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MSC-01258

WEIGHT ESTIMATING AND FORECASTING DURING CONCEPTUAL DESIGN

CONTRACT NAS9-10326

FINAL BRIEFING MATERIAL

NOVEMBER 1970



MARTIN MARIETTA CORPORATION
Denver Division
Denver, Colorado

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FOREWORD

This final briefing material is submitted by the Martin Marietta Corporation to the National Aeronautics and Space Administration Manned Spacecraft Center, Houston, Texas, in accordance with Contract Number NAS9-10326.

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STUDY OBJECTIVE

- PROVIDE TWO METHODS FOR ESTIMATING THE WEIGHT OF MANNED SPACECRAFT AND SPACESTATION CONFIGURATIONS DURING CONCEPTUAL DESIGN.

- PROVIDE A MEANS OF FORECASTING VEHICLE WEIGHT TO BE EXPECTED AT TIME OF DELIVERY.

		MANHOUR DISTRIBUTION	
ORIGINAL CONTRACT (1-5-70)	$98,353 Fixed Price	Staff Engineer	1700
	5183 Minimum Direct Manhours	Programmer	255
		Senior Engineer	3162
		Clerical	66
REVISED CONTRACT (8-28-70)	$96,144 Fixed Price	Staff Engineer	2000
	5183 Minimum Direct Manhours	Programmer	255
		Senior Engineer	1920
		Clerical	66
		Engineer	942

TASK	Ahl	Klina	Senior Engr.	Engineer	Programmer	TOTAL
1. Data Collection & Compilation	192	232	474	74	972	
2. Weight Growth Study	200		508		708	
3. Weight Estimation Formulations (Vol. II)	702		682	650	2034	
4. Weight Estimation Formulations (Vol. I)	120			200	320	
5. Computer Program Development		399			240	639
6. Handbook Preparation	232		294			526
Total Technical Labor	1446	631	1958	924	240	5199
Clerical						150
GRAND TOTAL						5349

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PROGRAM SCHEDULE

DENVER DIVISION

	ITEM	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
I.	STUDY PLAN	▲											
II.	DATA COLLECTION	——	▲										
III.	DATA COMPILATION		——	——	——	▲							
IV.	WEIGHT ESTIMATION FORMULATIONS (VOL. II)					——	——	——	——	▲			
V.	WEIGHT ESTIMATION FORMULATIONS (VOL. I)								——	——	▲		
VI.	COMPUTER PROGRAM DEVELOPMENT								——	——	——	▲	
VII.	HANDBOOK PREPARATION									——	——	——	▲
VIII.	HANDBOOK DRAFT COMPUTER PROGRAM MANUAL DRAFT SUMMARY REPORT DRAFT												▲
IX.	FINAL BRIEFING MATERIAL												▲
X.	MSC COMMENTS FOR ITEM VIII.												▲
XI.	HANDBOOK FINAL COMPUTER PROGRAM MANUAL FINAL SUMMARY REPORT FINAL SUPPLEMENTARY DATA REPORT												▲

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DEN 066232-02(2-69)

STUDY REPORTS

MARTIN MARIETTA
DENVER DIVISION

REPORT	SUBMITTAL DATE	COMMENTS
Study Plan	12 January 1970	Approval received 19 January.
Monthly Progress	Monthly	Nine issues submitted.
Midterm Briefing	23 July 1970	Postponed one month from original contract date.
Handbook - Draft	2 November 1970	Final copies to be submitted by 3 December 1970, including Supplementary Data Report.
Computer Program Manual - Draft	2 November 1970	
Summary Report - Draft	2 November 1970	
Final Briefing	18 November 1970	

CONFIGURATION DESCRIPTION AND MISSION (PER NASA STATEMENT OF WORK)

- MISSION MODEL

  VINTAGE: 1973 to 1978
  GRAVITY: ZERO TO 1G (EARTH)
  ALTITUDE: 100 TO 300 N.MI.
  ORBITAL INCLINATION: ZERO TO 90 DEG.
  CREW COMPARTMENT ATMOSPHERE: 5 TO 14.7 PSIA
  MIN. PARTIAL PRESS OF OXYGEN: 3.45 TO 3.01 PSIA
  LAUNCH ENVIRONMENT: T-IIIM, SATURN IB, SATURN V, INTERMEDIATE 20(SIC/SIVB) AND INTERMEDIATE 21 (SIC/SII).
  LAUNCH SITE: ETR

- SPACE STATIONS

  LAUNCH CONFIGURATION: SINGLE AND MULTIPLE (WITH ORBITAL MATING).
  CREW SIZE: 6 TO 100.
  VOLUME: 10K to 400K CU. FT.
  MISSION DURATION: 30 DAYS TO 10 YEARS.

- LOGISTIC SPACECRAFT

  L/D: HIGH AND LOW.
  LAUNCH ENVIRONMENT: L/V 'S NOTED ABOVE OR IIRV.
  SINGLE MISSION AND REUSABLE TYPES.
  CREW SIZE: 3 TO 30.
  VOLUME: 5K TO 50K CU. FT.
  ON-ORBIT STAYTIME: 2 TO 180 DAYS.
  USEFUL PAYLOAD TO ORBIT: 5K TO 50K LB.
  USEFUL PAYLOAD RETURNED TO EARTH: 0.1K TO 20K LB.

MARTIN MARIETTA
DENVER DIVISION

HANDBOOK
FOR
WEIGHT ESTIMATING AND FORECASTING
OF
MANNED SPACE SYSTEMS DURING CONCEPTUAL DESIGN

VOLUME I

VOLUME II

SUPPLEMENTARY REPORT

SAMPLES OF SPACE SYSTEMS AND AIRCRAFT USED IN THE WEIGHT CORRELATIONS

List C (I-2)

MODEL	CODE NAME	DESIGN STATUS: PRELIMINARY	INTERMEDIATE	FINAL
X-15	X-15			X
DYNASOAR	X-20		X	
MANNED SATELLITE CAPSULE (McDONNELL)	MSC-M	X		
MERCURY REENTRY MODULE	MER-RM			X
MERCURY ADAPTER	MER-A			X
MERCURY LAUNCH ESCAPE SYSTEM	MER-LES			X
GEMINI REENTRY MODULE	GEM-RM			X
GEMINI ADAPTER	GEM-A			X
APOLLO COMMAND MODULE	CM			X
APOLLO SERVICE MODULE	SM			X
APOLLO LAUNCH ESCAPE SYSTEM	AP-LES			X
APOLLO ADAPTER	AP-A			X
LUNAR MODULE DESCENT STAGE	LM-D			X
LUNAR MODULE ASCENT STAGE	LM-A			X
SV-5L	PRIME			X
X-24/SV-5P	PILOT			X
LIFTING BODY REENTRY VEHICLE - COLD STRUCTURE (MARTIN MARIETTA)	LBRV-CM	X		
LIFTING BODY REENTRY VEHICLE - WARM STRUCTURE (MARTIN MARIETTA)	LBRV-WM	X		
SPACE TRANSPORTATION SYSTEM PHASE A BOOSTER (McDONNELL DOUGLAS)	STSA-BM	X		
SPACE TRANSPORTATION SYSTEM PHASE A ORBITER (McDONNELL DOUGLAS)	STSA-OM	X		
SPACE TRANSPORTATION SYSTEM PHASE A BOOSTER (GENERAL DYNAMICS)	STSA-BG	X		
SPACE TRANSPORTATION SYSTEM PHASE A ORBITER (GENERAL DYNAMICS)	STSA-OG	X		
SPACE TRANSPORTATION SYSTEM PHASE A BOOSTER (NORTH AMERICAN)	STSA-BN	X		
SPACE TRANSPORTATION SYSTEM PHASE A ORBITER (NORTH AMERICAN)	STSA-ON	X		
SPACE TRANSPORTATION SYSTEM PHASE A BOOSTER (LOCKHEED)	STSA-BL	X		
SPACE TRANSPORTATION SYSTEM PHASE A ORBITER (LOCKHEED)	STSA-OL	X		
SPACE TRANSPORTATION SYSTEM PHASE B BOOSTER (MARTIN MARIETTA)	STSB-BM	X		
SPACE TRANSPORTATION SYSTEM PHASE B ORBITER (MARTIN MARIETTA)	STSB-OM	X		

ACTUAL AIRCRAFT USED FOR ONE OR MORE WEIGHT CORRELATIONS:

B-36J	B-58A	KC-130F	F-4D	A3J-1	F-104F
B-47B	XB-70A	C-133B	F-5A	F-100D	F-105F
B-52A	C-119H	C-135A	F-8E	F-101B	

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SAMPLES OF SPACE SYSTEMS AND AIRCRAFT USED IN THE WEIGHT CORRELATIONS

MARTIN MARIETTA
DENVER DIVISION

List C (I-2) - con't

MODEL	CODE NAME	DESIGN STATUS: PRELIMINARY	INTERMEDIATE	FINAL
SKYLAB ORBITAL WORK SHOP	OWS		X	
SKYLAB INSTRUMENTATION UNIT	IU		X	
SKYLAB AIRLOCK MODULE	AM		X	
SKYLAB MULTIPLE DOCKING ADAPTER	MDA		X	
SKYLAB APOLLO TELESCOPE MOUNT	ATM		X	
SKYLAB 1A CARRIER (MARTIN MARIETTA)	1AC	X		
MANNED ORBITTING LABORATORY MODULE	MOL-LM		X	
MANNED ORBITTING MISSION MODULE	MOL-MM		X	
MANNED ORBITAL RESEARCH LABORATORY (MARTIN MARIETTA)	MORL	X		
MANNED ORBITAL RESEARCH LABORATORY RESUPPLY (DOUGLAS)	MORL-RS	X		
SUBSYSTEMS TEST BED	STB			X
ZERO GRAVITY PHASE B STUDY (McDONNELL DOUGLAS)	SSB-OG	X		
ARTIFICIAL GRAVITY PHASE B STUDY (McDONNEL DOUGLAS)	SSB-AG	X		
ATTACHED MODULE PHASE B STUDY (MARTIN MARIETTA)	SSB-AM	X		
FREE-FLYING MODULE PHASE B STUDY (MARTIN MARIETTA)	SSB-FM	X		
EARTH ORBIT SPACE STATION STUDY (NASA)	EOSS	X		
TITAN SERIES:				
	T-I			X
	T-II			X
	T-III			X
	T-IIIM		X	

ACTUAL SPACE SYSTEMS USED FOR ONE OR MORE WEIGHT CORRELATIONS:

TRANSTAGE (MARTIN MARIETTA)
S-IC S-IVB

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SECTION 1. PROPORTIONALITY WEIGHT ESTIMATION METHOD

SECTION 2. GROUP ACCUMULATION WEIGHT ESTIMATION METHOD

SECTION 3. WEIGHT GROWTH DATA

PROPORTIONALITY WEIGHT ESTIMATION METHOD (I-1)

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DENVER DIVISION

PREMISE

- TOTAL VEHICLE WEIGHT IS COMPRISED OF FIXED WEIGHTS PLUS VARIABLE WEIGHTS WHICH ARE PREDICTABLE PROPORTIONS OF TOTAL VEHICLE WEIGHT

COMPOSITION

- EQUATION
- DEFINITIONS AND VALUES FOR THE TERMS IN THE EQUATION

INTENDED USAGE

- WEIGHT ESTIMATION OF FIRST PHASE DESIGNS
- INDICATION OF VEHICLE WEIGHT GROWTH SENSITIVITY

INPUTS

- MINIMUM AMOUNT OF DESIGN PARAMETERS

  (E.G., PRELIMINARY MISSION DESCRIPTION, CREW QUANTITY, WEIGHT OF CARGO AND PASSENGERS)

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PROPORTIONALITY WEIGHT ESTIMATION METHOD (I-1)

MARTIN MARIETTA
DENVER DIVISION

EQUATION

$$\text{TOTAL VEHICLE WEIGHT, LB.} = \Big[WGNIAC(1 + CENCS) + WCREW(1 + CENCS + CPPACS) + CLESM(ZNCRE_n) + WCARDN + (WCARUP - WCARDN)C3\Big] \div \Big[(1 - CLNCHP - CLES - CADAPT)(1 - C\emptyset CP - CD\emptyset SR)C3 - C\emptyset CP(CLRPS + CRRESP)(1 - CLNCHP - CLES - CADAPT) - CSAIEP - CLREN - CLNCHP(CLRPS + CRRESP)\Big]$$

, where

$$C3 = 1 - CLRAD - CABEN - CABEF - C\emptyset CSAU - CPPSCD - CBAL - CABEF(CABEFS + CRRESP).$$

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EXAMPLE OF DEFINITIONS AND VALUES OF WEIGHT FACTORS

CABEN = WEIGHT FACTOR FOR AIR BREATHING ENGINES AND ACCESSORIES

= 0.071 FOR STS JET ENGINES

= 0.107 FOR AIRCRAFT JET AND TURBOPROP ENGINES

= 0.167 FOR AIRCRAFT JET-RECIPROCATING ENGINE COMBINATION

= 0.188 FOR AIRCRAFT RECIPROCATING ENGINES

CABEF = WEIGHT FACTOR FOR ATMOSPHERIC CRUISE FUEL

= 0.011 FOR VERY SHORT RANGE STS ORBITERS WITH SUBSONIC JET ENGINES

= 0.079 FOR SHORT RANGE STS BOOSTERS WITH SUBSONIC JET ENGINES

= 0.141 FOR SHORT RANGE AIRCRAFT WITH RECIPROCATION ENGINES

= 0.262 FOR MEDIUM RANGE AIRCRAFT WITH TURBOPROP ENGINES

= 0.339 FOR MEDIUM RANGE AIRCRAFT WITH SUBSONIC JET ENGINES

= 0.533 FOR LONG RANGE AIRCRAFT WITH SUBSONIC JET ENGINES

= 0.533 FOR MEDIUM RANGE AIRCRAFT WITH SUPERSONIC JET ENGINES

= 0.552 FOR VERY LONG RANGE (10,000 MILES) AIRCRAFT WITH RECIPROCATING ENGINES

CABEFS = WEIGHT FACTOR FOR AIR BREATHING ENGINE FUEL SYSTEM

= 0.036 FOR AIRCRAFT

= 0.108 FOR STS BOOSTERS

= 0.508 FOR STS ORBITERS

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EXAMPLE OF SUBSTANTIATING DATA *

TABLE A

SUBSTANTIATING DATA FOR PROPORTIONALITY WEIGHT ESTIMATION METHOD

NO.	ITEM	SOLUTION	NO.	ITEM	SOLUTION
1	WSAIEP		28	CSAIEP	1/27
2	WLRAD		29	CLRAD	2/18
3	WABEN		30	CABEN	3/18
4	WABEFS		31	CABEFS	4/5
5	WABEF		32	CABEF	5/18
6	WLREN		33	CLREN	6/27
7	WLRPS		34	CLRPS	7/(21 + 24)
8	WRRESP		35	CRRESP	8/(5 + 21 + 24)
9	WØCSAU		36	CØCSAU	9/18
10	WPPSCD		37	CPPSCD	10/18
11	WGNIAC		38	CGNIAC	11
12	WENCS		39	CENCS	12/(11 + 13)
13	WCREW		40	CPPACS	14/13
14	WPPACS		41	ZNCREW	
15	WLESM		42	CLESM	15/41
16	WCARDN		43	CBAL	17/18
17	WBAL		44	CØCP	21/23
18	EW3	$\sum$ 1 THRU 17	45	CDØSR	22/23
19	WCARDN		46	CLNCHP	24/27
20	WCARUP		47	CLES	25/27
21	WØCP		48	CADAPT	26/27
22	WDØSR				
23	GW2	$\sum$ 18 THRU 22			
24	WLNCHP				
25	WLES				
26	WADAPT				
27	GW1	$\sum$ 23 THRU 26			

* PRESENTED IN THE SUPPLEMENTARY REPORT (PAGE 9)

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PROCEDURE FOR UPDATING *

1. ADD NEW DATA TO TABLE A IN THE SUPPLEMENTARY REPORT

2. AMEND THE WEIGHT FACTOR VALUES LISTED IN VOLUME I, SECTION 1, AS THE NEW DATA MAY INDICATE

*PRESENTED IN THE SUPPLEMENTARY REPORT (PAGE 268)

GROUP ACCUMULATION WEIGHT ESTIMATION METHOD (I-2)

MARTIN MARIETTA
DENVER DIVISION

PREMISE

- TOTAL VEHICLE WEIGHT IS COMPRISED OF THE ACCUMULATED WEIGHT OF TWENTY MAJOR SUBSYSTEMS (MORE OR LESS)
- EACH SUBSYSTEM WEIGHT IS PREDICTABLE THROUGH AN EMPIRICAL RELATIONSHIP WITH A FEW SIGNIFICANT PARAMETERS

COMPOSITION

- GRAPHS OF PARAMETERS VS. WEIGHT, OR TABULAR DATA, FOR EACH MAJOR SUBSYSTEM
- DEFINITIONS OF WEIGHT PARAMETERS

INTENDED USAGE

- WEIGHT ESTIMATION OF SECOND PHASE DESIGNS

INPUTS

- MODERATE AMOUNT OF DESIGN PARAMETERS

  (E.G., CONFIGURATION GEOMETRY, LOAD FACTORS, REENTRY VELOCITY, PROPULSION TYPE AND THRUST, PROPELLANT TYPE AND QUANTITY, BREATHING OXYGEN REQUIREMENTS, CREW QUANTITY, WEIGHT OF CARGO AND PASSENGERS)

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FIGURE I-2.1.1 WING

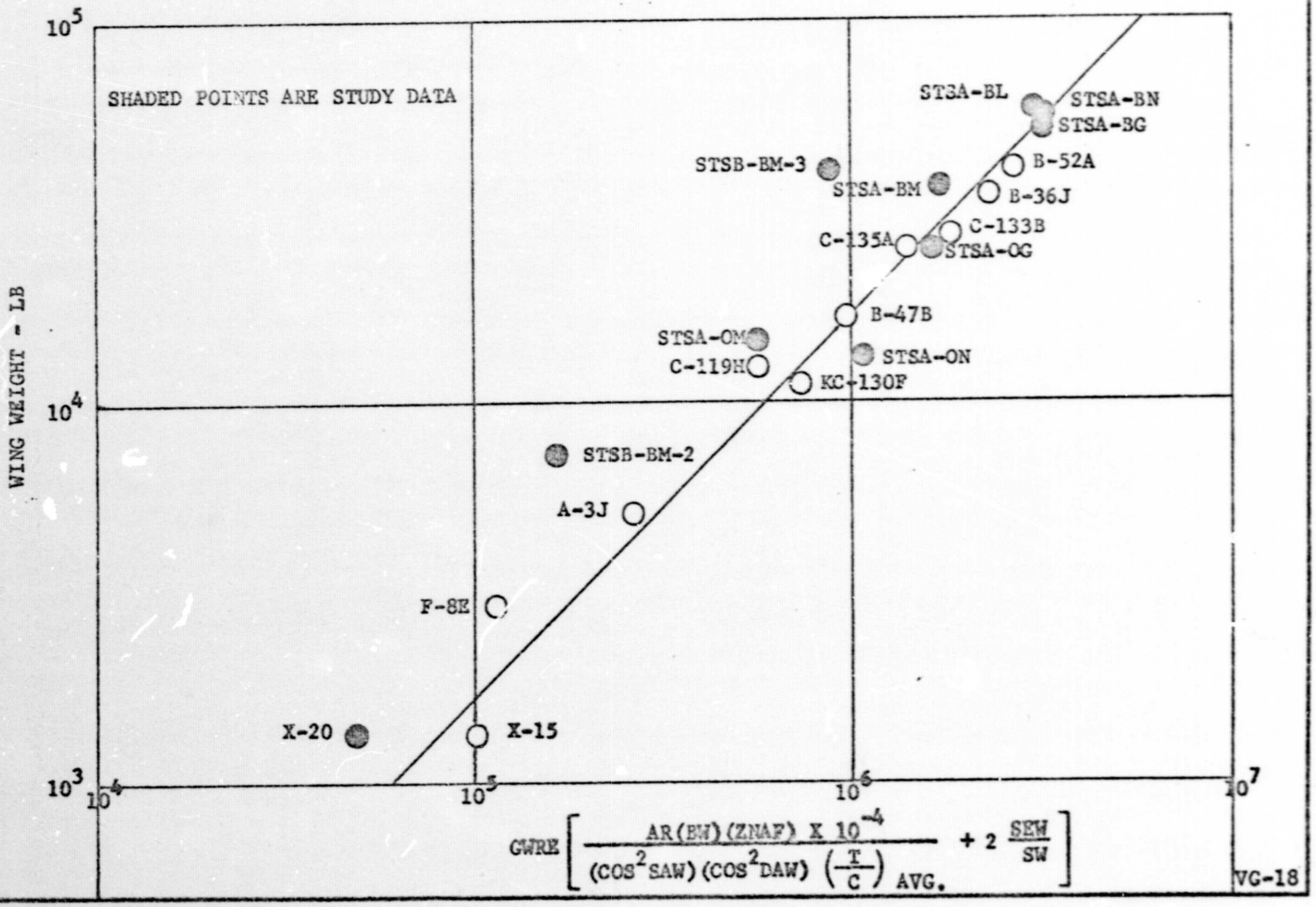
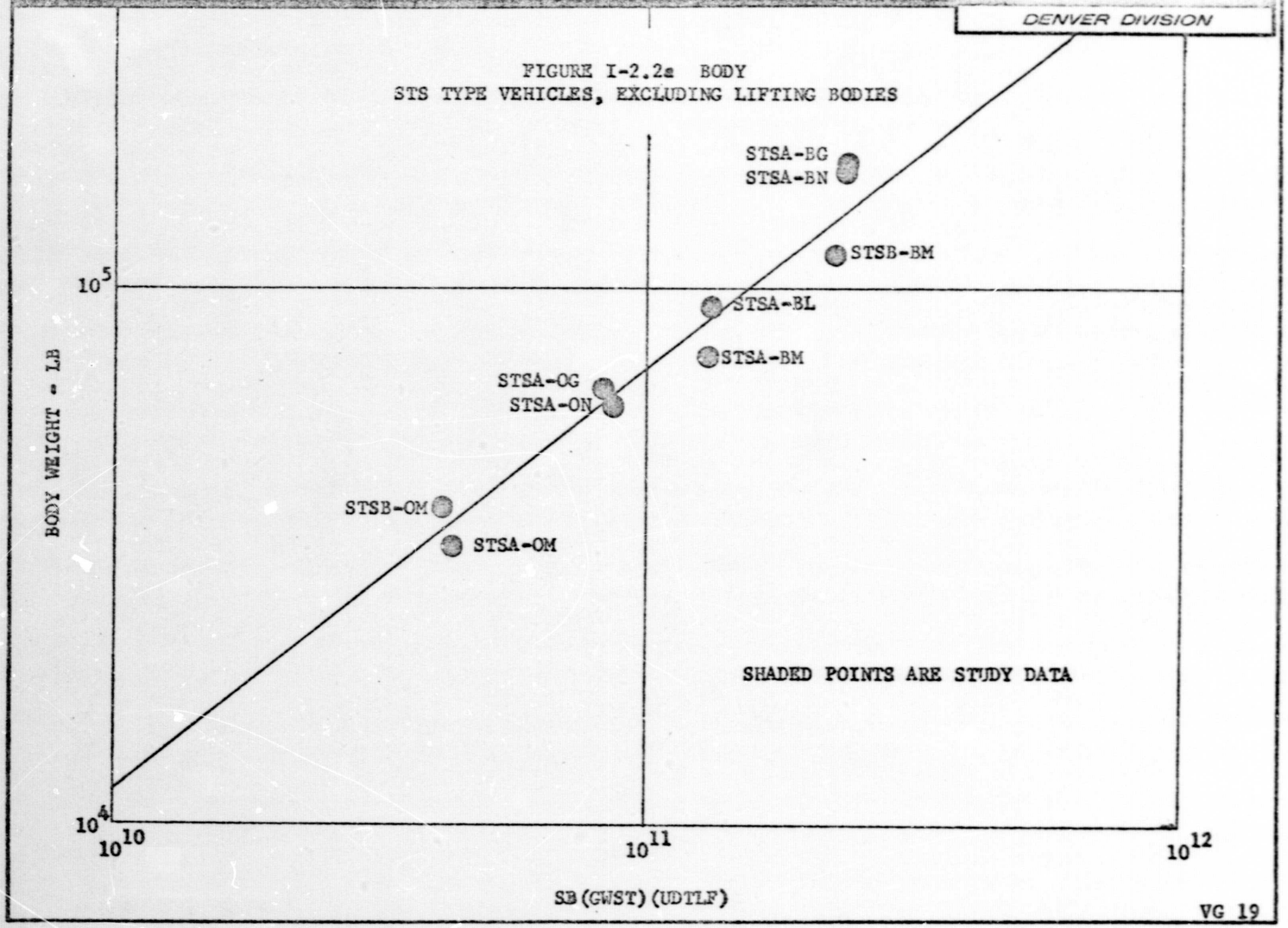


FIGURE I-2.2a BODY
STS TYPE VEHICLES, EXCLUDING LIFTING BODIES



GROUP ACCUMULATION WEIGHT ESTIMATION METHOD (I-2)

FIGURE I-2.4a LAUNCH, RECOVERY, AND DOCKING REENTRY VEHICLES

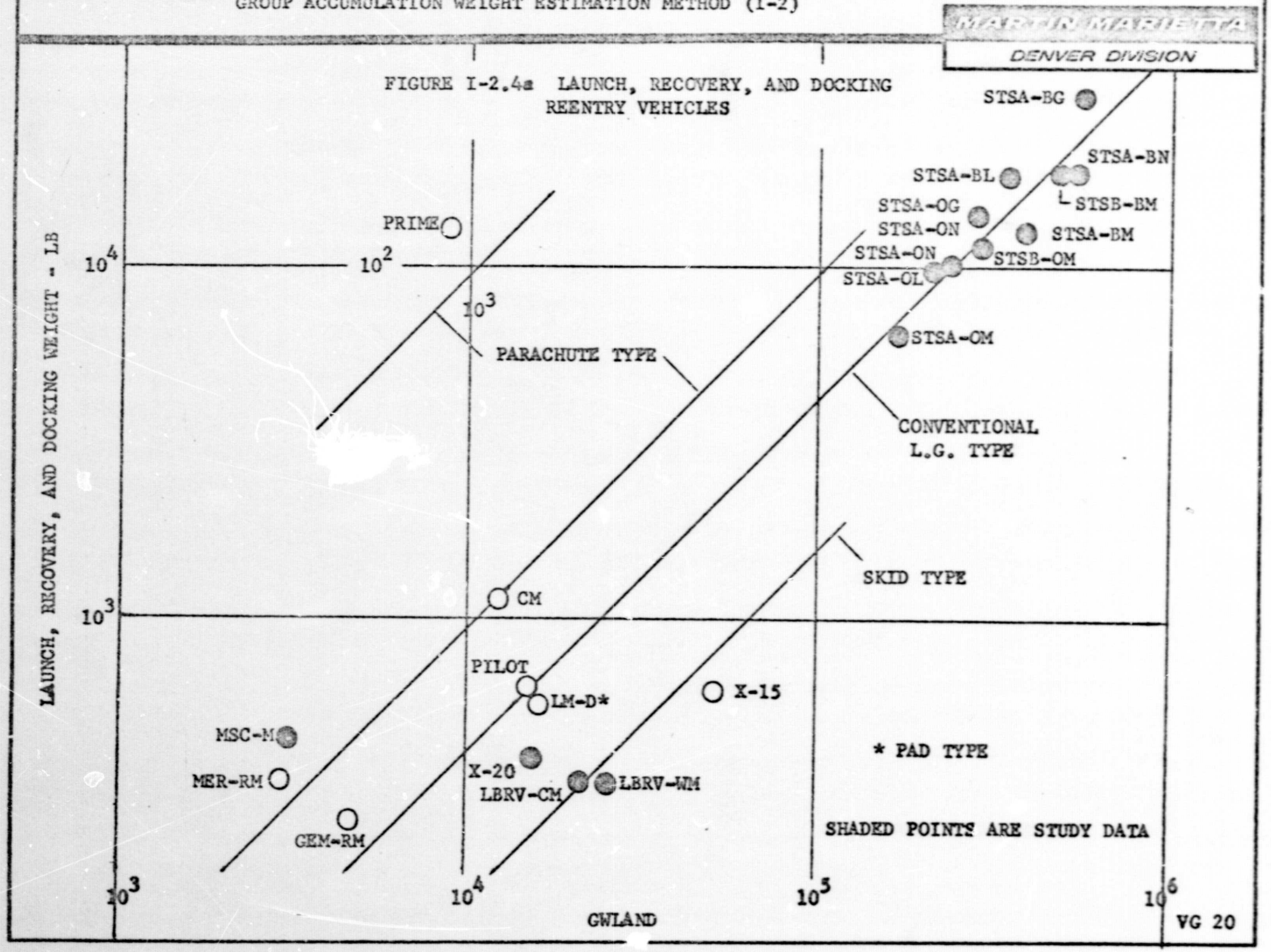
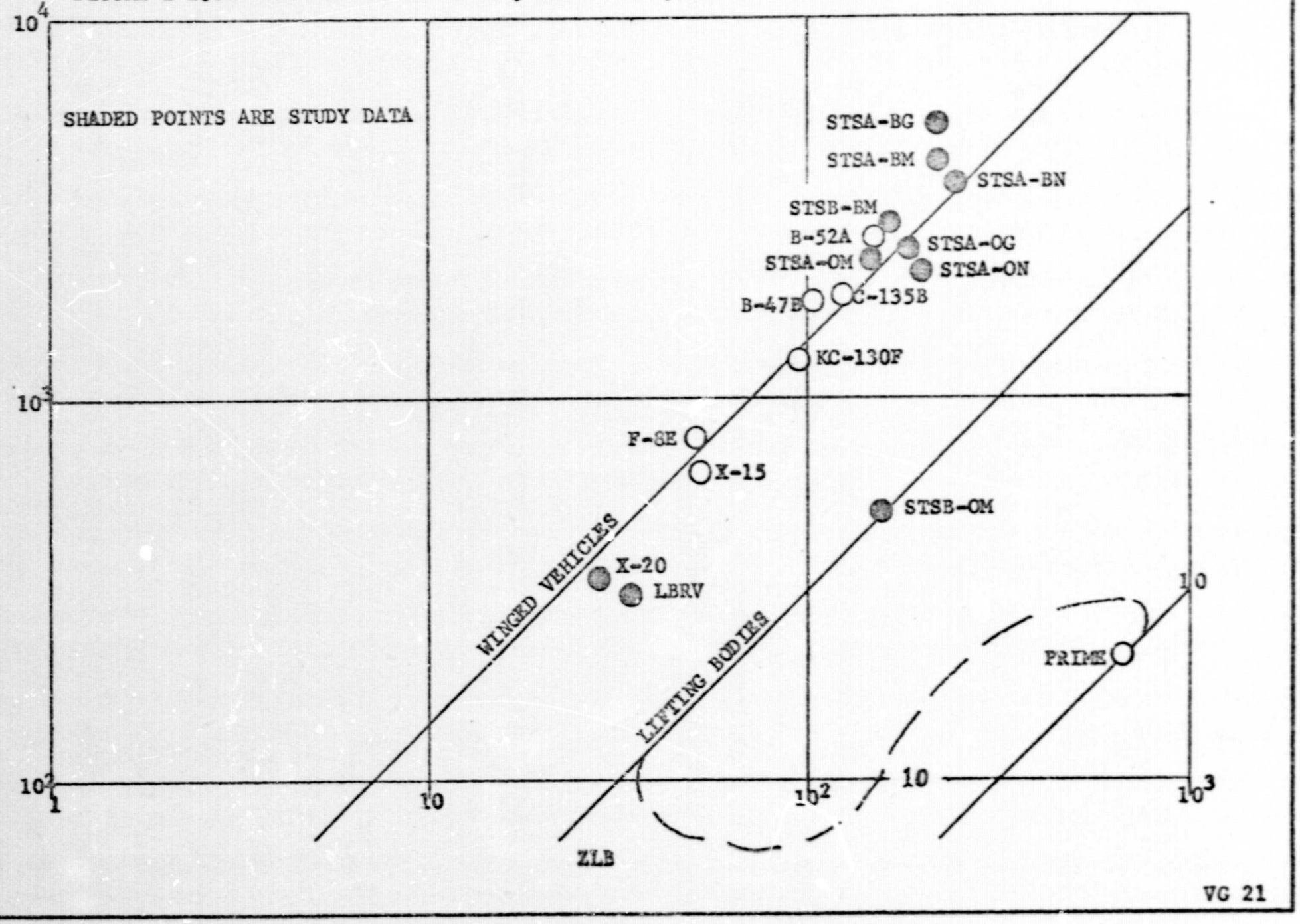


FIGURE I-2.6b ORIENTATION CONTROLS, SEPARATION, AND ULLAGE



PROCEDURE FOR UPDATING *

1. ADD NEW DATA TO THE FIGURES AND TABLES IN VOLUME I, SECTION 2

2. AMEND THE SLOPE AND/OR LOCATION OF THE TREND LINES ON THE FIGURES, AND THE STATEMENTS ON THE TABLES, IN VOLUME I, SECTION 2, AS THE NEW DATA MAY INDICATE

* PRESENTED IN THE SUPPLEMENTARY REPORT (PAGE 268)

COMPOSITION

- GENERAL PHILOSOPHY AND OBSERVATIONS

- WEIGHT GROWTH HISTORIES: APOLLO LM MERCURY GEMINI
  MOL/OV SKYLAB OWS PRIME
  TITAN I TITAN II TITAN III TITAN IIIM

- EQUATIONS FOR FORECASTING WEIGHT GROWTH:
  1. TREATING THE VEHICLE AS CONSISTING OF FOUR MAJOR SUBDIVISIONS:
     STRUCTURE, PROPULSION, EQUIPMENT, AND PROPELLANT
  2. TREATING THE VEHICLE AS A WHOLE

- DEFINITIONS AND VALUES OF THE TERMS IN THE EQUATIONS

GENERAL PHILOSOPHY AND OBSERVATIONS

- WEIGHT GROWTH = TOTAL WEIGHT CHANGE OVER A TIME INTERVAL
- WEIGHT GROWTH IS MEANINGFUL IN DESIGN PHASES C AND D ONLY
- WEIGHT GROWTH MAY BE GOOD OR BAD
- THE POINT DESIGN DETAIL WEIGHT ESTIMATION METHOD IS INTENDED TO INCLUDE AVERAGE WEIGHT GROWTH (IF DESIGN PARAMETERS REMAIN UNCHANGED, WEIGHT GROWTH SHOULD BE MINIMAL)
- BY NATURAL LAW, WEIGHT GROWTH WILL BE THAT ALLOWED BY THE MOST CRITICAL OF:
  - PROPELLANT WEIGHT/VEHICLE WEIGHT
  - TOTAL THRUST/VEHICLE WEIGHT
  - USABLE INTERNAL VOLUME

GENERAL PHILOSOPHY AND OBSERVATIONS - CONT'D

- WEIGHT GROWTH IS AFFECTED BY:
  - PRODUCT DEFINITION - DEGREE OF CLARITY AND SERIOUSNESS OF PURPOSE
  - WEIGHT ESTIMATION METHODS - QUALITY
  - PRELIMINARY DESIGN CONCEPTS - SOUNDNESS AND RELIABILITY
  - OPTIMISM - DEGREE INDUCED BY THE EVER-PRESENT COMPETITIVE SITUATION
  - DESIGN SCHEDULES - ADEQUACY
  - DESIGN BUDGETS - ADEQUACY
- WEIGHT GROWTH MAY BE CONTROLLED BY:
  - WEIGHT CONSCIOUSNESS AMONG ALL CONCERNED, WHEN SUFFICIENTLY CONVINCED OF THE TRUE CONSEQUENCES OF OVERWEIGHT
  - DESIGNING NO EXCESS USABLE VOLUME INTO THE VEHICLE
  - OFFERING MONETARY BONUS FOR UNDERWEIGHT, PENALTY FOR OVERWEIGHT
  - IMPLEMENTING A STRONG WEIGHT CONTROL OPERATION BY WEIGHT SPECIALISTS DURING THE ENTIRE DESIGN PERIOD

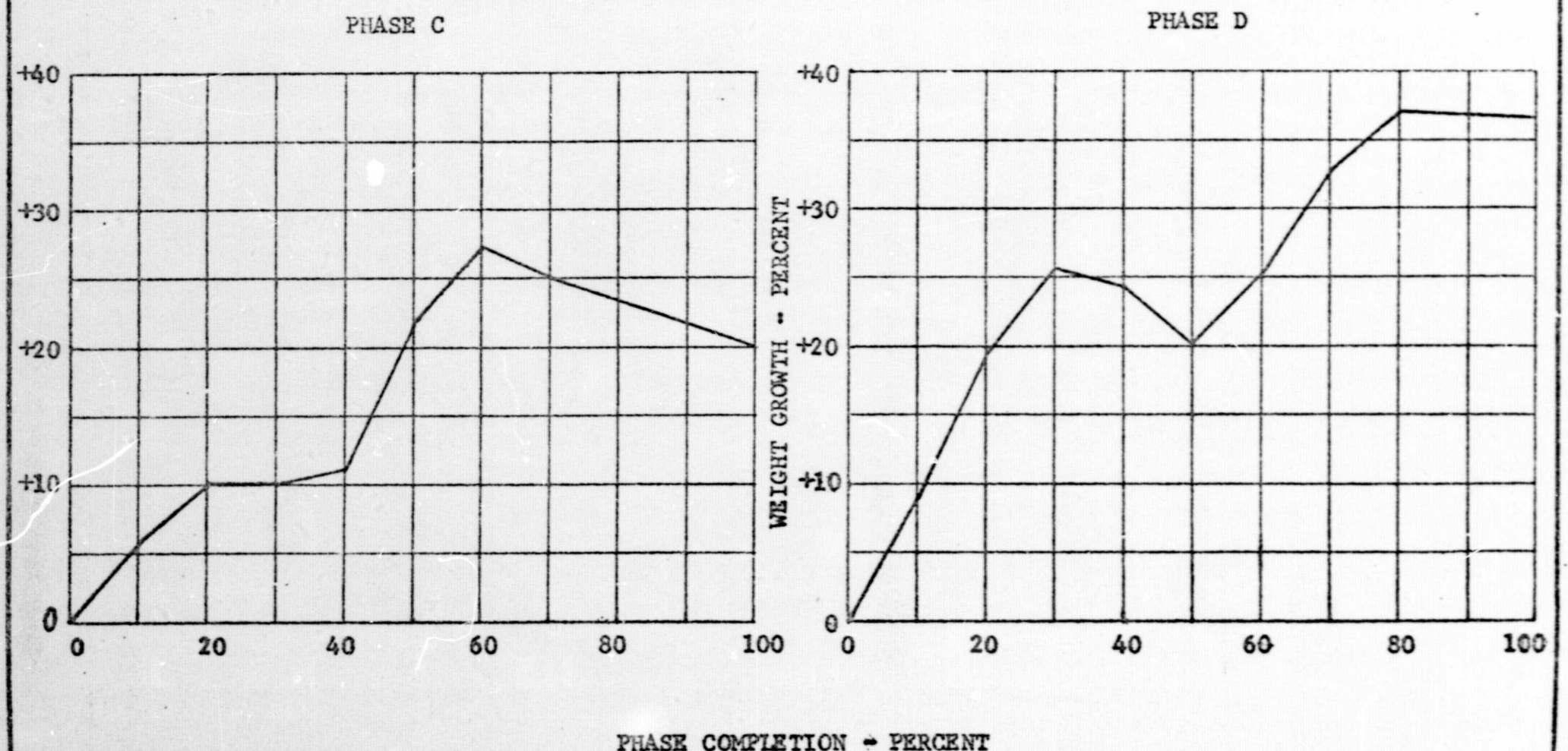
MARTIN MARIETTA
DENVER DIVISION

INDEX OF CHARTED WEIGHT GROWTH HISTORIES

	APOLLO	LM	MERCURY	GEMINI	PRIME	MOL/OV	MOL/LM	OWS	TITAN I	TITAN II	TITAN III	TITAN IIIM
PHASE C: (UNITS)												
TOTAL VEHICLE	X	X	X	X	X	X.						
STRUCTURE	X	X	X									
PROPULSION	X	X	X									
EQUIPMENT	X	X	X									
PROPELLANT	X	X	X									
PHASE D: (UNITS)												
TOTAL VEHICLE (WET)	X	X	X	X	X	X	X	X				
TOTAL VEHICLE (DRY)									X	X	X	X
STRUCTURE	X	X	X									
PROPULSION	X	X	X									
EQUIPMENT	X	X	X									
PROPELLANT	X	X	X									
PHASE C: (COMPOSITES)												
VEHICLE (MAX/AVG/MIN)	←											→
STRUCTURE (AVG)	←											→
PROPULSION (AVG)	←											→
EQUIPMENT (AVG)	←											→
PROPELLANT (AVG)	←											→
PHASE D: (COMPOSITES)												
VEHICLE (MAX/AVG/MIN)	←											→
VEHICLE (MAX/AVG/MIN)										←		→
STRUCTURE (AVG)	←											→
PROPULSION (AVG)	←											→
EQUIPMENT (AVG)	←											→
PROPELLANT (AVG)	←											→

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FIGURE I-3.11 Weight Growth
AVERAGE OF APOLLO, LM, AND MERCURY STRUCTURE



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EQUATIONS FOR FORECASTING WEIGHT GROWTH, DEFINITIONS AND GROWTH FACTOR VALUES

1. WGRØ = KS(WS) + KPS(WPS) + KEQ(WEQ) + KVP(WVP), or

2. WGRØ = KVEH(WVEH), where

KEQ = EQUIPMENT WEIGHT GROWTH FACTOR
= 0.0055 FOR EXPANDABLE BOOSTER STEPS DURING PHASE D
= 0.14 (+0.26) FOR SPACECRAFT DURING PHASE C
= 0.28 (+0.10) FOR SPACECRAFT DURING PHASE D
= 0.146 FOR UNCLUSTERED SPACE STATIONS DURING PHASE C
= 0.067 FOR UNCLUSTERED SPACE STATIONS DURING PHASE D
= 0.482 FOR CLUSTERED SPACE STATIONS DURING PHASE D

KPS = PROPULSION WEIGHT GROWTH FACTOR
= 0.0044 FOR EXPENDABLE BOOSTER STEPS DURING PHASE D
= 0.40 (± Q23) FOR SPACECRAFT DURING PHASE C
= 0.22 (± 0.08) FOR SPACECRAFT DURING PHASE D
= 0.031 FOR UNCLUSTERED SPACE STATIONS DURING PHASE C
= 0.010 FOR UNCLUSTERED SPACE STATIONS DURING PHASE D
= 0.072 FOR CLUSTERED SPACE STATIONS DURING PHASE D

ETC.

PROCEDURE FOR UPDATING*

1. ADD NEW DATA TO THE TABLES AND FIGURES IN VOLUME I, SECTION 3

2. AMEND THE WEIGHT GROWTH FACTOR VALUES LISTED IN VOLUME I, SECTION 3, AS THE NEW DATA MAY INDICATE

*PRESENTED IN THE SUPPLEMENTARY REPORT (PAGE 268)

SECTION I. POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD

SECTION 2 SPACE TRANSPORTATION SYSTEM SIZING PROGRAM

POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD (II-1)

MARTIN MARIETTA
DENVER DIVISION

PREMISE

TOTAL VEHICLE WEIGHT IS THE SUMMATION OF THE WEIGHTS OF MANY INDIVIDUAL ELEMENTS, EACH OF WHICH IS A FUNCTION OF ITS OWN PARTICULAR PARAMETERS

COMPOSITION

SERIES OF FUNCTIONALLY CODED WEIGHT EQUATIONS, DIVIDED INTO MAJOR FUNCTIONAL GROUPS

DEFINITIONS FOR THE TERMS IN THE EQUATIONS FOR EACH MAJOR FUNCTIONAL GROUP

COMPLETE LIST OF INPUT DEFINITIONS AND FACTOR VALUES FOR THE METHOD

INTENDED USAGE

WEIGHT ESTIMATION OF THIRD PHASE DESIGNS - MANUALLY OR BY COMPUTER

GENERATION OF DATA FOR USE IN THE SIZING PROGRAM

INPUTS

NUMEROUS DESIGN PARAMETERS

(E.G., DETAILED DATA OF INTERNAL AND EXTERNAL STRUCTURAL GEOMETRY, STRUCTURAL MATERIAL TYPES, PROPERTIES, AND MINIMUM GAGE LIMITATIONS, LOAD FACTORS, LANDING GEAR ARRANGEMENT, ENGINE TYPES, LOCATIONS, AND THRUST RATINGS, TANK SIZES AND SHAPES, PRESSURES, INPUT/OUTPUT POWER REQUIREMENTS OF ELECTRO-MECHANICAL EQUIPMENT, TYPES AND PROPERTIES OF THE MAIN PROPELLANT AND OTHER LIQUIDS AND GASES IN THE VEHICLE, MAXIMUM REENTRY VELOCITY, MISSION DURATION, CREW QUANTITY, WEIGHT OF CARGO AND PASSENGERS)

EQUATIONS FOR 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

EQUATION FOR WING BENDING MATERIAL WEIGHT (WING TYPE 1)

1.1.1.1 BENDING MATERIAL (SPANWISE)

$$WBMW1 = BMPW1(ZN\emptyset FW1), \text{ where}$$

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

$$WSRW = DENSWM/UTSWM,$$

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

$$ZN\emptyset FW1 = CN\emptyset FW1\ (3.08)\left\{\left[\frac{SEW1}{\cos DAW1} + CCTW1(SW1-SEW1)\right]\cdot(SEW1-SSSW1-SAIL1-SELW1-\tfrac{1}{2}STEF1-SLEF1-\tfrac{1}{2}SSB1)\right\}^{1/3} \div \left\{SEW1\left[BMPW1+CWTF1(TFPP1)\right]\right\}^{1/3}.$$

EQUATION FOR SKIN AND FRAMES WEIGHT OF BODY PRESSURE COMPARTMENT NO. 1

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 (DENSEM), whichever is

larger, where

WSRB = DENSEM/UTSEM, and

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

EQUATION FOR MAIN PROPELLANT WEIGHT

$$WFUEL1 + W\emptyset XID1 = \sum_{I=1}^{I=8} ZNPT(I) \cdot V\emptyset LT(I) \cdot DENP(I) \cdot (1. - CULL)$$

EXAMPLE OF INPUT LIST

GROUP 1.3 VERTICAL TAIL INPUTS

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

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EXAMPLE OR INPUT LIST - Cont'd

Variable	Definition	Units
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
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
CWRE	1	1.1
HB	2	2.
ZLHT	1	1.2

SAMPLE PROBLEM

INPUT

(GROUP) $LIST1

(0) ISIZE=0,

(1.1) BBW1=30., BW1=146., CABEW1=1., CAIL1=1., CCTW1=1., CLGP=1., CNØFW1=1., CRIBW1=1., CRW1=29.7, CSSW1=1., CSW1=25.6, CTEF1=1., CTEW1=9.9, DAW1=7., DENSWM=.162, GWRE=235000., SAIL1=274., SAW1=11., SEW1=2010., SSSW1=470.72, STEF1=530., SW1=2890., TSW1=3.6, TTEW1=1.2, TYPEW=1., UTSWM=1.22E5, ENAEW1=4., ENAF=3.75,

(1.2) BBHT=30., BHT=89.2. CCTHT=1., CELHT=1., CNØFHT=2.49, CRIBHT=1., CSHT=30.2, CTHT=9.25, CWSSHT=1, DAHT=0., DENSHT=.162, SAHT=12., SEHT=1170., SELHT=585., SHT=2070., SSSHT=351., TSHT=4.2, TTHT=1.1, UTSHTM=1.22E5, ZLHT=74.75,

(1.3) BVT=29.2, CNØFVT=1., CRBAL=.027, CRIBVT=1., CRVT=30.5, CTVT=11.1, CWSSVT=1., DAVT=90., DENSVT=.162, SAVT=26., SRUD=213., SSSVT=216.975, SVT=607.5, TRVT=1.83, TTVT=.67, UTSVTM=1.22E5, ZLVEH=208.3, ZLVT=75.75, ZNVT=1.,

$END
$LIST2

(2) BB=30., CBASF=.17, CBSV=2.5, CLGPB=1., CLRPB=1., CSSB=1., CSSV=1., DENSBM=.1, GWST=8.6E5, GWST1=3990.E3, HB=21.7, SB=17111., UTSBM=75.E3, VB=92983., WBAC=2610.E3, ZLB=202., ZLST=208.3, ZNB=1.,

(3) CTPBH=7.5, CTPGB=2.6, CTPHT=2.6, CTPVT=.8, CTPW=2.8, VMAX=25.E3,

(4) CATØP=1., CMLGB=.0065, CMLGC=.53, CMLGF=1., CMLGS=1., CNLGC=1., CNLGF=1., CNLGS=1., CWHAN=2.E5, GWLAND=2.5E5, WRAID=20., WSP4=364., ZLBC=97.2, ZLGCG=10., ZLMLGE=9.6, ZLNLGZ=9.2, ZNLD=4.02, ZNMLG=2., ZNNLG=2.,
$END

ETC.

SAMPLE PROBLEM - CONT'D

PROGRAM

FOR

WEIGHT ESTIMATING AND FORECASTING

OF

MANNED SPACE SYSTEMS

DURING CONCEPTUAL DESIGN

MODEL

NAA ORBITER HIGH CROSS RANGE

DATE 26 OCT 1970

BY WILLIAM AHL

SAMPLE PROBLEM - CONT'D

WEIGHT SUMMARY

DATE 26 OCT 1970

		WEIGHT (LB)
1.0	AERODYNAMIC SURFACES	34333
1.1	WING	22294
1.1.1	PRIMARY STRUCTURE	14149
1.1.1.1	BENDING MATERIAL	12606
1.1.1.1.1	EXPOSED	7021
1.1.1.1.2	CARRY THRU	5585
1.1.1.2	SHEAR MATERIAL	742
1.1.1.2.1	EXPOSED	572
1.1.1.2.2	CARRY THRU	170
1.1.1.3	RIBS	801
1.1.2	SECONDARY STRUCTURE	2419
1.1.3	PROVISION FOR VARIABLE SWEEP	0
1.1.4	PROVISION FOR TIP FINS	0
1.1.5	PROVISION FOR LANDING GEAR	1507
1.1.6	PROVISION FOR FUEL TANKAGE	0
1.1.7	PROVISION FOR AIR BREATHING ENGINES	190
1.1.8	CONTROL SURFACES	4028
1.1.8.1	AILERONS	1518
1.1.8.2	ELEVONS	0
1.1.8.3	SPOILERS	0
1.1.8.4	TRAILING EDGE FLAPS	2510
1.1.8.5	LEADING EDGE FLAPS	0
1.1.8.6	LEADING EDGE SLATS	0
1.1.8.7	SPEED BRAKES	0
1.1.18	SPECIAL FEATURES	0
1.1.19	CONTINGENCY	0
1.1.20	GROWTH	0

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SAMPLE PROBLEM -(CONT'D)

5.0	MAIN PROPULSION		73874
5.1	LIQUID ROCKET ENGINES		12744
5.1.1	ENGINES AND ACCESSORIES		11988
5.1.2	GIMBALS		756
5.2	SOLID PROPELLANT PROPULSION (INERTS)		0
5.6	AIR BREATHING ENGINES AND ACCESSORIES		22919
5.6.1	ENGINES		17048
5.6.2	STRUCTURAL PROVISION		5476
5.6.2.1	MOUNTS		350
5.6.2.2	PYLONS		0
5.6.2.3	NACELLES		3456
5.6.2.4	FIREWALLS		304
5.6.2.5	AIR INDUCTION		1139
5.6.2.6	AIR INDUCTION CONTROLS		228
5.6.3	ACCESSORIES		395
5.6.3.1	CONTROLS		273
5.6.3.2	EXHAUSTS		122
5.6.3.3	STARTERS		0
5.6.3.4	WATER INJECTION SYSTEM		0
5.6.3.5	OIL SYSTEM		0
5.7	PURGE SYSTEM (CHILLDOWN)		690
5.8	FUEL CONTAINERS		19445
5.8.1	NON-INTEGRAL TANK	NO. 2	5502
5.8.1.1	STRUCTURE		4122
5.8.1.1.1	FORWARD DOME		0
5.8.1.1.2	BARREL		3117
5.8.1.1.3	AFT DOME		1004
5.8.1.2	BAFFLING AND ANTIVORTEX WEBS		73
5.8.1.6	SUPPORTS		328
5.8.1.7	INSULATION		980
5.8.1.9	CONDUIT		0

SAMPLE PROBLEM - CONT'D

11.0	COMMUNICATION	522			
11.1	INTERCOMMUNICATION		0		
11.2	NEAR EARTH COMMUNICATION		0		
11.2.1	TRANSCEIVERS			0	
11.2.2	ANTENNAS			0	
11.3	DEEP SPACE COMMUNICATION		0		
11.3.1	TRANSCEIVERS, AMPLIFIERS			0	
11.3.2	ANTENNAS			0	
11.4	TV SYSTEM		0		
11.4.1	CAMERA			0	
11.4.2	MONITOR			0	
11.4.3	REMOTE CAMERA STATION			0	
11.5	TRACKING BEACON		0		
11.9	COMMAND SYSTEM		0		
11.9.1	RECEIVERS			0	
11.9.2	PROCESSORS			0	
11.10	RANGING		0		
11.18	SPECIAL FEATURES		0		
11.19	CONTINGENCY		0		
11.20	GROWTH		0		
12.0	ENVIRONMENTAL CONTROL SYSTEM	748			
12.1	EQUIPMENT	73			
12.2	PERSONNEL	432			
12.2.1	ATMOSPHERE		26		
12.2.1.1	TANKS			0	
12.2.1.2	LINES, VALVES, ETC.			26	
12.2.2	PRESSURIZATION		304		
12.2.3	TEMPERATURE		70		
12.2.3.1	ATM. CONDITIONING AND DISTRIBUTION			14	
12.2.3.2	INSULATION (INTERNAL TO PRESS COMPT)			56	
12.2.5	ODOR REMOVAL		32		
12.3	COOLANT SYSTEM (EXCLUDING FLUIDS)	242			
12.18	SPECIAL FEATURES		0		
12.19	CONTINGENCY		0		
12.20	GROWTH		0		

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POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD (II-1)

MARTIN MARIETTA
DENVER DIVISION

SAMPLE PROBLEM - (CONT'D)

23.0	INFLIGHT LOSSES		11673
2331	VENTED PRESSURE GASES - FUEL SYSTEM		0
23.2	VENTED PRESSURE GASES - OXID SYSTEM		0
23.3	FUEL - RCS		603
23.4	OXID - RCS		2997
23.5	FUEL - ELECTRICAL POWER (FUEL CELL)		265
23.6	OXID - ELECTRICAL POWER (FUEL CELL)		1560
23.7	SERVICE ITEMS		2311
23.7.3	PURGE SYSTEM GASES		0
23.7.4	PNEUMATIC SYSTEM GASES		0
23.7.5	FROST		0
23.7.7	SEPARATION SYSTEM PROPELLANTS		2311
23.7.10	COOLANT FLUIDS		0
23.8	GAS GENERATOR PROPELLANTS - PRIME POWER		3936
23.18	SPECIAL FEATURES		0
25.0	FULL THRUST PROPELLANTS		611319
25.1	FUEL - MAIN PROPULSION		91414
25.2	OXID - MAIN PROPULSION		519254
25.4	FUEL - AUXILIARY PROPULSION		652
25.5	SOLID PROP. - AUX. PROPULSION		0
25.18	SPECIAL FEATURES		0
	TAKEOFF	922033	
	BURNOUT	311365	
	REENTRY	299926	
	LANDING	299041	
	DRY	292754	
	EMPTY	242153	

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SAMPLE PROBLEM - CONT'D

INTEGRAL TANK AREAS		SQ FT	
BARREL	FWD BODY		0
BARREL	AFT BODY		0
FORWARD DOME	FWD BODY		0
FORWARD DOME	AFT BODY		0
AFT DOME	FWD BODY		0
AFT DOME	AFT BODY		0
UNPRESSURIZED BODY AREA		SQ FT	17111
VOLUME OF FWD PROPELLANT TANK		CU FT	0
VOLUME OF AFT PROPELLANT TANK		CU FT	0
VOLUME OF BLADDER TANK		CU FT	0
INDUCED ENVIRONMENT PROTECTION			
WING UNIT WEIGHT		LB/SQ FT	1.7
HORIZONTAL TAIL UNIT WEIGHT		LB/SQ FT	1.6
VERTICAL TAIL UNIT WEIGHT		LB/SQ FT	.5
BODY UNIT WEIGHT		LB/SQ FT	1.7
MAIN PROPULSION			
TANKS (NON-INTERGRAL)	NO. 1		
WETTED AREA - BARREL		SQ FT	778
FWD DOME		SQ FT	249
AFT DOME		SQ FT	274
VOLUME		CU FT	3638
PRESSURE - BARREL		PSIG	141
FWD DOME		PSIG	136
AFT DOME		PSIG	148
WEIGHT/STRENGTH RATIO		1/IN	1.33E-06
LOADED FUEL		LB	92547
LOADED OXIDIZER		LB	525210
LOADED AIRBREATHING FUEL		LB	652
CONTINGENCY (TOTAL)		LB	0
GROWTH (TOTAL)		LB	0

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SAMPLE PROBLEM - CONT'D

SPECIAL OUTPUT			
WING			
UNIT WEIGHT		LB/SQ FT	7.7
ULT. LOADING	TYPE 1	LB/SQ FT	375.0
ULT. LOADING	TYPE 2	LB/SQ FT	0.
ULT. LOADING	TYPE 3	LB/SQ FT	0.
NON-OPTIMUM FACTOR	TYPE 1		1.8
NON-OPTIMUM FACTOR	TYPE 2		0.
NON-OPTIMUM FACTOR	TYPE 3		0.
WEIGHT/STRENGTH RATIO		1/IN	1.33E-06
HORIZONTAL TAIL			
UNIT WEIGHT		LB/SQ FT	3.3
ULT. LOADING		LB/SQ FT	583.5
NON-OPTIMUM FACTOR			1.5
WEIGHT/STRENGTH RATIO		1/IN	1.33E-06
VERTICAL TAIL			
UNIT WEIGHT		LB/SQ FT	8.7
NON-OPTIMUM FACTOR			1.7
WEIGHT/STRENGTH RATIO		1/IN	1.33E-06
BODY			
UNIT WEIGHT		LB/SQ FT	4.0
WEIGHT/STRENGTH RATIO	BODY	1/IN	1.33E-06
WEIGHT/STRENGTH RATIO	TANK 1	1/IN	0.
WEIGHT/STRENGTH RATIO	TANK 2	1/IN	0.
WETTED AREA		SQ FT	
COMPARTMENT 1			0
COMPARTMENT 2			0
FORWARD BULKHEAD	COMPT. 1		0
FORWARD BULKHEAD	COMPT. 2		0
INTERMEDIATE BLKD	COMPT. 1		0
INTERMEDIATE BLKD	COMPT. 2		0
AFT BULKHEAD	COMPT. 1		0
AFT BULKHEAD	COMPT. 2		0

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PROCEDURE FOR UPDATING*

1. ADD NEW SAMPLE DATA TO TABLES 1-1 THROUGH 25-1 IN THE SUPPLEMENTARY REPORT, SECTION 2
2. ESTIMATE WEIGHTS FOR THE NEW SAMPLES, USING THE POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD
3. COMPARE THE ESTIMATED WEIGHTS WITH THE REPORTED OR ACTUAL WEIGHTS OF THE NEW SAMPLES, AT THE LOWEST POSSIBLE LEVEL OF DETAIL (WEIGHT GENERATION), AND ADD POINTS TO FIGURES 1-1 THROUGH 17-1 IN THE SUPPLEMENTARY REPORT, SECTION 2, AS APPLICABLE.
4. AMEND THE VARIOUS WEIGHT FACTORS IN THE INPUT LISTS IN VOLUME II, SECTION 1, AS THE NEW DATA MAY INDICATE.

*PRESENTED IN THE SUPPLEMENTARY REPORT (PAGE 268)

TABLE 1-2*

HORIZONTAL TAIL

WEIGHTS AND PARAMETERS

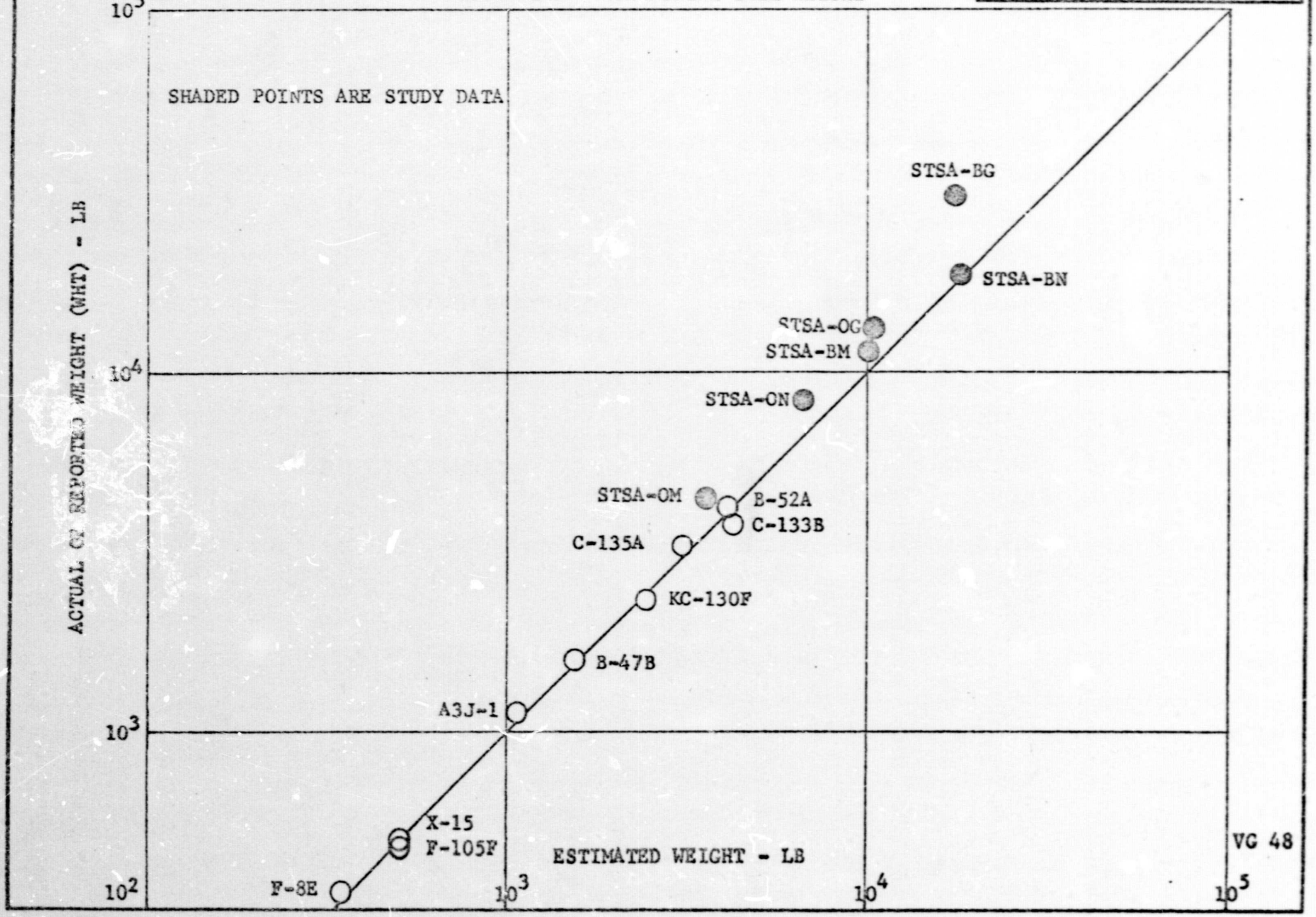
REPORTED OR ACTUAL WEIGHTS		CHT
1.2	WHT	CRIBHT
1.2.1	WPSHT	CSHT
1.2.1.1	WBMHT	CTHT
1.2.1.2	WSMHT	CWSSHT
1.2.1.3	WRHT	DAHT
1.2.2	WSSHT	DENSHT
1.2.3	WELHT	GWRE
1.2.18	WSPHT	SAHT
1.2.19	WCØNHT	SEHT
1.2.20	WGRØHT	SELHT
ESTIMATED WEIGHTS		SHT
1.2	WHT	SSSHT
PARAMETERS		TSHT
	BBHT	TTHT
	BHT	UTSHTM
	CCØNHT	WSPHT
	CCTHT	ZLHT
	CELHT	ZLVEH
	CGRØHT	

*PRESENTED IN THE SUPPLEMENTARY REPORT (SECTION 2)

POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD (II-1)

CONVAIR AEROSPACE
DENVER DIVISION

FIGURE 1-2 HORIZONTAL TAIL WEIGHT



SPACE TRANSPORTATION SYSTEM SIZING PROGRAM (II-2)

MARTIN MARIETTA
DENVER DIVISION

PREMISE

- VEHICLE TO BE TESTED IS A LIQUID ROCKET PROPELLED TYPE
- VEHICLE TO BE TESTED IS ACCEPTABLY SIZED FOR THE INPUT CONDITION
- VEHICLE TO BE TESTED IS RESIZED ONLY FOR COMPUTED CHANGES OF PROPELLANT VOLUME RESULTING FROM THE FLIGHT PERFORMANCE CHECK, AND FOR ARBITRARY VOLUME CHANGES FOR THE PAYLOAD
- VEHICLE TO BE TESTED IS RESIZED WITHIN $\pm$ 10% OF THE INPUT CONDITION IF THE INPUT CONDITION IS TO BE CONSIDERED A REASONABLE MODEL
- VEHICLE TO BE TESTED RETAINS THE INPUT CONDITIONS OF THE FIXED WEIGHTS, AND THE UNIT WEIGHTS AND UNIT LOADS OF THE VARIABLE WEIGHTS

COMPOSITION*

- COMPUTERIZED SERIES OF ITERATIVE EQUATIONS
- COMPLETE LIST OF INPUT DEFINITIONS FOR THE PROGRAM

*REFER TO THE COMPUTER PROGRAM MANUAL, MSC-01260, FOR DETAILS

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SPACE TRANSPORTATION SYSTEM SIZING PROGRAM (XI-2)

MARTIN MARIETTA
DENVER DIVISION

INTENDED USAGE

- TO CHECK THE VALIDITY OF A POINT DESIGN WEIGHT AFTER THE REQUIRED PROPULSIVE CAPABILITY OF THE VEHICLE HAS BEEN SATISFIED
- TO DETERMINE THE EFFECTS ON A POINT DESIGN WEIGHT CAUSED BY CHANGES IN PROPULSIVE CAPABILITY OR PAYLOAD VOLUME OF A VEHICLE

INPUTS*

- WHEN OPERATED IN SERIES WITH THE POINT DESIGN PROGRAM:

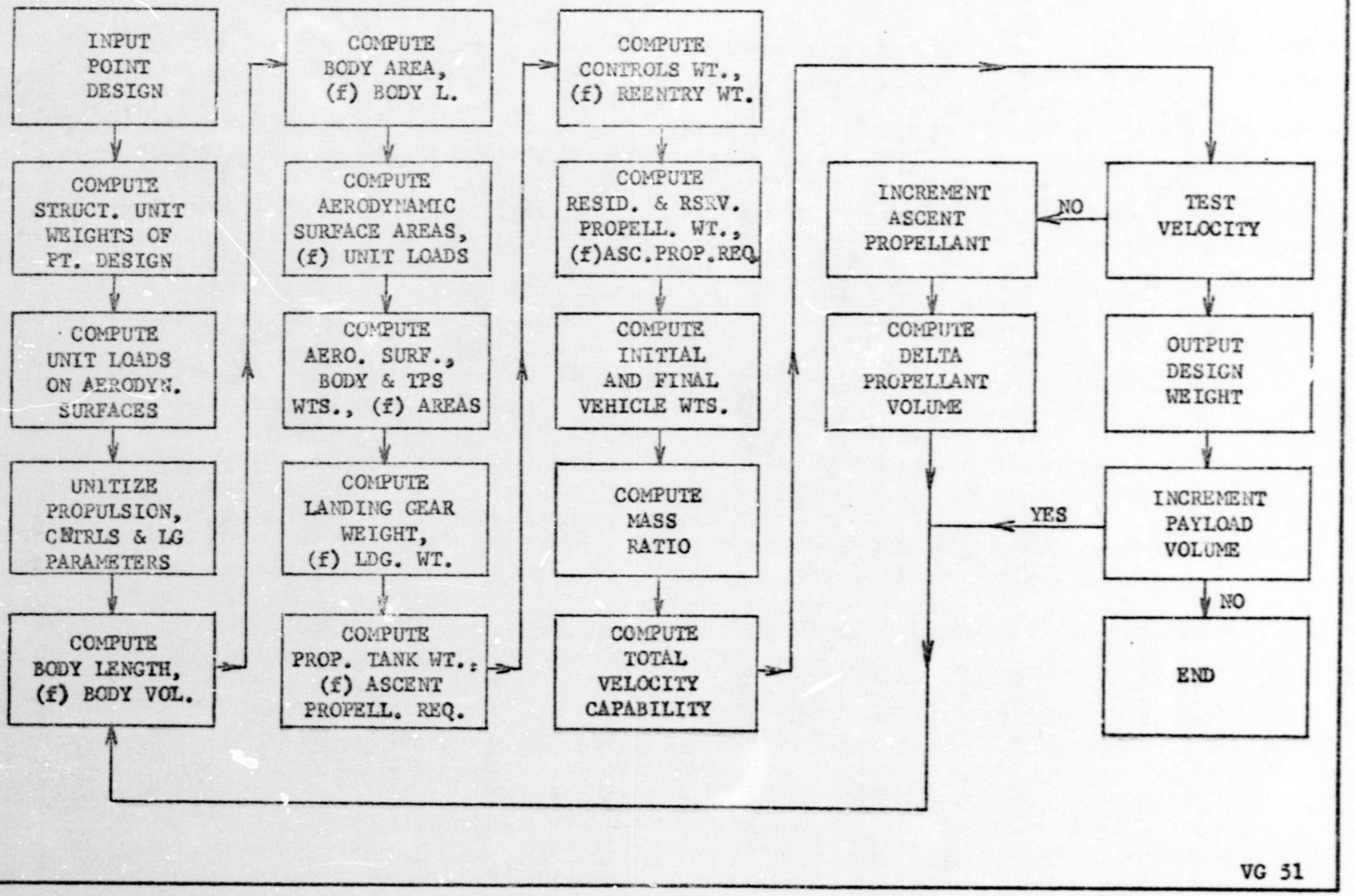
  STAGE IDENTIFICATION
  ENGINE VACUUM SPECIFIC IMPULSE
  CHANGE IN PAYLOAD VOLUME
  STAGE TOTAL DELTA VELOCITY

- WHEN OPERATED INDEPENDENTLY OF THE POINT DESIGN PROGRAM:

  THE FOREMENTIONED DATA PLUS APPROXIMATELY 100 DATA AVAILABLE FROM ANY INDEPENDENT POINT DESIGN WEIGHT ASSESSMENT

*REFER TO THE COMPUTER PROGRAM MANUAL, MSC-01260, FOR DETAILS

FIGURE II-2. SIZING ROUTINE FLOW DIAGRAM



MARTIN MARIETTA
DENVER DIVISION

SAMPLE PROBLEM*

INPUT

```
(GROUP)$LIST1
  (0)  ISIZE=1., KN=20, STØPT=2., VISP=460., VPLDEL=2000., VREQ=16500., VTØL=5.,
       $END
```

OUTPUT

SIZING WEIGHT SUMMARY

AERODYNAMIC SURFACES
- WING
- HORIZONTAL TAIL
- VERTICAL TAIL

BODY

INDUCED ENVIRONMENT PROTECTION

LAUNCH, RECOVERY, AND DOCKING

MAIN PROPULSION

ORIENTATION CONTROLS

PRIME POWER SOURCE

POWER CONVERSION AND DISTRIBUTION

GUIDANCE AND NAVIGATION

INSTRUMENTATION

COMMUNICATION

ENVIRONMENTAL CONTROL SYSTEM

PERSONNEL PROVISIONS

CREW STATION CONTROLS AND PANELS

PERSONNEL

CARGO

BALLAST

RESIDUAL PROPELLANT AND SERVICE ITEMS

RESERVE PROPELLANT AND SERVICE ITEMS

INFLIGHT LOSSES

THRUST DECAY PROPELLANT

FULL THRUST PROPELLANT

THRUST BUILDUP PROPELLANT

TAKEOFF

BURNOUT

REENTRY

LANDING

DRY

EMPTY

* PRESENTED IN THE COMPUTER PROGRAM MANUAL

SAMPLE PROBLEM*

OUTPUT - CONT'D
DESIGN DATA SUMMARY

AERODYNAMIC SURFACES	
WING AREA	SQ FT
WING UNIT WEIGHT	LB/SQ FT
HORIZONTAL TAIL AREA	SQ FT
HORIZONTAL TAIL UNIT WEIGHT	LB/SQ FT
VERTICAL TAIL AREA	SQ FT
VERTICAL TAIL UNIT WEIGHT	LB/SQ FT
BODY	
WETTED AREA	SQ FT
UNIT WEIGHT	LB/SQ FT
STRUCTURAL LENGTH	FT
INTERNAL VOLUME	CU FT
PROPULSION PARAMETERS	
THRUST/WEIGHT AT START	
THRUST/WEIGHT AT BURNOUT	
TOTAL LOADED PROPELLANT	LB
TOTAL THRUST	LB
PERFORMANCE	
VELOCITY (INCLUDING LOSSES)	FPS
SPECIFIC IMPULSE (VACUUM)	SEC
STAGE MASS RATIO	

*PRESENTED IN THE COMPUTER PROGRAM MANUAL

SECTION 1. SUBSTANTIATING DATA FOR VOLUME I, SECTION 1

SECTION 2. SUBSTANTIATING DATA FOR VOLUME II, SECTION 1

SECTION 3. SUGGESTED UPDATING PROCEDURES

SECTION 1. SUBSTANTIATING DATA FOR VOLUME I, SECTION 1

- EQUATION RATIONALE FOR THE PROPORTIONALITY WEIGHT ESTIMATION METHOD

- DATA TABULATION OF 44 VEHICLE SAMPLES FOR SUBSTANTIATING THE VALUES OF THE PROPORTIONALITY WEIGHT FACTORS

SECTION 2. SUBSTANTIATING DATA FOR VOLUME II, SECTION 1

- RATIONALE FOR EQUATIONS USED IN THE POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD
  - BENDING MATERIAL - WING, HORIZONTAL AND VERTICAL TAILS
  - SHEAR MATERIAL - WING, HORIZONTAL AND VERTICAL TAILS
  - NON-OPTIMUM FACTOR FOR PRIMARY STRUCTURE WEIGHT - WING, HORIZONTAL AND VERTICAL TAILS
  - VARIABLE SWEEP PROVISION - WING
  - TIP FINS PROVISION - WING
  - TEE-TAIL PROVISION - VERTICAL TAIL
  - SKIN AND FRAMES - BODY PRESSURE COMPARTMENTS, INTEGRAL AND NON-INTEGRAL TANKS
  - BULKHEADS - BODY PRESSURE COMPARTMENTS, INTEGRAL AND NON-INTEGRAL TANKS
  - SURFACE AREA, ENCLOSED VOLUME - BODY PRESSURE COMPARTMENTS, INTEGRAL AND NON-INTEGRAL TANKS
  - SECONDARY SOLID PROPULSION SYSTEM WEIGHT (DEORBIT, ABORT, SEPARATION)
- DATA TABULATION FOR ALL MAJOR VEHICLE SUBSYSTEMS - REPORTED OR ACTUAL WEIGHTS, AND ESTIMATED WEIGHTS COMPUTED BY THE POINT DESIGN METHOD
- GRAPHS OF REPORTED OR ACTUAL WEIGHTS VS. POINT DESIGN METHOD ESTIMATED WEIGHTS OF MOST OF THE MAJOR VEHICLE SUBSYSTEMS (BALLAST, GUIDANCE AND NAVIGATION, AND PROPELLANTS ARE EXCEPTED)

SECTION 3. SUGGESTED UPDATING PROCEDURES

- FOR THE PROPORTIONALITY WEIGHT ESTIMATION METHOD
- FOR THE GROUP ACCUMULATION WEIGHT ESTIMATION METHOD
- FOR THE WEIGHT GROWTH DATA
- FOR THE POINT DESIGN DETAILED WEIGHT ESTIMATION METHOD

RECAP OF HANDBOOK

MARTIN MARIETTA
DENVER DIVISION

VOLUME I (110 PAGES)

SECTION 1 PROPORTIONALITY METHOD, 1 EQUATION, 24 INPUTS (MAX.)

SECTION 2 GROUP ACCUMULATION METHOD, GRAPHS, 48 INPUTS (MAX.), CODE INDEX OF SAMPLES

SECTION 3 WEIGHT GROWTH DATA, 2 FORECASTING EQUATIONS, 20 INPUTS (MAX.), GROWTH HISTORIES OF 11 SAMPLES, GENERAL OBSERVATIONS

VOLUME II (216 PAGES)

SECTION 1 POINT DESIGN METHOD, APPROXIMATELY 500 EQUATIONS, APPROXIMATELY 900 TO 1550 INPUTS (MAX.), 440 INPUTS TYPICAL FOR STS, 120 INPUTS TYPICAL FOR SPACE STATION

SECTION 2 SPACE TRANSPORTATION SYSTEM SIZING PROGRAM. BRIEF DESCRIPTION, APPROXIMATELY 140 EQUATIONS, 8 INPUTS (MAX.) WHEN USED WITH THE POINT DESIGN PROGRAM, 116 INPUTS (MAX.) WHEN USED INDEPENDENTLY OF THE POINT DESIGN PROGRAM

SUPPLEMENTARY REPORT (269 PAGES)

SECTION 1 RATIONALE AND DATA FOR SUBSTANTIATING THE PROPORTIONALITY METHOD PRESENTED IN VOLUME I, SECTION 1

SECTION 2 RATIONALE, DATA AND ESTIMATED WEIGHTS FOR SUBSTANTIATING THE POINT DESIGN METHOD PRESENTED IN VOLUME II, SECTION 1

SECTION 3 SUGGESTED UPDATING PROCEDURES FOR THE PROPORTIONALITY, GROUP ACCUMULATION, AND POINT DESIGN METHODS, AND FOR WEIGHT GROWTH FORECASTING

SUGGESTED ADDITIONAL EFFORT

MARTIN MARIETTA
DENVER DIVISION

- COLLECTION OF NEW DESIGN INFORMATION
- INCORPORATION OF NEW DESIGN DATA INTO EXISTING METHODS
- OPERATION OF EXISTING METHODS TO DETERMINE CONFIDENCE LEVEL
- EXPAND GROUP ACCUMULATION METHOD TO PROVIDE MORE COMPREHENSIVE VOLUME I APPROACH
- DEVELOP SEMI-ANALYTICAL WEIGHT ESTIMATION METHOD FOR STRUCTURE AND TPS SYSTEMS

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