the vertical tail inputs plus the following inputs:

Variable	List	Group
GWRE	1	1.1
HB	2	2.
ZLHT	1	1.2

TABLE II LIST 2 INPUT DEFINITIONS
(Pg. 152-163)

GROUP 2. BODY INPUTS
(Pg. 152-158)

Variable	Definition	Units
BB	Maximum width of body	FT
CAABC1	Wetted area factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DABC1 and bulkhead shape. Refer to figure 5-2 for value.	
CAABC2	Wetted area factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DABC2 and bulkhead shape. Refer to figure 5-2 for value.	
CAEPB	Weight factor for provisions for air breathing engines in or on body = 1. For internal installations. = 0.5 For external installations.	
CAFBC1	Wetted area factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape. Refer to figure 5-2 for value.	
CAFBC2	Wetted area factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape. Refer to figure 5-2 for value.	
CAIBC1	Wetted area factor for intermediate pressure bulkheads in body pressure compartment No. 1, a function of ZLIBC1/DIBC1 and bulkhead shape. Refer to figure 5-2 for value.	
CAIBC2	Wetted area factor for intermediate pressure bulkheads in body pressure compartment No. 2, a function of ZLIBC2/DIBC2 and bulkhead shape. Refer to figure 5-2 for value.	
CBAC	Weight factor for stringers and longerons in aircraft bodies only = 5.	
CBASF	Weight factor for body bulkheads and special frames = 0. For service modules, adapters, fixed shrouds, LM-D and LES. = 0.42 For bomber aircraft and Gemini type spacecraft. = 0.60 For fighter aircraft. = 0.17 For all other applications including transport aircraft, STS winged bodies, unwinged lifting bodies, space stations and LM-A.	
CBSV	Weight factor for stringers and longerons in space vehicle bodies only = 2.5 For winged bodies. = 5. For unwinged lifting bodies. = 8. For service modules, adapters, fixed shrouds, LES, LM and space stations. = 16. For Gemini type spacecraft.	
CCØNB	Weight contingency factor for body	
CGRØB	Weight growth factor for body	

Variable	Definition	Units
CIT1	Factor for identifying main propellant tank No. 1 = 1. If tank is integral type. = 0. If tank is non-integral type.	
CIT2	Factor for identifying main propellant tank No. 2 = 1. If tank is integral type. = 0. If tank is non-integral type.	
CKABC1	Kick frame area factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DABC1 and bulkhead shape. Refer to figure 5-3 for value.	
CKABC2	Kick frame area factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DABC2 and bulkhead shape. Refer to figure 5-3 for value.	
CKFBC1	Kick frame area factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape. Refer to figure 5-3 for value.	
CKFBC2	Kick frame area factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape. Refer to figure 5-3 for value.	
CKIBC1	Kick frame area factor for intermediate pressure bulkheads in body pressure compartment No. 1, a function of ZLIBC1/DIBC1 and bulkhead shape. Refer to figure 5-3 for value.	
CKIBC2	Kick frame area factor for intermediate pressure bulkheads in body pressure compartment No. 2, a function of ZLIBC2/DIBC2 and bulkhead shape. Refer to figure 5-3 for value.	
CLGPB	Weight factor for landing gear provisions in body = 8. If body supports a complete landing gear. = 1. If body supports the nose landing gear only. = 0. If the body supports no landing gear.	
CLRPB	Weight factor for liquid rocket engine provisions in body = 1.	
CSAC	Weight factor for body skin and frames in aircraft only = 1. For bombers and fighters. = 2. For transports.	
CSB	Body wetted area factor = 0.89 For a high L/D unwinged lifting body. = 1.18 For a low L/D unwinged lifting body. = 1.32 For a winged aircraft body. = 1.52 For a winged space vehicle body. = 1.1 For a Gemini shape body.	

Variable	Definition	Units
CSB (cont'd)	= 1.54 For adapters, service modules and cylindrical space stations. = 1.39 For LES. = 2.21 For LM-A. = 3.56 For LM-D.	
CSSB	Weight factor for body secondary structure = 1.	
CSSV	Weight factor for skin and frames in unpressurized body of space vehicles only = 1. For winged bodies, like STS. = 1. For service modules, like SM. = 1. For space stations. = 1. For adapters, like AP-A. = 1. For LES. = 1. For fixed shrouds, like AM-FS. = 1.5 For unwinged low L/D lifting bodies, like STSA-OL. = 0.3 For LM-D and LM-A. = 2. For unwinged high L/D lifting bodies, like LBRV-CM. = (0.009)(VB) For Gemini type spacecraft.	
CTABC1	Material thickness factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DABC1 and bulkhead shape. Refer to figure 5-4 for value.	
CTABC2	Material thickness factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DABC2 and bulkhead shape. Refer to figure 5-4 for value.	
CTFBC1	Material thickness factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape. Refer to figure 5-4 for value.	
CTFBC2	Material thickness factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape. Refer to figure 5-4 for value.	
CTIBC1	Material thickness factor for intermediate pressure bulkheads in body pressure compartment No. 1, a function of ZLIBC1/DIBC1 and bulkhead shape. Refer to figure 5-4 for value.	
CTIBC2	Material thickness factor for intermediate pressure bulkheads in body pressure compartment No. 2, a function of ZLIBC2/DIBC2 and bulkhead shape. Refer to figure 5-4 for value.	
CVABC1	Volume factor for aft bulkhead of body pressure compartment No. 1, a function of ZLABC1/DAPC1 and bulkhead shape. Refer to figure 5-5 for value.	
CVABC2	Volume factor for aft bulkhead of body pressure compartment No. 2, a function of ZLABC2/DAPC2 and bulkhead shape. Refer to figure 5-5 for value.	

Variable	Definition	Units
CVB	Body volume factor = 0.18 For a high L/D unwinged lifting body. = 0.38 For a low L/D unwinged lifting body. = 0.59 For winged aircraft bodies. = 0.65 For winged space vehicles. = 0.30 For Gemini shape bodies. = 0.69 For adapters, service modules, and cylindrical space stations. = 0.67 For LES. = 0.82 For LM-D. = 0.46 For LM-A.	
CVFBC1	Volume factor for forward bulkhead of body pressure compartment No. 1, a function of ZLFBC1/DFPC1 and bulkhead shape. Refer to figure 5-5 for value.	
CVFBC2	Volume factor for forward bulkhead of body pressure compartment No. 2, a function of ZLFBC2/DFPC2 and bulkhead shape. Refer to figure 5-5 for value.	
DAPC1	Diameter at aft end of wall of body pressure compartment No. 1. If aft end of compartment is not circular, an equivalent DAPC1 = (compartment height X compartment width)$^{.5}$.	FT
DAPC2	Diameter at aft end of wall of body pressure compartment No. 2. If aft end of compartment is not circular, an equivalent DAPC2 = (compartment height X compartment width)$^{.5}$.	FT
DENIT1	Density of structural material of main integral propellant tank No. 1	LB/CU IN
DENIT2	Density of structural material of main integral propellant tank No. 2	LB/CU IN
DENSBM	Density of body structural material	LB/CU IN
DFPC1	Diameter at forward end of wall of body pressure compartment No. 1. If forward end of compartment is not circular, an equivalent DFPC1 = (compartment height X compartment width)$^{.5}$.	FT
DFPC2	Diameter at forward end of wall of body pressure compartment No. 2. If forward end of compartment is not circular, an equivalent DFPC2 = (compartment height X compartment width)$^{.5}$.	FT
DIBC1	Average diameter of intermediate pressure bulkheads in body pressure compartment No. 1	FT
DIBC2	Average diameter of intermediate pressure bulkheads in body pressure compartment No. 2	FT

Variable	Definition	Units
GWST	Total vehicle stage weight at initiation of full thrust (at launch or in flight) (an assigned value)	LB
GWST1	Total weight of stage 1 at launch (an assigned value)	LB
HB	Maximum height of body	FT
PPC1	Ultimate design pressure for body pressure compartment No. 1	PSIG
PPC2	Ultimate design pressure for body pressure compartment No. 2	PSIG
SB	Wetted area per structural body. If an assigned value is not available, SB may be estimated as (CSB)(ZLB)·(HB+BB).	SQ FT
TMPC1	Minimum allowable material thickness of wall or bulkheads of body pressure compartment No. 1	IN
TMPC2	Minimum allowable material thickness of wall or bulkheads of body pressure compartment No. 2	IN
UTSBM	Ultimate tensile strength of body structural material at the critical design temperature	LB/SQ IN
VB	Structural volume per body. If an assigned value is not available, VB may be estimated as (CVB)(ZLB)(HB)(BB)	CU FT
WBAC	Weight of body and contents, when ZNAF applies, for aircraft only	LB
WSPB	Special features weight of body, per vehicle	LB
ZLABC1	Convexity height of aft bulkhead of body pressure compartment No. 1	FT
ZLABC2	Convexity height of aft bulkhead of body pressure compartment No. 2	FT
ZLB	Overall structural length of body	FT
ZLFBC1	Convexity height of forward bulkhead of body pressure compartment No. 1	FT
ZLFBC2	Convexity height of forward bulkhead of body pressure compartment No. 2	FT
ZLIBC1	Average convexity or concavity height of intermediate pressure bulkheads in body compartment No. 1	FT
ZLIBC2	Average convexity or concavity height of intermediate pressure bulkheads in body compartment No. 2	FT
ZLST	Overall length of vehicle stage	FT
ZLWPC1	Length of wall of body pressure compartment No. 1	FT
ZLWPC2	Length of wall of body pressure compartment No. 2	FT

Variable	Definition	Units
ZNABEB	Quantity of air breathing engines in or on each body	
ZNB	Quantity of identical bodies per vehicle	
ZNIBC1	Quantity of intermediate pressure bulkheads per body in body pressure compartment No. 1	
ZNIBC2	Quantity of intermediate pressure bulkheads per body in body pressure compartment No. 2	

Note: The body weight, excluding weight for wing and horizontal tail carry-through structure, may be estimated independently by using the body inputs plus the following inputs:

Variable	List	Group	Variable	List	Group
ATLF	3	5.	PBT(I)	3	5.
CAAD(I)	3	5.	PFDT(I)	3	5.
CAFD(I)	3	5.	PGT(I)	3	5.
CBAR	3	5.	TABE	3	5.
CBARM	3	5.	TLRE	3	5.
CBLK	3	5.	TLRE1	3	5.
CBLKM	3	5.	TMT(I)	3	5.
CCD(I)	3	5.	UDTLF	3	5.
CKAD(I)	3	5.	UTST(I)	3	5.
CKFD(I)	3	5.	VNSST(K)	3	5.
CPRØP(I)	3	5.	VMAX	2	3.
CTAD(I)	3	5.	WUP1	3	5.
CTFD(I)	3	5.	ZLAD(I)	3	5.
CVAD(I)	3	5.	ZLBT(I)	3	5.
CVFD(I)	3	5.	ZLCD(I)	3	5.
DAT(I)	3	5.	ZLFD(I)	3	5.
DENP(I)	3	5.	ZNLD	2	4.
DENSW	3	5.	ZNLRE	3	5.
DFT(I)	3	5.	ZNLRE1	3	5.
GWLAND	2	4.	ZNPT(I)	3	5.
PADT(I)	3	5.	ZNSST(K)	3	5.

To estimate the body weight independently, and include weight for wing and horizontal tail carry-through structure, it is necessary to include most of the inputs in Groups 1.1 and 1.2 of List 1.

(Blank)

GROUP 3. INDUCED ENVIRONMENT PROTECTION INPUTS
(Pg. 159-160)

Variable	Definition	Units
CCØNEP	Weight factor for induced environment protection contingency	
CGRØEP	Weight factor for induced environment protection growth	
CMP	Weight factor for meteorite protection = 0.06 For ATM. = 0.35 For MDA and space stations.	
CNP	Weight factor for noise protection = 0.12 For AM. = 0.41 For MER-LES.	
CRP	Weight factor for radiation protection = 1.	
CTPBB	Weight factor for body thermal protection - ballistic reentry vehicles only = 1. For vehicle like MER-RM, GEM-RM and CM.	
CTPBH	Weight factor for base heating thermal protection = 7.5 For STS earth orbiters, SM, LM-D and LM-A. = 12. For STS boosters. = 19. For AP-LES. = 1.3 For MER-LES.	
CTPGB	Weight factor for body thermal protection - glide reentry vehicles only = 2.6 For STS earth orbiters. = 11. For STS boosters. = 5. For vehicles like X-15, X-20 and LBRV-WM. = 9. For vehicles like PRIME and LBRV-CM.	
CTPHT	Weight factor for horizontal tail thermal protection = 2.6 For STS earth orbiters. = 3. For STS boosters. = 5. For vehicles like X-15.	
CTPNRB	Weight factor for body thermal protection - non-reentry space vehicles only = 0.14 For ATM. = 0.34 For AM, IU, adapters and space stations. = 0.45 For MDA and SM. = 0.54 For LM-D and LM-A.	
CTPVT	Weight factor for vertical tail thermal protection = 0.8 For STS earth orbiters. = 2.4 For STS boosters. = 5. For vehicles like X-15 and X-20. = 9. For vehicles like PRIME.	
CTPW	Weight factor for wing thermal protection = 2.8 For STS earth orbiters. = 3.5 For STS boosters. = 5. For vehicles like X-15 and X-20.	

Variable	Definition	Units
CTPW (cont'd)	= 9. For vehicles like PRIME Note - All thermal protection weight factors will vary considerably because of their dependence on the degree of optimization associated with the combination of active and passive thermal protection, primary structure and internal insulation.	
TSRE	Total solid rocket motor thrust of vehicle	LB
VMAX	Maximum design velocity	FT/SEC
WSPIEP	Weight of induced environment protection special features	LB

Note: The induced environment protection weight may be estimated independently by using the IEP inputs plus the following inputs:

Variable	List	Group	Variable	List	Group
BB	2	2.	DAVT	1	1.3
BBW1	1	1.1	DAWT1	1	1.1
BBW3	1	1.1	DAWT3	1	1.1
BFW1	1	1.1	DAW1	1	1.1
BFW3	1	1.1	DAW3	1	1.1
BW1	1	1.1	HB	2	2.
BW3	1	1.1	SB	2	2.
CFW1	1	1.1	SEHT	1	1.2
CFW3	1	1.1	SEW1	1	1.1
CSW1	1	1.1	SEW2	1	1.1
CSW3	1	1.1	SVT	1	1.3
CTEW1	1	1.1	TLRE	3	5.
CTEW3	1	1.1	ZNB	2	2.
CTF1	1	1.1	ZNLRE	3	5.
CTF3	1	1.1	ZNVT	1	1.3
DAHT	1	1.2	ZLB	2	2.
BCW3	1	1.1			
CSB	2	2.			

GROUP 4. LAUNCH, RECOVERY AND DOCKING INPUTS
(Pg. 161-163)

Variable	Definition	Units
BWØLC	Span of outrigger landing gear attachment points	FT
CATØP	Factor for launch fittings = 1.	
CCØN4	Factor for contingency for launch, recovery and docking	
CDGCH	Weight factor for drag parachutes = 0.0015 For average energy system (bombers). = 0.003 For high energy system (fighters).	
CDØLTH	Weight factor for docking latching mechanisms = 39. (CM).	
CDØPØS	Weight factor for docking repositioning devices = 7.9 For drogue. = 51. For probe.	
CDØTUN	Weight factor for docking tunnels = 22.	
CDRCH	Weight factor for drogue parachutes = 1. For nornal use. = 2. If 100 percent backup is used.	
CFLØAT	Weight factor for flotation gear = 7. E-3 For partial flotation system (CM). = 1.5E-2 For full flotation system (PRIME).	
CGRØ4	Weight factor for growth for launch, recovery and docking.	
CHAN	Weight factor for handling fittings = 1.	
CIMPS	Weight factor for impact system = 0.06 For skirt type (MER-RM). = 0.017 For crushable ribs for emergency land landing and crew seat attenuation struts (CM).	
CLMMGF	Weight factor for landing pads (LM-D type) = 1.	
CLMMGS	Weight factor for landing gear struts (LM-D type) = 1.	
CMACH	Weight factor for main parachutes = 30. = 44. For main parachute with air pickup capability.	
CMCREL	Weight factor for backup for main parachutes = 0. For normal use (no backup). = 1. If 100 percent backup is used.	
CMLGB	Weight factor for landing gear brakes = 0.0065 For bombers and transports. = 0.01 For fighters.	

Variable	Definition	Units
CMLGC	Weight factor for controls for main landing gear = 0.53 For aircraft. = 0.21 For LM-D type gear.	
GMLGF	Weight factor for main landing gear wheels, tires, etc. (aircraft type) = 1.	
CMLGS	Weight factor for main landing gear struts (aircraft type) = 1.	
CNLGB	Weight factor for brakes on nose gear (ratio of static weight on nose gear to total weight); on bicycle type, forward gear is considered as nose gear. = 0. If nose gear does not contain brakes.	
CNLGC	Weight factor for nose landing gear controls = 1.	
CNLGF	Weight factor for nose landing gear wheels, tires, etc. = 1.	
CNLGS	Weight factor for nose landing gear struts = 1.	
CØLG	Weight factor for outrigger landing gear = 1.	
CPICH	Weight factor for vehicle's pilot parachute = 1.	
CSTCH	Weight factor for structural and release systems for deployable aerodynamic devices = 1.	
CTLG	Weight factor for tail landing gear = 0.0025 For bomber type. = 0.008 For retractable skid type. = 0.023 For retractable wheel type.	
DIAPAD	Diameter of landing pads (LM-D type)	FT
DIDØCK	Diameter of docking tunnel and port	FT
GRVR	Gravity ratio for landing gear (LM-D type), ratio of gravity environment for landing gear operation to that of earth's gravity	
GWHAN	Design handling gross weight (an assigned value)	LB
GWLAND	Landing gross weight (an assigned value)	LB
VSINK	Vehicle design sinking velocity at landing. If sink velocity is specified for altitude other than sea level, convert to sea level equivalent velocity by multiplying by the square root of the ratio of the air density at the specified altitude to that at sea level.	FT/SEC

Variable	Definition	Units
WCØCH	Weight of parachute sequencing controls = 5. For manned system. = 14. For unmanned system.	LB
WRAID	Weight of recovery aids = 8. For unmanned vehicles. = 20. For manned vehicles.	LB
WSEPAR	Weight of separation provisions = 15. For manned vehicle separated from aircraft. = 5. For unmanned vehicle separated from aircraft. = 30. For manned vehicle separated from space booster.	LB
WSP4	Weight of special features for launch, recovery and docking.	LB
ZLBG	Length between main landing gear and nose landing gear, or length between forward and aft landing gears for bicycle type	FT
ZLDØCK	Length of each docking tunnel (average if different)	FT
ZLGCG	Length between main landing gear and landing longitudinal center of gravity. Aft gear is used if bicycle type.	FT
ZLMLGE	Length of main landing gear fully entended (axle to trunnion)	FT
ZLMMGS	Length of landing gear (LM-D type) measured from contact point on the pad to the upper fitting on the body	FT
ZLMTG	Length between main landing gear and tail landing gear	FT
ZLNLGE	Length of nose landing gear fully entended (axle to trunnion)	FT
ZLØLGE	Length of outrigger landing gear fully extended (axle to trunnion)	FT
ZNDØCK	Quantity of docking locations	
ZNLD	Ultimate design landing vertical load factor	
ZNMLG	Quantity of main landing gear assemblies	
ZNNLG	Quantity of nose landing gear assemblies	

Note: The launch, recovery and docking weight may be estimated independently by using the launch, recovery and docking inputs plus the following inputs:

Variable	List	Group
BW1	1	1.1
GWST	2	2.

TABLE III LIST 3 INPUT DEFINITIONS
(Pg. 164-181)

GROUP 5. MAIN PROPULSION INPUTS
(Pg. 164-176)

Variable	Definition	Units
ATLF	Maximum allowable ultimate thrust load factor	
BNAAE	Width of air breathing engine nacelles	FT
CAAD(I)	Wetted area factor for aft dome of main propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape. Refer to Figure 5-2 for value. Program accepts I from 1 through 8.	
CABE	Weight factor for air breathing engines = 0. If known engine weight WUABE is entered. = 1. If engine weight WUABE is not entered.	
CAFD(I)	Wetted area factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape. Refer to Figure 5-2 for value. When ZLFD(I) = zero, CAFD(I) = zero. Program accepts I from 1 through 8.	
CAIAE	Weight factor for air breathing engine air induction control = 0.003 For external engines. = 0.01 For internal engines (mach number less than 2.5). = 0.077 For internal engines (mach number more than 2.5).	
CAIND	Weight factor for air inductions ducts = 1.	
CANG1	Cant angle of nozzles of solid propellant system	DEG
CASAE	Weight factor for air breathing engine starters = 0. If included in engine weight. = 0.0031 If ground dependent. = 0.0068 If self sufficient.	
CBAF	Weight factor for main propellant tank baffling and antivortex webs = 1.	
CBAR	Weight factor for body pressure compartment walls or main propellant tank barrels (unrestricted by minimum allowable thickness). = 1.	
CBARM	Weight factor for body pressure compartment walls or main propellant tank barrels (restricted by minimum allowable thickness). = 1.	

Variable	Definition	Units
CBLK	Weight factor for body pressure compartment bulkheads or main propellant tank domes (unrestricted by minimum allowable thickness) = 1.	
CBLKM	Weight factor for body pressure compartment bulkheads or main propellant tank domes (restricted by minimum allowable thickness) = 1.	
CCD(I)	Special weight factor for aft dome of main propellant tank No. (I). Program accepts I from 1 through 8. = 3. When dome is common to adjoining forward and aft tanks and is concave to the forward tank. = 2. When dome is common to adjoining forward and aft tanks and is convex to the forward tank. = 0. When dome is not common to two tanks.	
CCØN	Weight factor for feed line conduit in main propellant tank = 1.	
CCØN5	Weight factor for contingency for main propulsion system	
CDAG1	Factor to account for drag and gravitational losses for solid propellant propulsion system = 1. For drag and gravitational free environment. = 0.8 to 1. For launch systems.	
CEIAE	Weight factor for air breathing engine water injection system = 1.	
CENGC	Weight factor for air breathing engine controls = 1.	
CENGE	Weight factor for air breathing engine exhaust = 1.	
CENGM	Weight factor for air breathing engine mounts = 1.	
CENGN	Weight factor for air breathing engine nacelles = 1.	
CFSAB	Weight factor for fuel distribution system for air breathing engines = 0.04 For conventional aircraft. = 0.0006 For shuttles.	

Variable	Definition	Units
CFSFS	Weight factor for pressurization system plumbing for liquid rocket fuel = 0.314 For space propulsion system (Apollo, LM-D, SL-A). = 0.0521 For large boosters (storable propellants). = 0.521 For large boosters (cryogenic propellants).	
CFSLE	Weight factor for fuel distribution system for liquid rocket engines = 0.004 For space propulsion system (Apollo, LM-D, LM-A). = 0.0005 For large boosters (storable propellants). = 0.0017 For large boosters (cryogenic propellants).	
CFSØS	Weight factor for oxidizer system lines, valves, etc. = 1.	
CFWAE	Weight factor for air breathing engine firewalls and fireseals = 0.004 For external engines. = 0.008 For internal engines.	
CGLRE	Weight factor for engine gimbal = 0.07 For simple systems. = 0.1 For redundant systems.	
CGRØ5	Weight factor for growth for main propulsion	
CINS(I)	Insulation weight factor for main propellant tank No. (I). Program accepts I from 1 through 8 = 1. If insulation is used.	
CISP1	Specific impulse for solid propellant propulsion = 215. To 240. for sea level. = 240. To 260. for vacuum.	SEC
CKAD(I)	Kick frame area factor for aft dome of propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape. Refer to Figure 5-3 for value. Program accepts I from 1 through 8.	
CKFD(I)	Kick frame area factor for forward dome of propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape. Refer to Figure 5-3 for value. When ZLFD(I) = zero, CKFD(I) = zero. Program accepts I from 1 through 8.	
CLRE	Weight factor for liquid rocket engines = 0.0125 For pump fed engines. = 0.038 For pressure fed engines. = 0. If known engine weight WURLE is entered.	
CMF1	Weight factor for mass fraction of solid propellant propulsion systems = See Figure 5-1.	

Variable	Definition	Units
CMLRE	Weight factor to account for supports, controls for liquid rocket engines = 1.11 For single mounted engines. = 1.2 For multiple mounted engines.	
CØSAE	Weight factor for air breathing engine oil system. = 1. If not integral with engine.	
CPLAE	Weight factor for air breathing engine pylons = 0.005 For fixed pylons. = 0.015 For foldable or retractable pylons.	
CPRØP(I)	Factor for identifying large propellant tanks. Program accepts I from 1 through 8. = 1. If tank contains fuel. = 0. If tank contains oxidizer, or if not applicable.	
CPS	Weight factor for engine childown = 0.00126 (SIVB)	
CSCD(I)	Aft dome wetted area factor for insulation on main propellant tank No. (I). Program accepts I from 1 through 8. = 1. If aft dome is common to an aft adjoining tank. = 0. If aft dome is not common to another tank.	
CSEG(I)	Barrel wetted area factor for insulation on main propellant tank No. (I). Program accepts I from 1 through 8. = 0.25 If tank barrel is attached Siamese-like to another tank barrel. = 0. If tank barrel is not attached to another tank barrel.	
CSUPT(I)	Weight factor for main propellant tank No. (I) supports. Program accepts I from 1 through 8. = 1. For non-integral tanks. = 0. For integral tanks.	
CTAD(I)	Material thickness factor for aft dome of main propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape. Refer to Figure 5-4 for value. Program accepts I from 1 through 8.	
CTFD(I)	Material thickness factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I) and dome shape. Refer to Figure 5-4 for value. When ZLFD(I) = zero, CTFD(I) = zero. Program accepts I from 1 through 8.	

Variable	Definition	Units
CULL	Tank ullage factor (e.g., 0.05)	
CVAD(I)	Volume factor for aft dome of main propellant tank No. (I), a function of ZLAD(I)/DAT(I) or ZLCD(I)/DAT(I), whichever is not zero, and dome shape. Refer to Figure 5-5 for value. If value is based on ZLCD(I)/DAT(I), CVAD(I) shall be a negative value. Program accepts I from 1 through 8.	
CVFD(I)	Volume factor for forward dome of main propellant tank No. (I), a function of ZLFD(I)/DFT(I), ZLCD(I-1)/DFT(I) or ZLAD(I-1)/DFT(I), whichever is not zero, and dome shape. Refer to Figure 5-5 for value. If value is based on ZLAD(I-1)/DFT(I), CVFD(I) shall be a negative value. Program accepts I from 1 through 8.	
DAT(I)	Diameter at aft end of barrel of main propellant tank No. (I). If aft end of barrel is not circular, an equivalent DAT(I) = (barrel height x barrel width)$^{.5}$. Program accepts I from 1 through 8.	FT
DCØN(I)	Diameter of feed line conduit in main propellant tank No. (I). If an assigned value is not available, DCØN(I) may be estimated as 0.0465 $\left[\frac{\text{ZNLRE (TLRE)}}{\text{ZNPT(I)}}\right]^{.25}$ exp. Program accepts I from 1 through 8.	
DELV1	Required net delta velocity for solid propellant propulsion systems	FT/SEC
DENP(I)	Density of propellant in main propellant tank No. (I)	LB/CU FT
DENSW	Density of water used for main propellant tank hydrostatic testing	LB/CU FT
DENT(I)	Density of structural material of main non-integral propellant tank No. (I). Program accepts I from 1 through 8.	LB/CU IN
DFT(I)	Diameter at forward end of barrel of main propellant tank No. (I). If forward end of barrel is not circular, an equivalent DFT(I) = (barrel height x barrel width)$^{.5}$. Program accepts I from 1 through 8.	FT
HNAAE	Height of air breathing engine nacelles	FT
PADT(I)	Ultimate design pressure for aft dome of main propellant tank No. (I). Program accepts I from 1 through 8.	PSIG
PBT(I)	Ultimate design pressure for barrel of main propellant tank No. (I). Program accepts I from 1 through 8.	PSIG

Variable	Definition	Units
PFDT(I)	Ultimate design pressure for forward dome of main propellant tank No. (I). Program accepts I from 1 through 8.	PSIG
PGT(I)	Ultimate design gas pressure in fully loaded main propellant tank No. (I). Program accepts I from 1 through 8.	PSIG
TABE	Thrust of each air breathing engine	LB
TLRE	Thrust of each liquid rocket engine (sea level or vacuum rating compatible with operating regime)	LB
TLRE1	Thrust per main liquid rocket engine operating during stage 1 (vacuum rating)	LB
TMT(I)	Minimum allowable material nominal thickness of barrel or domes of main propellant tank No. (I). Program accepts I from 1 through 8.	IN
UDTLF	Ultimate design thrust load factor = 1.5 (ZNLRE)• (TLRE)/GWST for stage 1 only, = 1.5 (ZNLRE1)• (TLRE)/GWST1-WUP1) for stage 2 only, or = ATLF, if smaller than either, but not equal to zero.	
UTST(I)	Ultimate tensile strength of structural material of main propellant tank No. (I), at the critical design temperature. Program accepts I from 1 through 8.	LB/SQ IN
VNSST(K)	Volume of each non-self-sealing tank for air breathing engines. Program accepts K from 1 through 5.	CU FT
WCEL1	Weight of vehicle or component at start of acceleration (excludes solid propellant propulsion system)	LB
WSP5	Weight of special features of main propulsion	LB
WUABE	Known weight of each air breathing engine = 0. If not known and CABE entered for engine estimate	
WULRE	Known weight of each liquid rocket engine = 0. If not known and CLRE entered for engine estimate	LB
WUP1	Usable propellant weight for stage 1 operation (an assigned value)	LB
ZLAD(I)	Convex height of aft dome of main propellant tank No. (I). Program accepts I from 1 through 8.	FT
ZLAID	Average length of air breathing engine air induction ducts (measured from tip of spike or ramp to engine face)	FT
ZLBT(I)	Length of barrel of main propellant tank No. (I). Program accepts I from 1 through 8.	FT

Variable	Definition	Units
ZLCD(I)	Concave height of aft dome of main propellant tank No. (I), in the case of a common dome, for example ZLCD(I) is to be used instead of ZLFD2. Program accepts I from 1 through 8.	FT
ZLCØN(I)	Length of feed line conduit in main propellant tank No. (I). Program accepts I from 1 through 8.	FT
ZLENG	Length for air breathing engine control. Sum of length from pilot to each engine measured planform through the body	FT
ZLEXE	Length of each air breathing engine exhaust (average length if different)	FT
ZLFD(I)	Convex height of forward dome of main propellant tank No. (I). When a forward dome is common to the forward adjoining tank, it shall be considered as part of the forward adjoining tank and not part of the aft adjoining tank. Program accepts I from 1 through 8.	FT
ZLNAE	Length of air breathing engine nacelles (average length if different)	FT
ZLPY	Length of air breathing engine pylons (if swept, use structural length)	LB
ZMACP	Maximum mach number for propulsion nacelles and pylons	
ZNABE	Quantity of air breathing engines/vehicle or stage	
ZNLRE	Quantity of liquid rocket engines/vehicle or stage	
ZNLRE1	Quantity of main liquid rocket engines operating during stage 1	
ZNNAE	Quantity of air breathing engine nacelles/vehicle or stage	
ZNPT(I)	Quantity of main propellant tanks No. (I), per vehicle (booster type). Program accepts I from 1 through 8.	
ZNSST(K)	Quantity of identical non-self-sealing tanks for air breathing engines. Program accepts K from 1 through 5.	
ZPSFT(K)	Quantity of identical pressurization tanks for liquid rocket fuel (each tank estimated by inputs in Group 5A). Program accepts K from 6 through 10.	
ZPSØT(K)	Quantity of identical pressurization tanks for liquid rocket oxidizer (each tank estimated by inputs in group 5A). Program accepts K from 16 through 20.	

Variable	Definition	Units
ZREFT(K)	Quantity of identical liquid rocket fuel tanks (non-booster type), (each tank estimated by inputs in group 5A). Program accepts K from 1 through 5.	
ZREØT(K)	Quantity of identical liquid rocket oxidizer tanks (non-booster type), (each tank estimated by inputs in group 5A). Program accepts K from 11 through 15.	

Note: The main propulsion weight may be estimated independently by using the main propulsion inputs, group 5A inputs, and the following inputs:

Variable	List	Group
WEØAE*	-	21
GWST	2	2.
GWST1	2	2.

* Indicates output (Refer to pp. 76, 127)

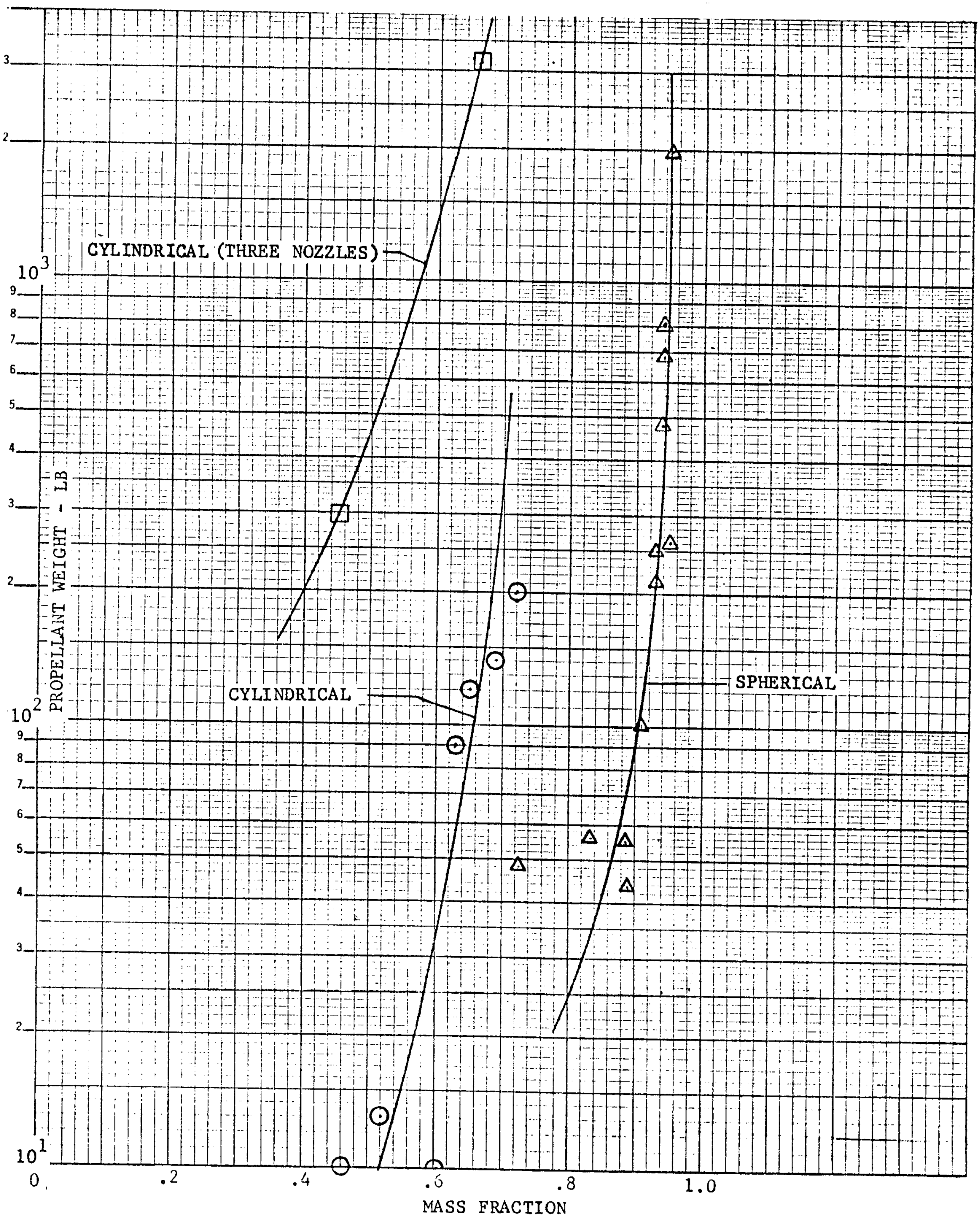


Figure 5-1 Mass Fraction of Solid Propellant Motors

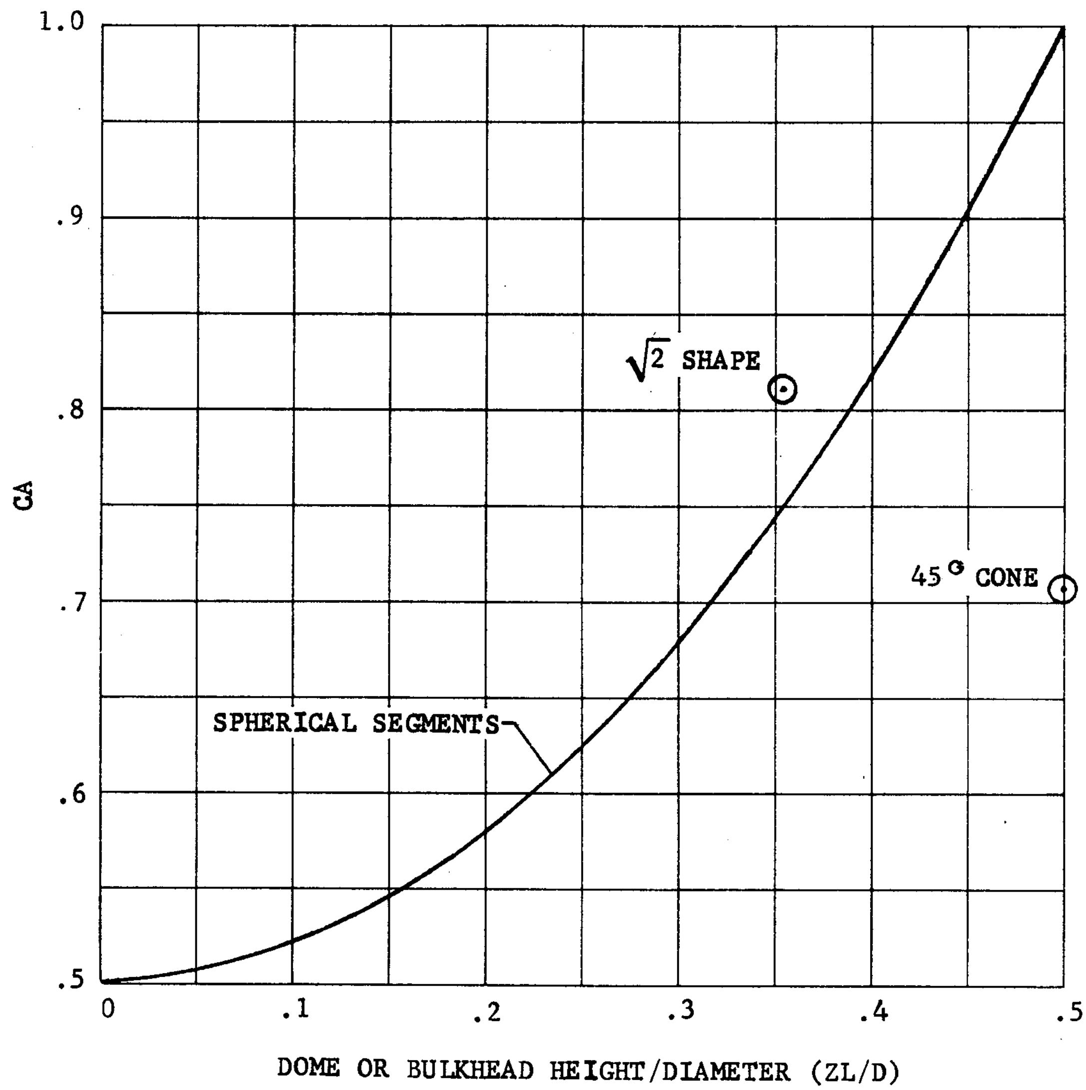


FIGURE 5-2 DOME OR BULKHEAD WETTED AREA FACTOR (CA)

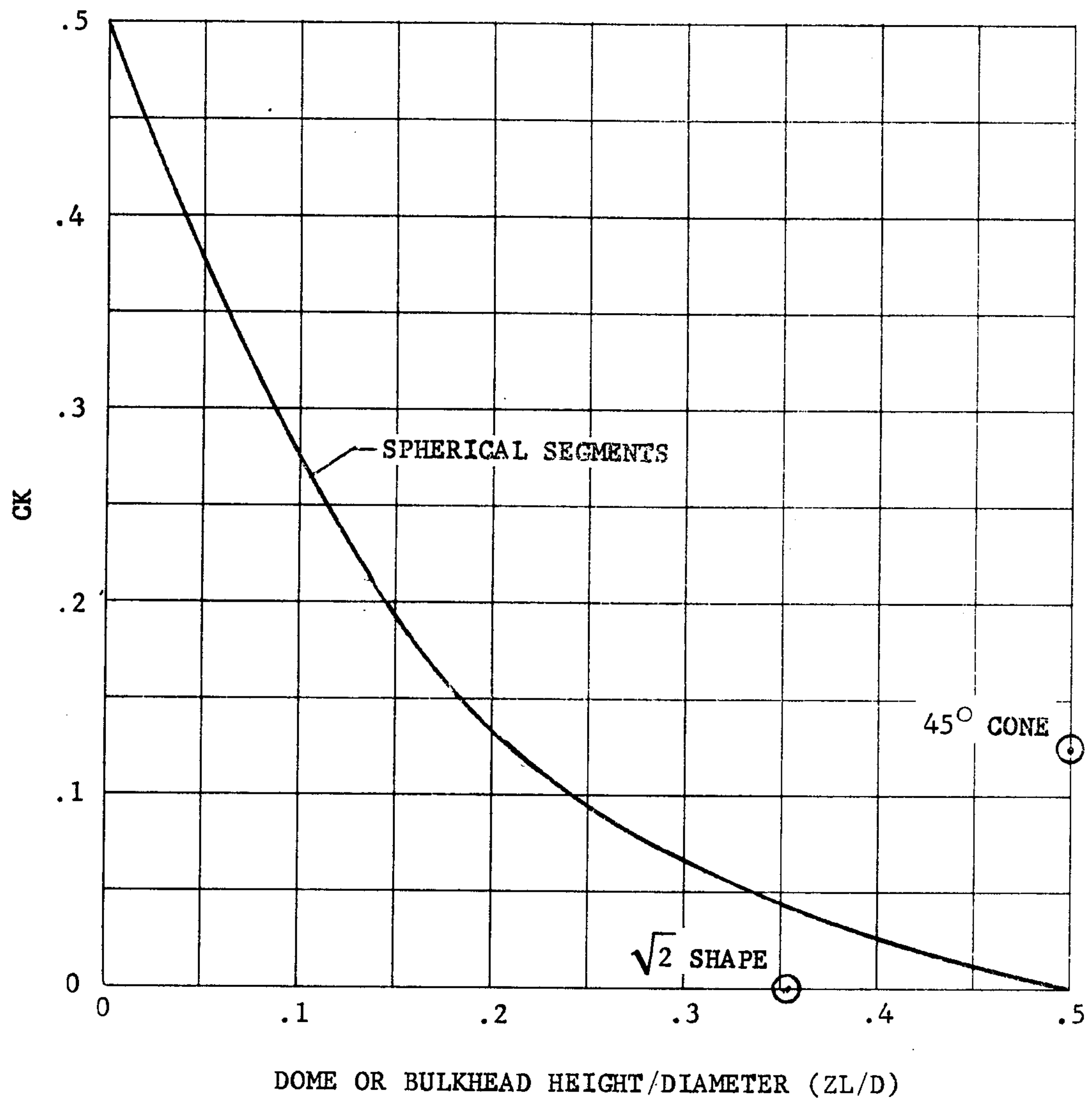


FIGURE 5-3 PRESSURE DOME OR BULKHEAD KICK FRAME AREA FACTOR (CK)

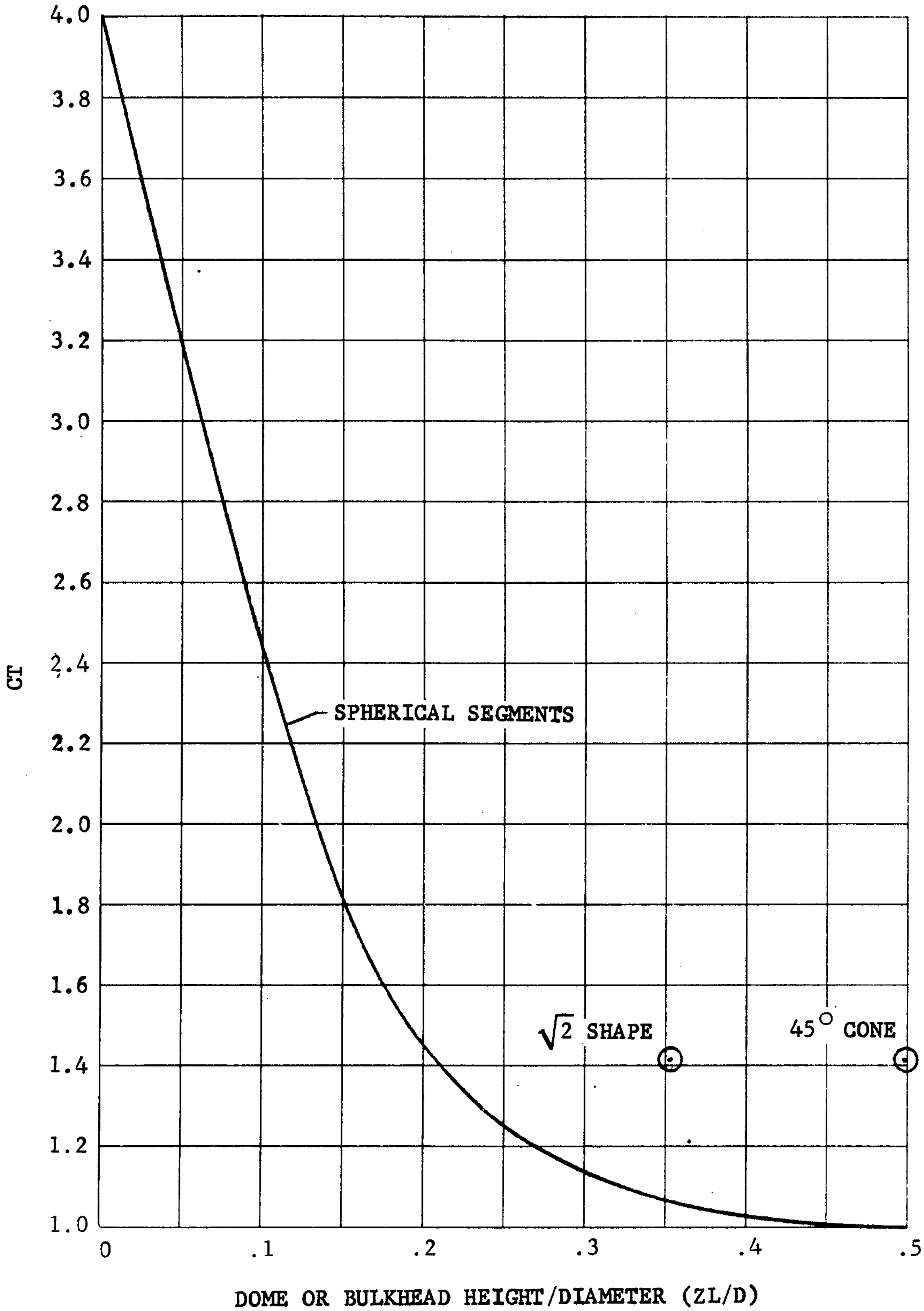


FIGURE 5-4 PRESSURE DOME OR BULKHEAD MATERIAL THICKNESS FACTOR (CT)

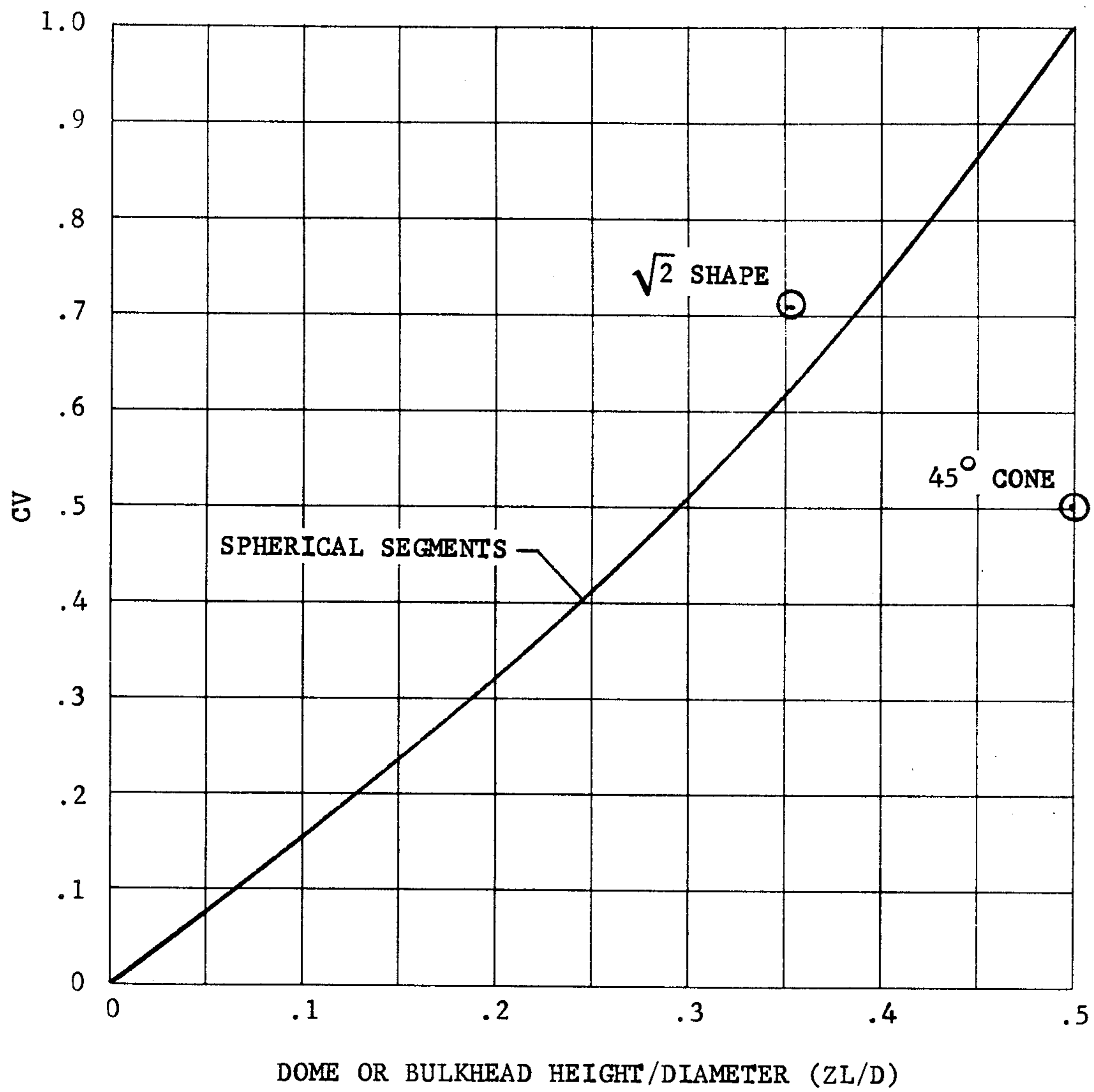


FIGURE 5-5 DOME OR BULKHEAD ENCLOSED VOLUME FACTOR (CV)

GROUP 5A. PRESSURE TANKS INPUTS
(Pg. 177-178)

Variable	Definition	Units
CMSC(K)	Weight factor for insulation and cover for spherical cryogenic tanks designed for long storage periods (Dewar type) = 1.	
CPSHL(K)	Weight factor for non-optimums of the pressure shell = 1.25 For spherical tanks without positive expulsion. = 1.35 For cylindrical tanks without positive expulsion. = 1.8 For spherical tanks with bladder type positive expulsion. = 2.3 For cylindrical tanks with bladder type positive expulsion. = 4.0 For cylindrical tanks with metallic bellows type positive expulsion (should be limited to tanks with less than .1 cu. ft. volume).	
CPTQI(K)	Weight factor for probe type quantity	
CSUP(K)	Weight factor for tank support = 0.51 For internally mounted tanks. = 2.7 For externally mounted tanks (e.g., Skylab's nitrogen and oxygen tanks).	
CULLT(K)	Factor for ullage for pressure tanks (ratio of unusable volume to total volume)	
DENCL(K)	Density of contained liquid or gas	LB/CU FT
DENTM(K)	Density of tank structural material	LB/CU IN
DT1(K)	Outside diameter of the smaller dome (twice the radius of the dome)	FT
DT2(K)	Outside diameter of the larger dome (twice the radius of the dome)	FT
FTUY(K)	The yield or ultimate strength of the tank structural material (see SFML(K))	LB/SQ IN
PRML(K)	The maximum limit pressure of the tank	PSIG
SFML(K)	Tank design yield or burst safety factor. Use factor compatible with FTUY(K) such that the ratio of SFML(K) over FTUY(K) is the larger.	
WINSU(K)	Unit weight of insulation and cover of tanks used for storable propellants or cryogenic propellants of short storage periods = 0.07 For storable propellants. = 0.20 to 0.35 For hydrogen tanks of boosters (consult thermodynamist for values for particular conditions).	LB/SQ FT
ZLTB(K)	Length of cylindrical section of tank (total length less one half of DT1(K) and DT2(K)).	FT

The pressure tanks inputs are used for pressure tanks serving various functions. Subscripts, as shown below, have been assigned to the various functions. See each group for corresponding inputs for quantity of tanks of each type.

GROUP	FUNCTION	SUBSCRIPTS
5.8	Main Fuel Containers	K = 1 To K = 5
5.10	Pressurant Containers - Main Fuel	K = 6 To K = 10
5.11	Main Oxidizer Containers	K = 11 To K = 15
5.12	Pressurant Containers - Main Oxidizer	K = 16 To K = 20
6.7	RCS Fuel Containers	K = 21 To K = 23
6.8	RCS Oxidizer Containers	K = 24 To K = 26
6.9	Pressurant Containers - RCS	K = 27 To K = 29
7.2	Fuel Cell Reactant Containers	K = 30 To K = 33
7.6	APU Propellant Containers	K = 34 To K = 39
12.1	Breathing Gas Containers	K = 40 To K = 42
14.2	Crew's Water Containers	K = 46 To K = 48

GROUP 6. ORIENTATION CONTROLS, SEPARATION AND ULLAGE INPUTS
(Pg. 179-181)

Variable	Definition	Units
CCBLC	Weight factor for boundary layer controls = 1.	
CCELE	Weight factor for elevon controls = 1.	
CCLES	Weight factor for leading edge flap/slat controls = 1.	
CCØN6	Weight factor for contingency for orientation controls, separation and ullage	
CCPC	Weight factor for elevator controls = 1.	
CCPCF	Weight factor for all movable pitch fin controls = 1.	
CCSB	Weight factor for speed brake controls = 1.	
CCSI	Weight factor for adjustable pitch fin incidence controls = 1.	
CCSPØ	Weight factor for spoiler controls = 1.	
CCTEF	Weight factor for trailing edge flap controls = 1.	
CCWIC	Weight factor for wing incidence controls = 1.	
CCYC	Weight factor for rudder controls = 1.	
CCYCF	Weight factor for all movable yaw fin controls = 1.	
CGRØ6	Weight factor for growth for orientation control, separation and ullage	
CRCFLV	Weight factor for RCS fuel distribution system = 0.47 For bipropellant. = 0.7 For monopropellant.	
CRCLV	Weight factor for RCS pressurization system lines, valves, etc. = 1.	
CRCØLV	Weight factor for RCS oxidizer distribution system = 0.47 For bipropellant = 0. For monpropellant	
CRCT(K)	Weight factor for RCS thrusters. Program accepts K from 1 through 5. = 0.465 For ablative nozzles. = 0.325 For radiant cooled nozzles. = 0. If WRCU(K) is entered.	

Variable	Definition	Units
CRCTS	Weight factor for RCS thruster supports = 1.	
CSEPR	Weight factor for separation rockets = 1.	
CSEPS	Weight factor for separation springs = 1.	
DELV2	Gross velocity increment for stage or component for separation	FT/SEC
TRCT(K)	Thrust of each RCS thruster (vacuum). Program accepts K from 1 through 5.	LB
WCEL2	Weight of vehicle or component to be accelerated by separation rockets or springs	LB
WCEL3	Weight of vehicle or component to react separation springs	LB
WCTC	Weight factor for trim controls = 10. For fighters. = 100. For bombers and transports.	LB
WPARKL	Weight factor for parking lock system (locks control surfaces when on the ground) = 150.	LB
WRCU(K)	Known unit weight of RCS thrusters. Program accepts K from 1 through 5. = 0. If not known, and CRCT(K) entered for thruster estimate.	LB
WSP6	Weight of special features for orientation controls, separation and ullage	LB
ZNRCT(K)	Quantity of identical RCS thrusters. Program accepts K from 1 through 5.	
ZRCFT(K)	Quantity of identical RCS fuel tanks (each tank is estimated by inputs in group 5A). Program accepts K from 21 through 23.	
ZRCØT(K)	Quantity of identical RCS oxidizer tanks (each tank is estimated by inputs in group 5A). Program accepts K from 24 through 26.	
ZRCPT(K)	Quantity of identical RCS pressurization tanks (each tank is estimated by inputs in group 5A). Program accepts K from 27 through 29.	

Note: The orientation control, separation and ullage weight may be estimated independently by using the orientation control, separation and ullage inputs, Group 5A inputs and the following inputs:

Variable	List	Group	Variable	List	Group
GWRE	1	1.1	SSP1	1	1.1
SAIL1	1	1.1	SSP2	1	1.1
SAIL2	1	1.1	SSP3	1	1.1
SAIL3	1	1.1	STEF1	1	1.1
SEHT	1	1.2	STEF2	1	1.1
SELHT	1	1.2	STEF3	1	1.1
SELW1	1	1.1	SVT	1	1.3
SELW2	1	1.1	WLEF1 *	—	1.1
SELW3	1	1.1	WLEF2 *	—	1.1
SEW1	1	1.1	WLEF3 *	—	1.1
SEW2	1	1.1	WLES1 *	—	1.1
SEW3	1	1.1	WLES2 *	—	1.1
SRUD	1	1.3	WLES3 *	—	1.1
SSB1	1	1.1	ZNAF	1	1.1
SSB2	1	1.1	ZNVT	1	1.3
SSB3	1	1.1	SELB	1	1.2

* Indicates output

TABLE IV-1 LIST 4 INPUT DEFINITIONS
(Pg. 182-200)

GROUP 7. PRIME POWER SOURCE INPUTS
(Pg. 182-184)

Variable	Definition	Units
APUHP	Shaft output power of each APU	SHP
CAPU	Weight factor for APU = 1. If WUAPU is not entered. = 0. If WUAPU is entered.	
CAPUA	Weight factor for APU accessories = 1.	
CCELL	Weight factor for hydrox fuel cells = 1.	
CCØN7	Weight factor for contingency for prime power source	
CGRØ7	Weight factor for growth for prime power source	
CPSB	Weight factor for batteries = See Figure 7-1.	
CSCDP	Weight factor for deployment and structural provisions as a function of total solar cell panel weight = 0.535 (e.g., Skylab's ATM). = 1.34 (e.g., Skylab's OWS).	
CSCPØ	Weight factor for solar cell weight as a function of power output = 1. = 0. If CSCSI is used.	
CSCSI	Weight factor for solar cell weight as a function of panel total effective area = 1. = 0. If CSCPØ is used.	
CVRC	Weight factor for voltage and recharge control for solar cell/battery system = 1.	
PERDI	Depletion ratio (ratio of consumed to maximum energy) of secondary storage batteries (such as used in conjunction with solar cell power system in earth orbit) = 0.3 (e.g., Skylab). = 1.0 For primary batteries and secondary batteries with few charge/recharge cycles.	
RPØB	Required total energy output for batteries	KWHR
RPØFC	Rated power of each fuel cell battery	KW
RPØSC	Total rated power of solar cells at 55 degrees centigrade operating temperature	KW
SSC	Total effective area of solar cells	SQ FT
WSP7	Weight of special features for prime power source	LB
WUAPU	Weight of known APU = 0.1 If CAPU is entered.	LB

Variable	Definition	Units
ZNAPT(K)	Quantity of identical tanks for gas generator propellant system (each tank estimated by inputs in Group 5A). Program accepts K from 34 through 39	
ZNAPU	Quantity of auxiliary power units	
ZNCEL	Quantity of fuel cell batteries	
ZNFCT(K)	Quantity of identical tanks for fuel cell reactants (each tank estimated by inputs in Group 5A). Program accepts K from 30 through 33.	

Note: The prime power source weight may be estimated independently by using the prime power source inputs plus the Group 5A inputs.

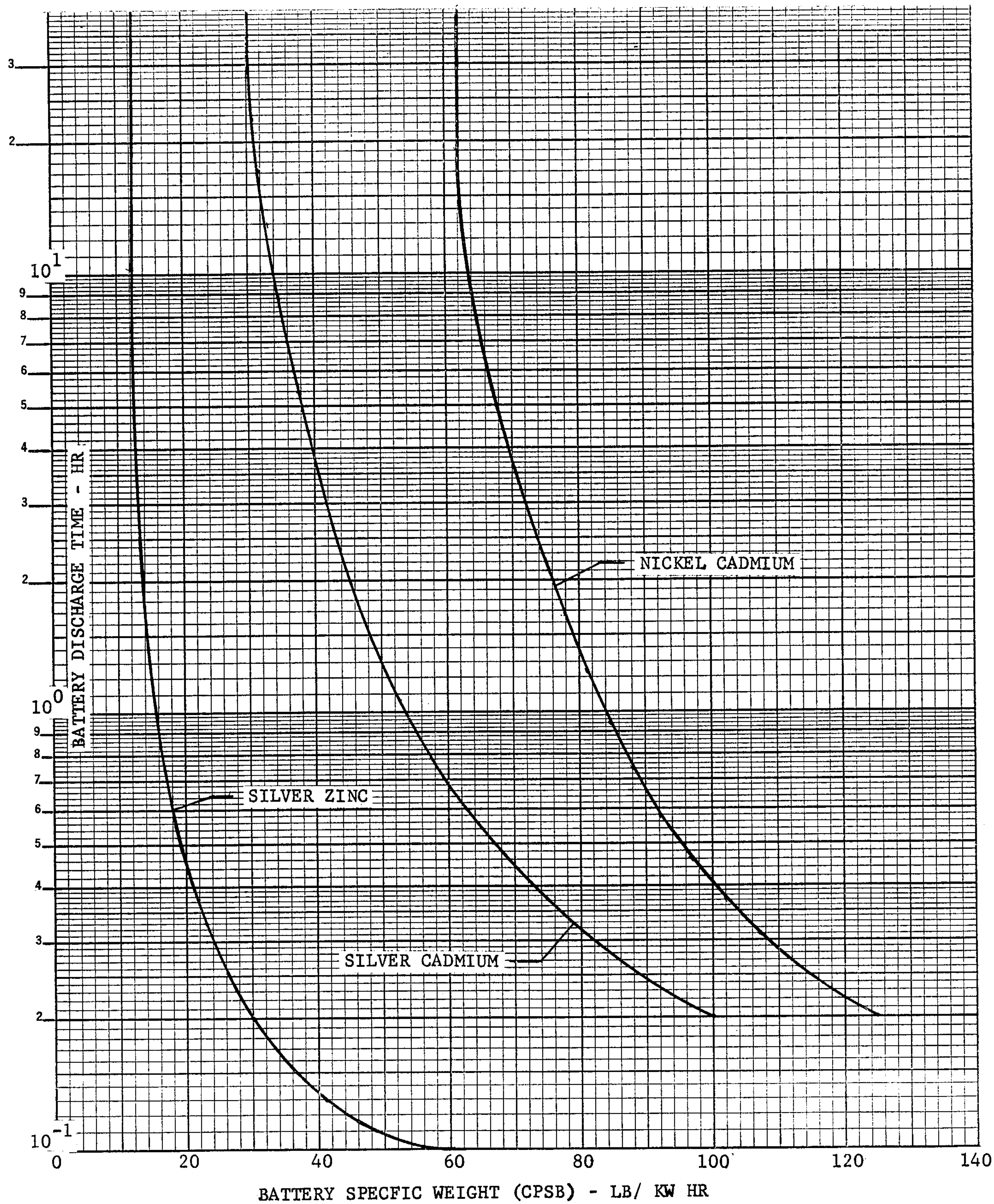


Figure 7-1 Battery Specific Weight

GROUP 8. POWER CONVERSION AND DISTRIBUTION INPUTS
(Pg. 185-187)

Variable	Definition	Units
BWM	Maximum vehicle lateral dimension	FT
CCØN8	Weight factor for contingency for power conversion and distribution	
CGRØ8	Weight factor for growth for power conversion and distribution	
CLGHYD	Weight factor for hydraulically actuated landing gear = 1.0	
CPCE	Weight factor for electrical power conversion equipment = 0.07 For aircraft. = 0.023 For space vehicles (Apollo, LM). = 0. If known equipment weight WPCEV is entered, or if no equipment is required.	
CPDE	Weight factor for electrical power distribution = 0.13 For space vehicles. = 0.046 For aircraft.	
CPDED	Weight factor for electrical power distribution for vehicle/component that does not contain electrical equipment (LES, adapter, etc.) = 1.	
CPF	Weight factor for magnitude of hydraulic pressure = 1. For 3000 psi system (see Figure 8-1 for other pressures).	
CPHC	Weight factor for hydraulic power conversion = 1.	
CPHD	Weight factor for hydraulic power distribution = 1.	
CSHYD	Area of control surfaces hydraulically operated divided by the total area of control surfaces	
WPCEV	Weight of known electrical power conversion equipment. If entered, CPCE is zero.	LB
WPLEP	Weight of payload that will require electrical power	LB
WSP8	Weight of special features of power conversion and distribution	LB

Note: The power conversion and distribution weight may be estimated independently by using the power conversion and distribution inputs plus the following inputs:

Variable	List	Group	Variable	List	Group
BB	2	2.	SLES3	1	1.1
CCPC	3	6.	SRUD	1	1.3
CCPCF	3	6.	SSB1	1	1.1
CCYC	3	6.	SSB2	1	1.1
CCYCF	3	6.	SSB3	1	1.1
HB	2	2.	SSP1	1	1.1
SAIL1	1	1.1	SSP2	1	1.1
SAIL2	1	1.1	SSP3	1	1.1
SAIL3	1	1.1	STEF1	1	1.1
SEHT	1	1.2	STEF2	1	1.1
SELHT	1	1.2	STEF3	1	1.1
SELW1	1	1.1	SVT	1	1.3
SELW2	1	1.1	WCØMM*	-	11.
SELW3	1	1.1	WCSCP*	-	15.
SLEF1	1	1.1	WGAN*	-	9.
SLEF2	1	1.1	WINST*	-	10.
SLEF3	1	1.1	WLG*	-	4.3
SLES1	1	1.1	WTPP*	-	7.
SLES2	1	1.1	ZLB	2	2.
SELB	1	1.2	ZNVT	1	1.3

*Indicates output

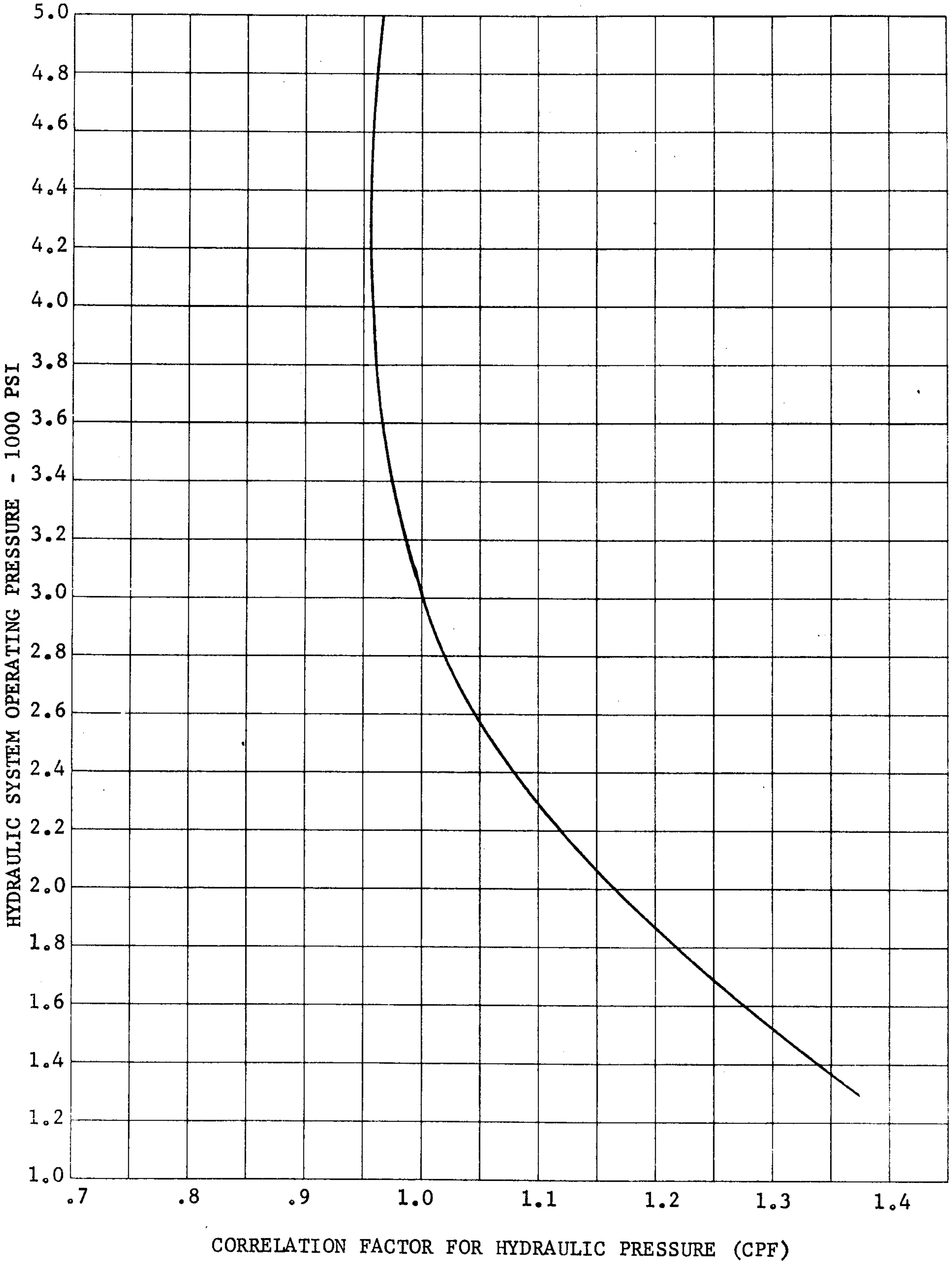


Figure 8-1 Hydraulic Pressure Correlation Factor

GROUP 9. GUIDANCE AND NAVIGATION INPUTS

Variable	Definition	Units
CCGN	Weight factor for guidance and navigation = 1.	
CCØN9	Weight factor for contingency for guidance and navigation	
CGRØ9	Weight factor for growth for guidance and navigation	
WGNC	Weight of known guidance and navigation components	LB

GROUP 10. INSTRUMENTATION INPUTS

Variable	Definition	Units
CCØN10	Weight factor for contingency for instrumentation	
CGRØ10	Weight factor for growth for instrumentation.	
CINST	Weight factor for instrumentation = 36. For experimential winged aircraft. = 11. For experimential lifting body aircraft. = 7.5 For space stations. = 3.6 For ballistic reentry vehicles. = 1.4 For propulsion modules of space vehicles (SM, LM-D, and GEM-A). = .85 For shuttles (this is an average of the reported values by the various contractors on phase A studies). = 0. When WINCØ is entered.	
WINCØ	Weight of known instrumentation system (CINST is zero when WINCØ is entered).	LB
WSP10	Weight of special features of instrumentation	LB

Note: The instrumentation weight may be estimated independently by using the instrumentation inputs plus the following inputs.

Variable	List	Group
BB	2	2.
HB	2	2.
ZLB	2	2.

GROUP 11. COMMUNICATION INPUTS
(Pg. 190-191)

Variable	Definition	Units
CCCR	Weight factor per command receiver = 15.	LB
CCØN11	Weight factor for contingency for communications	
CCTB	Weight factor per tracking beacon = 15.	LB
CDSCA	Weight factor for deep space communication antennas = 14. For fixed type to 165.0 for movable type (see TABLE IV-12).	LB
CDSCU	Weight factor per deep space transceiver and amplifier = 35.	LB
CGRØ11	Weight factor for growth for communications	
CICØM	Weight factor for intercommunication system = 4. For voice system. = 8. For voice and BIO-med data transmission.	
CNECA	Weight factor per near earth communication antenna = 5. to 140. (see TABLE IV-12).	LB
CNECU	Weight factor for near earth communication transmitters, receivers, and transceivers = 8.5	
CTVC	Weight factor per TV camera = 14.	LB
CTVM	Weight factor per TV monitor 25.	LB
CTVRS	Weight factor per TV remote camera station = 5.	LB
WCCP	Weight factor for command processors = 10. to 45. per vehicle (see TABLE IV-12).	LB
WCØMME	Weight of known communication system (this is entered in lieu of details if the weight of the system is known).	LB
WCRAN	Weight factor for ranging communication system = 10.	LB
WSP11	Weight of special features of communications	LB
ZNCCR	Quantity of command receivers	
ZNDSC	Quantity of deep space communication units	
ZNECU	Quantity of near earth communication units	
ZNICØM	Quantity of intercommunication stations in vehicle or module	

Variable	Definition	Units
ZNTB	Quantity of tracking beacons	
ZTVC	Quantity of TV cameras	
ZTVM	Quantity of TV monitors	
ZTVRS	Quantity of TV remote camera stations	

GROUP 12. ENVIRONMENTAL CONTROL SYSTEM INPUTS
(Pg. 192-193)

Variable	Definition	Units
CASCD	Weight factor for atmosphere control system lines, valves, etc. = 1.	
CBGHE	Weight factor for gaseous helium storage tanks for atmosphere control = 0. If tank is estimated by inputs in Group 5A. = 1.	
CCØN12	Weight factor for contingency for ECS	
CCØØL	Weight factor for coolant system = 0.0095 For ballistic reentry bodies from earth orbits. = 0.021 For ballistic reentry bodies from translunar return, and aircraft = 0.040 For space vehicles (non-reentry) and shuttle boosters. = 0.095 For shuttle orbiters.	
CESCE	Weight factor for ECS-equipment = 1.	
CGN	Weight factor for gaseous nitrogen storage tanks for atmosphere control = 0. If tank is estimated by inputs in Group 5A. = 1.	
CGØX	Weight factor for gaseous oxygen storage tanks for atmosphere control = 0. If tank is estimated by inputs in Group 5A. = 1.	
CGRØ12	Weight factor for growth for ECS	
CLIØH	Weight factor for lithium hydroxide CO_2 removal equipment = 1.	
CMØSI	Weight factor for molecular sieve CO_2 removal equipment = 1.	
CPCS	Weight factor for pressurization control system = 0.060 For space vehicles. = 0.38 For aircraft.	
CSCN	Weight factor for supercritical nitrogen storage tanks for atmosphere control = 0. If tank is estimated by inputs in Group 5A. = 1.	
CSCØX	Weight factor for supercritical oxygen storage tanks for atmosphere control = 0. If tank is estimated by inputs in Group 5A. = 1.	
CTCI	Factor for pressurized compartment internal insulation = 1.	

Variable	Definition	Units
CTCS	Weight factor for atmosphere conditioning and distribution (used when the system services only the vehicle or module being estimated) = 1.	
CTCSC	Weight factor for atmosphere conditioning and distribution (used when the system also services other modules, (e.g., Skylab's AM) = 1.	
TIMED	Design duration for crews systems or resupply interval	HR
VØLAC	Total volume of the pressurized compartments which are serviced by the atmosphere conditioning and distribution (same as VØLPC for vehicles such as Mercury and Gemini)	CU FT
VØLPC	Volume of the pressurized compartment of the vehicle or module	CU FT
WELCØ	Weight of electronic or electrical equipment serviced by the coolant system but not contained within the vehicle (such as the electronics contained in the CM which is cooled by the coolant system in the SM)	LB
WSP12	Weight of special features of ECS	LB
ZACST(K)	Quantity of identical tanks for atmosphere gases (each tank estimated by inputs in Group 5A). Program accepts K from 40 through 42.	
ZCSTN	Quantity of supercritical nitrogen storage tanks used for atmosphere control	
ZCSTØ	Quantity of supercritical oxygen storage tanks for atmosphere control	
ZNCE	Quantity of crew the ECS and other accommodations are provided for	

Note: The environmental control system weight may be estimated independently by using the ECS inputs, Group 5A inputs and the following inputs:

Variable	List	Group
WBGHE	5	22.
WBGN	5	22.
WBGØX	5	22.
WBLN	5	22.
WBLØX	5	22.
WCØMM*	-	11.
WCSCP*	-	15.
WGAN*	-	9.
WINST*	-	10.
WPLEP	4	8.

*Indicates output

GROUP 14. PERSONNEL PROVISIONS INPUTS
(Pg. 194-195)

Variable	Definition	Units
CCAHA	Weight factor for cargo handling = 0.03 (recommended until data is available).	
CCØN14	Weight factor for contingency for personnel provisions	
CFØCØ	Weight factor for food containers (non-refrigerated) = 1.	
CFØRE	Weight factor for food refrigeration system = 1.	
CFPC	Weight factor for non-structural flooring, platforms, and ceilings = 1.	
CGALL	Weight factor for food preparation equipment = 1.	
CGRØ14	Weight factor for growth for personnel provisions	
CHAND	Weight factor for handrails and restraints = 1.	
CINLI	Weight factor for interior lights = 1.	
CINPA	Weight factor for interior paint = 1.	
CPART	Weight factor for non-structural partitions and interior doors = 1.	
CPFØD	Ratio of food (by weight) that requires refrigeration or cold storage	
CSEAT	Weight factor per crew seat = 70. For aircraft non-ejection seats. = 95. For spacecraft non-ejection seats. = 150. For subsonic ejection seats. = 250. For supersonic ejection seats.	LB
CSLEE	Weight factor for sleeping restraints = 1.	
CSTCA	Weight factor for crew's system storage cabinets = 1.	
CWACØ	Weight factor for crew's water containers = 1. = 0. If tanks are estimated by inputs in Group 5A.	
CWADI	Weight factor for crew's water distribution and pressurization system = 1.	

Variable	Definition	Units
CWAMA	Weight factor for waste management = 1.	
CWTAD	Weight factor for work tables and desks = 1.	
PCAHA	Portion of cargo requiring special handling equipment (by weight)	
SFPC	Total area of non-structural flooring, platforms, and ceilings	SQ FT
SPART	Total area of non-structural partitions and interior doors	SQ FT
WSP14	Weight of special features of personnel provisions	LB
ZWACØ(K)	Quantity of crew's water containers (used when tanks are estimated by inputs in group 5A). Program accepts K from 46 through 48.	

Note: The personnel provisions weight may be estimated independently by using the personnel provisions inputs, group 5A inputs, and the following inputs:

Variable	List	Group
TIMED	3	12.
VØLPC	3	12.
WCARGØ	3	18.
WFØØD*	-	17.
WWAT*	-	17.
ZNC	3	17.
ZNCE	3	12.
WCACØ	4	18.

*Indicates output

GROUP 15. CREW STATION CONTROLS AND PANELS INPUTS

Variable	Definition	Units
CCØN15	Weight factor for contingency for crew station controls and panels	
CCSSC	Weight factor per crew station controls and panels for aircraft and spacecraft = 140. For aircraft and spacecraft except for Mercury and Gemini type (non-propulsive earth orbiting spacecraft). = 55. For Mercury and Gemini.	LB
CGRØ15	Weight factor for growth for crew station controls and panels	
RCSCP	Weight portion of the crew station controls and panels of the total space station cluster contained within the module being estimated = 1. For non-clustered type space stations	
WSP15	Weight of special features of crew station controls and panels	LB

Note: Crew station controls and panels weight may be estimated by using the crew station controls and panels inputs plus the following inputs:

Variable	List	Group
VØLAC	4	12.
ZNC	4	17.

GROUP 17. PERSONNEL INPUTS
(Pg. 197-198)

Variable	Definition	Units
CCHUT	Weight factor for each personal parachute = 23.	LB
CCØL	Weight factor for crew clothing changes (lb/man day) = .3 to 1.	
CCØN17	Weight factor for contingency for personnel	
CCREW	Weight factor for each crew (average weight of each crew without clothing and equipment)	LB
CCWG	Weight factor for constant wear garment for each crew = 8.	LB
CEXC	Weight factor for exercise equipment for each crew = 10.	LB
CFEXT	Weight factor for each portable fire extinguisher = 8.	LB
CFØØD	Weight of food entered as a total amount (CFPMD is zero if CFØØD is entered)	LB
CFPMD	Weight of food allowance (lb/man day) = 1.70 to 2.45 = 0. If CFØØD is entered.	
CGRØ17	Weight factor for growth for personnel	
CHYGE	Weight factor for hygienic equipment = 1.	
CPLSS	Weight factor for each portable life support system = 30. to 100.	LB
CPRCU	Weight factor for privacy curtains = 1.	
CPRGA	Weight factor for each protective garment = 20.	LB
CPRST	Weight factor for each pressure suit = 20. to 50.	LB
CRC	Weight factor for first aid equipment per crew = 5. to 10.	LB
CRECR	Weight factor for recreation equipment per crew = 8.	LB
CSK	Weight factor for survival kits per crew = 15. to 40.	LB
CWAT	Weight of crew water entered as a total amount (CWAT is zero if CWPMD is entered).	LB

Variable	Definition	Units
CWPMD	Weight of crew water allowance (lb/man day) = 6.07 (for drinking purpose only). (increase if margin, timewise, is desired) = 32.47 (for drinking and washing). (increase if margin, timewise, is desired) = 0. If CWAT is entered.	
WACCØ	Weight factor for accessory containers, retainers, etc. = 5. to 70.	LB
WMMLB	Weight factor for maps, manuals, logbooks = 20. to 70.	LB
WMT	Weight factor for maintenance tools = 2. to 30.	LB
WSP17	Weight of special features of personnel	LB
ZCHUT	Quantity of personal parachutes	
ZFEXT	Quantity of portable fire extinguishers	
ZNC	Quantity of crew at launch and/or reentry	
ZNPS	Quantity of pressure suits	
ZPLSS	Quantity of portable life support systems	
ZPRGA	Quantity of protective garments	

Note : Personnel weight may be estimated independently by using the personnel inputs plus the following inputs:

Variable	List	Group
TIMED	4	12.
ZNCE	4	12.

GROUP 18. CARGO INPUTS

Variable	Definition	Units
CCØN18	Weight factor for contingency for cargo	
CGRØ18	Weight factor for growth for cargo	
WCACØ	Weight of cargo containers	LB
WCARGØ	Weight of cargo	LB
WCARRE	Weight of cargo and passengers during return trip	LB
WEXP	Weight of experiments	LB
WPAS	Weight of each passenger (=165.0, typical) plus additional weight if provisions and accessories are to be included for each passenger	LB
WSCIN	Weight of scientific instruments	LB
WSP18	Weight of special features of cargo	LB
ZNPAS	Quantity of passengers	

GROUP 20. BALLAST INPUTS

Variable	Definition	Units
CBLST1	Weight factor for ballast allowance for ballistic reentry bodies and lifting bodies = 0.02 For ballistic reentry bodies. = 0.07 For lifting bodies.	
CBLST2	Weight factor for ballast allowance for launch escape towers (Mercury and Apollo) = 0.044	
CCØN20	Weight factor for contingency for ballast	
CGRØ20	Weight factor for growth for ballast	
WLESC	Gross weight at launch escape (reentry body plus launch escape tower) (an assigned value)	LB
WSP20	Weight of special features for ballast	LB

Note: Ballast weight may be estimated independently by using the ballast inputs plus the following inputs:

Variable	List	Group
GWRE	1	1.1

TABLE IV-2
SKYLAB GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Orbital flight, one year life, manned part time, passive rendezvous and docking, separate orientation system for experiment package pointing.

GUIDANCE COMPONENTS

ATM	
Rate Gyro (13)	148.5
Acquisition Sun Sensor	3.7
Fine Sun Seeker	24.0
Star Tracker	31.3
Computers (2)	190.0
OWS Comp. Interface Assembly	110.0
Roll Readout Package	25.0
C. and D. Logic Distributor	110.0
Star Tracker Electronics	28.2
Fine Sun Seeker Signal Condition	7.0
Fine Sun Seeker Preamplifiers Assembly	7.5
Fine Sun Seeker Electronics	18.0
Acquisition Sun Seeker Electronics	3.0
Experiment Pointing Electronics	175.0
Total Weight	881.2 Lb
MDA	
Outside Lights	6.4
Docking Targets	24.0
Total Weight	30.4 Lb
OWS	
Power Converter (2)	20.0
Relay Module	6.0
Coupling	4.0
Total Weight	30.0 Lb

TABLE IV-3

APOLLO LUNAR MODULE GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Lunar orbital, landing, and takeoff flights, manned, powered maneuvering and rendezvous, and non-reentry (earth).

GUIDANCE COMPONENTS

Descent Stage	
Landing Radar	43.4 Lb
Ascent Stage	
Rate Gyro Assembly	2.0
ATCA	23.8
Telescope	23.5
Rendezvous Radar	77.7
External Lights	25.4
Docking Targets, Lights	7.8
ADT Button Box	1.6
IMU	40.9
Computer	69.1
Servo	17.7
NVB-Navigation	5.2
PTA Torquer	14.4
Total Weight	309.1 Lb

TABLE IV-4

PRIME GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Suborbital flight non-powered, unmanned lifting body reentry, and parachute recovery (air recovery - primary; water recovery - secondary).

GUIDANCE COMPONENTS

Computer	14.1
Altitude Reference	22.3
Autopilot	6.1
Total Weight	42.5 Lb

TABLE IV-5

X-15 GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Suborbital flight, manned, powered boost, non-powered glide, reentry and landing, and atmospheric landing.

GUIDANCE COMPONENTS

SAS Controller and Servo	62
Gyro	13
Total Weight	75 Lb

TABLE IV-6

X-20 GUIDANCE AND NAVIATION EQUIPMENT

MISSION - Low altitude orbital flight of one revolution, manned, non-powered glide, reentry, and landing, and atmospheric landing.

GUIDANCE COMPONENTS

Air Data	5
Rate Gyro	11
Accelerometer	5
Computer Package	98
Platform	40
Coupler	111
Digital Computer	97
Signal Converter	20
Programmer	10
Total Weight	397

TABLE IV-7

MERCURY GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Orbital flight, non-powered, manned, ballistic reentry and parachute landing.

GUIDANCE COMPONENTS

Attitude Gyro	14.8
Rate Gyro	6.0
Accelerometer	.6
Periscope	45.3
Horizon Scanner	8.4
Calibrator	31.3
Rate Damper	5.2
Total Weight	111.6 Lb

TABLE IV-8

MOL GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Orbital flight, non-powered, manned, non-reentry.

GUIDANCE COMPONENTS

Velocity Sensor	5
Attitude Gyroscope	27
Horizon Sensors	35
Guidance Evaluation	69
Digital Computer	92
Keyboard Unit	21
Data Adapter Unit	34
Sensors Interface Assembly	40
Interface and Display Electronics	30
Growth	5
Total Weight	358 Lb

TABLE IV-9

GEMINI GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Orbital flight, manned, powered orbital maneuvering and rendezvous, ballistic reentry and parachute landing.

GUIDANCE COMPONENTS

Rate Gyro	8.5
Horizon Sensors	22.0
Rendezvous Radar	74.3
Navigation Aids	7.7
Attitude Control Package	17.4
Computer	58.9
Platform	33.2
Platform Electronics	39.8
Total Weight	261.8 Lb

TABLE IV-10

APOLLO GUIDANCE AND NAVIGATION EQUIPMENT

MISSION - Translunar and lunar orbital flight, powered maneuvering and rendezvous, ballistic reentry (CM), and parachute landing.

GUIDANCE COMPONENTS

Command Module

Gyro Package	45.0
Bellows assembly	10.7
Optical Subsystem	60.7
Optical Shroud	3.4
Computer	70.7
IMU	45.2
Navigation Base	17.4
Power Servo Assembly	49.2
Coupling Data Unit	36.5
PIPA Electronics	8.5
Signal Conditioner	5.8
Computer Keyboard	36.0
Control Electronics	16.5
Servo Amplifier	12.4
Display Electronics	24.8
Solenoid Driver Amplifier	20.6
Gyro Display Coupler	24.7
Total Weight	488.1 Lb

Service Module

Rendezvous Radar Transponder	17.5
External Lights	21.7
Total Weight	39.2 Lb

Launch Escape System

Q Ball Sensor	25.0 Lb

TABLE IV-11

SOME ADDITIONAL EQUIPMENT FOR ATMOSPHERIC CRUISING AND LANDING

	WEIGHT (Lb)
Instrument Landing System	16
Loran/Tacan	60
Radio Compass	80
Air Data System	60
Doppler Navigation	120
Radio Beacon	
Aircraft	55
Space Vehicles	8
Direction Finder	
Aircraft	70
Space Vehicles	30

TABLE IV-12
VALUES OF COMMUNICATION VARIABLES

VARIABLE	VEHICLE	VALUE
WCCP	CM	46
	LM-A	10
	AM	44
	ATM	17
CDSCA	SM	164
	LM-D	13.5
	LM-A	35
CNECA	X-15	10
	X-20	49
	MSC-M	4
	MER-RM	99
	GEM-RM	2.6
	GEM-A	1
	CM	40
	PRIME	0.5
	PILOT	4
	AM	137
	MOL-LM	71

TABLE V LIST 5 INPUT DEFINITIONS
(Pg. 207-213)

GROUP 21. RESIDUAL PROPELLANT AND SERVICE ITEMS INPUTS
(Pg. 207-208)

Variable	Definition	Units
CECSF	Weight factor for closed circuit coolant loop fluid of ECS = 1.	
CEØAE	Weight factor for engine oil for air breathing engines = 35. If known quantity is not available.	LB/ENG
CEØLRE	Weight factor for engine oil for liquid rocket engines = 5. If known quantity is not available.	LB/ENG
CFØME1	Weight factor for main propulsion fuel outage = 0.008 For boosters. = 0.024 For space vehicles (Apollo).	
CFPG	Weight factor for main propulsion fuel pressurizing gas = 0.0016 For ambient temperature stored helium. = 0.00054 For cryogenic stored helium. = 0.0012 When vaporized propellant is used as pressurant (LOX/LH2 system, MR = 7).	
CFTAE2	Weight factor for trapped fuel of auxiliary propulsion system = 0.2 For jet fuels (aircraft).	
CFTEP	Weight factor for trapped fuel used for electrical power (cryogenic hydrogen) = 0.035	
CFTME1	Weight factor for main propulsion trapped fuel = 0.005 For boosters. = 0.016 For space vehicles (Apollo).	
CØØME1	Weight factor for main propulsion oxidizer outage = 0.008 For boosters. = 0.024 For space vehicles (Apollo).	
CØPG	Weight factor for main propulsion oxidizer pressurizing gas = 0.0016 For ambient temperature stored helium. = 0.00054 For cryogenic stored helium. = 0.0067 When vaporized propellant is used as pressurant (LOX/LH2 system, MR = 7).	
CØTEP	Weight factor for trapped oxidizer used for electrical power (cryogenic oxygen) = 0.008	
CØTME1	Weight factor for main propulsion trapped oxidizer = 0.005 For boosters. = 0.016 For space vehicles (Apollo).	
CRCSP	Weight factor for trapped RCS propellant = 0.1	

Variable	Definition	Units
CRCSPG	Weight factor for RCS propellant pressurizing gas = 0.006 For helium = 0.034 For nitrogen	
CTPGG	Weight factor for gas generator trapped propellant used for prime power source = 0.016	
DECØMG	Density of compartment gas at launch	LB/CU FT
DENF1	Density of main propulsion fuel	LB/CU FT
DENF2	Density of auxiliary propulsion fuel	LB/GAL
DENØ1	Density of main propulsion oxidizer	LB/CU FT
WPNSG	Weight of trapped pneumatic system gases	LB
WPSG	Weight of trapped purge gas	LB
WSP21	Weight of special features of residual propellants and service items	LB

GROUP 22. RESERVE PROPELLANT AND SERVICE ITEMS INPUTS

Variable	Definition	Units
CFRAE2	Weight factor for fuel reserve for auxiliary propulsion	
CFRCR	Weight factor for fuel reserve for RCS	
CFREP	Weight factor for fuel reserve for electrical power (fuel cells)	
CFRME1	Weight factor for fuel reserve for main propulsion	
CØRME1	Weight factor for oxidizer reserve for main propulsion	
CØRCR	Weight factor for oxidizer reserve for RCS	
CØREP	Weight factor for oxidizer reserve for electrical power (fuel cells)	
CPRGG	Weight factor for gas generator propellant reserve for prime power source	
CRCH2Ø	Weight factor for coolant reserve	
WBGHE	Weight of loaded quantity of gaseous helium for atmosphere control	LB
WBGN	Weight of loaded quantity of gaseous nitrogen for atmosphere control	LB
WBGØX	Weight of loaded quantity of gaseous oxygen for atmosphere control	LB
WBLN	Weight of loaded quantity of supercritical nitrogen for atmosphere control	LB
WBLØX	Weight of loaded quantity of supercritical oxygen for atmosphere control	LB
WSP22	Weight of special features for reserve propellant and service items	LB

GROUP 23. INFLIGHT LOSSES INPUTS

Variable	Definition	Units
CLPRE	Portion of inflight losses consumed prior to reentry	
WCH2Ø	Weight of loaded quantity of coolant fluids	LB
WFLEP	Weight of loaded quantity of fuel for electrical power (fuel cells)	LB
WFRØST	Weight of frost lost during flight	LB
WFVEN1	Weight of vented pressurizing gas of main propulsion fuel system (vented fuel)	LB
WØLEP	Weight of loaded quantity of oxidizer for electrical power (fuel cells)	LB
WØVEN1	Weight of vented pressurizing gas of main propulsion oxidizer system (vented oxidizer)	LB
WPLGG	Weight of loaded quantity of gas generator propellant for prime power source	LB
WPNSGE	Weight of nominally consumed pneumatic system gases	LB
WPSGE	Weight of nominally consumed purge system gases	LB
WRCSF1	Weight of loaded quantity of RCS fuel	LB
WRCSØ1	Weight of loaded quantity of RCS oxidizer	LB
WSP23	Weight of special features for inflight losses	LB

GROUP 24. THRUST DECAY PROPELLANT INPUTS

Variable	Definition	Units
CTDF	Weight factor for thrust decay fuel for main propulsion - a function of total thrust	
CTDØ	Weight factor for thrust decay oxidizer for main propulsion - a function of total thrust	
WSP24	Weight of special features for thrust decay propellant	LB

GROUP 25. FULL THRUST PROPELLANT INPUTS

Variable	Definition	Units
CFPGMP	Weight factor to be used when vaporized propellants stored in the main propellant tanks are used as pressurant = 1.	
CLFU1	Weight factor to be used when RCS fuel is stored in main propulsion fuel tanks = 1.	
CLØU1	Weight factor to be used when RCS oxidizer is stored in main propulsion oxidizer tanks = 1.	
WSP25	Weight of special features for full thrust propellant	LB

GROUP 26. THRUST BUILDUP PROPELLANT INPUTS

Variable	Definition	Units
CTBUF	Weight factor for thrust buildup fuel for main propulsion - a function of total thrust	
CTBUØ	Weight factor for thrust buildup oxidizer for main propulsion - a function of total thrust	
WSP26	Weight of special features for thrust buildup propellant	LB

Note: Collectively, the weight of groups 21 through 26 may be estimated independently by using their inputs and the following inputs:

Variable	List	Group	Variable	List	Group
CMF1	3	5.	WCØØL*	-	12.
CPRØP(K)	3	5.	WPDH*	-	7.
CSEPR	3	6.	WPRØP(K)*	-	5.
DELV2	3	6.	WSPS1*	-	6.
RPØFC	4	7.	ZNABE	3	5.
VNSST(K)	3	5.	ZNCEL	4	7.
VØLPC	4	12.	ZNLRE	3	5.
ZREØT(K)	3	5.	ZNSST(K)	3	5.
WCEL2	3	6.	ZREFT(K)	3	5.
WCØN(K)*	-	5A.	TLRE	3	5.

*Indicates output

SECTION 2. SPACE TRANSPORATION SYSTEM SIZING PROGRAM

The sizing program is structured specifically for rocket powered vehicles (space shuttle, expendable stage, etc.). Its primary function is to solve for the amount of propellant necessary to achieve a stipulated gross velocity. Since the solution is an iterative one, the sizing program is for computer use only; the computer utilization is explained in the Computer Program Manual, MSC-01260.

The sizing program operates on outputs generated from the point design method of Section 1 (or any other point design source), plus inputs of stipulated gross velocity and the vacuum specific impulse of the engines. The logic of the sizing program assumes the point design input case is properly sized for the input condition. Resizing of a vehicle is made only if necessitated by a computed change in propellant weight to satisfy the velocity requirements of the mission, or when an input is made to the sizing program which indicates a stipulated change in volume for payload containment.

The logic of the sizing program limits the acceptable amount of computed size change between the point design and the sized vehicle. In general, if the size change exceeds ± 10%, a reconfiguring of the point design is recommended, because a large size change could infer significant changes in the quantity of engines and the shape and arrangement of the vehicle subsystems.

The sizing program, while searching for the proper propellant weight, continually revises the weights of the following subsystems in the manner indicated. Subsystems not shown are assumed to be of unchanging weight.

Aerodynamic Surfaces:

Surface weight/surface area is constant.

Reentry gross weight/surface area is constant.

Body:

Body weight/body area is constant

Body area/(body volume) $^{2/3}$ is constant

Body volume = point design body volume + volume changes due to propellant and/or payload changes.

Thermal Protection:

T.P. weight/aerodynamic surfaces and body area is constant.

Launch Gear:

Launch gear weight/vehicle stage weight is constant.

Recovery Gear:

Recovery gear weight/vehicle landing weight is constant.

Handling Gear:

Handling gear weight/vehicle handling weight is constant.

Propellant Tanks:

Tanks weight/propellant weight is constant.

Orientation Controls:

O.C. weight/reentry gross weight is constant.

Ballast:

Ballast weight/vehicle landing gross weight is constant.

All Propulsion Liquids and Gases Except Those Expended for Full Thrust (Residuals):

Residuals weight/full thrust propellant weight is constant.

The flow diagram for the sizing program is presented on Figure II-2.

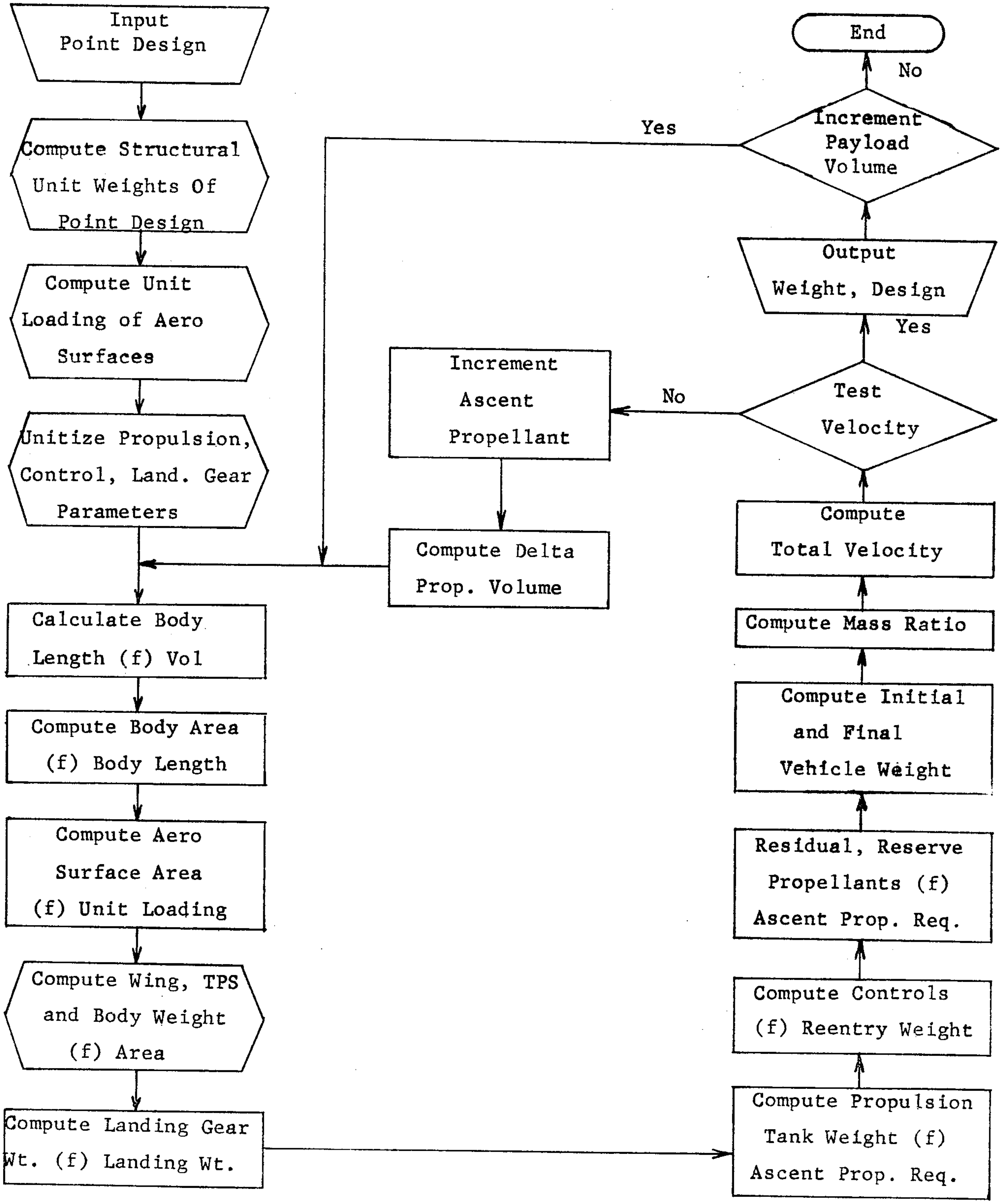


FIGURE II-2. SIZING ROUTINE FLOW DIAGRAM