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SEATIDE ANALYSIS PROCESS. VOLUME V. RELATIVE COST MODEL (RCM),(U)

FEB 75 R K MCDONOUGH DAAB09-72-C-0062

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1 of 3

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SEATIDE

SEATIDE ANALYSIS PROCESS

VOLUME V

RELATIVE COST MODEL (RCM)

REPORT NO. 00.1636
FEBRUARY 1976
(CONTRACT DAAB09-72-C-0062)

VOUGHT SYSTEMS DIVISION
LTV AEROSPACE CORPORATION
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VOLUME V.

RELATIVE COST MODEL (RCM),

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FOREWORD

(U) This report was prepared by the Vought Systems Division, LTV Aerospace Corporation, P.O. Box 6267, Dallas, Texas 75222 under U. S. Army Electronics Command Contract DAAB09-72-C-0062. The work was initiated under the direction of Captain R. A. Dowd, USN and completed under Captain W. A. Greene, USN, Chief, Long Range Forecast Division, Directorate of Estimates, Defense Intelligence Agency (DIA-DE-1).

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Mr. L. D. Cardwell	Propulsion

(U) This report has been prepared in the following volumes:

Volume	Classification	Title
I	S	Summary
IIA	U	Naval Engagement Model (NEM) - Users Manual
IIB	U	NEM - Appendices A - I
IIC	S	NEM - Appendices J - M
IID	U	NEM - Appendix N
IIIA	U	Cruise Missile - Concept Generation and Screening Model (CM-CGSM) - Users Manual
IIIB	U	CM-CGSM Appendices A-B
IIIC	S	CM-CGSM Appendix C
IIID	U	CM-CGSM Appendices D-G
IIIE	U	CM-CGSM Appendix H
IV	SU	Relative Worth Model (RWM)
V	U	Relative Cost Model (RCM)

(U) Persons contributing to the Cost Model work in Volume V include:

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ABSTRACT

(U) The SEATIDE Analysis Process is a semi-automated procedure for the generation of time-phased, high value cruise missile weapon systems concepts, together with the supporting technology and intelligence indicators which would reflect that these technological goals are being achieved. The SEATIDE process can also be used to evaluate the effectiveness of fixed force levels, existing forces in SAL environments, or Naval defenses.

(U) The Defense Intelligence Agency, through its Directorate of Estimates, and The Advanced Research Projects Agency (ARPA) have sponsored the development of this computer based analysis at the weapon system and Naval force structure level. A previous process, RIPTIDE, was developed for DIA for use in analysis of strategic missile systems.

(U) Generic to the SEATIDE Analysis Process are three major computer models: The Naval Engagement Model (NEM), Cruise Missile Concept Generation and Screening Model (CM-CGSM) and Relative Worth Model (RWM). The NEM evaluates force effectiveness, tactics, and task force configurations; the CM-CGSM enables definition and selection of candidate, advanced cruise missile system concepts; and the RWM permits assessment of worth in accordance with a variety of objective and subjective criteria. Each of these models has been checked out by DIA.

(U) In addition to exercising the computer models, there are several other analytical and engineering tasks to be performed, e.g., the identification of areas of current interest and the associated criteria and potential concepts, the creation of a foreign technology data bank in a format needed by the computer models, the engineering of concepts to the required detail, and the use of a verification analysis loop.

VOUGHT SYSTEMS DIVISION
LTV AEROSPACE CORPORATION

TITLE

RELATIVE COST MODEL (RCM)

VOLUME V

NO.

DATE 20 February 1975

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APPROVED BY J. Matthews

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VOLUME V

I. INTRODUCTION

On 28 June 1972, the Vought Systems Division, a division of LTV Aerospace Corporation, contracted with the Defense Intelligence Agency (DIA) to develop the SEATIDE Analysis Process in support of the DIA Long Range Forecast Division (DE-1). The SEATIDE Analysis process is defined to be:

> ". . . a semi-automated procedure for the generation of time phased, high value naval cruise missile concepts, together with the supporting technology and the intelligence indicators which would reflect that these technological goals are being achieved. . . . "

Generic to the SEATIDE Analysis Process are three major computer models: the Naval Engagement Model (NEM), the Cruise Missile Concept Generation and Screening Model (CM-CGSM), and the Relative Worth Model (RWM).

On 24 June 1974, a modification was made to the basic SEATIDE contract (Mod P00008) to expand the existing SEATIDE methodology to include a cruise missile relative cost model. This expansion would be done within the Cruise Missile Concept Generation and Screening Model to allow screening and ranking based on program generated relative cost estimates of cruise missiles rather than the use of missile volume and weight. This relative cost model is contractually limited to cruise missile RDT&E and first unit procurement costs. All missiles were costed as though they were produced in the U.S.

It is recognized that this relative cost model does not address all areas of missile full life cycle costs or address costs from the Soviet point of view. These limitations were necessary due to budgetary restrictions and contractual specifications.

This volume documents the development of the relative cost model. It contains the data sources, the cost estimating relationships (CERs) developed from those data, a parametric exercise of each CER over a range of values, and a discussion of the model structure. Appendices to this volume contain a program listing of the relative cost model and the results of two test cases using the expanded SEA-TIDE process. User instructions as to the input/output scheme for the updated CM-CGSM containing the relative cost model are found in Volume IIIA, as revised on 20 February 1975.

II. RELATIVE COST MODEL (RCM) DEVELOPMENT

2.1 APPROACH AND DATA SOURCES

The purpose of the RCM is to provide for cruise missile screening and ranking within the SEATIDE Concept Generation and Screening Model (CM-CGSM) and Relative Worth Model (RWM) on the basis of missile cost. The RCM required input and level of detail were to be compatible with the CM-CGSM. The RCM was to address both missile system RDT&E and first unit procurement costs. Total force costing over a production cycle was not to be included.

Numerous cost data sources were investigated during the RCM development. Primary data sources were the CAMS model (Reference 1), the ADTC cost model (Reference 2), the Tactical missile RDT&E cost model (Reference 3), and RAND studies (Reference 4 and 5). Costing equations were selected for use which addressed costs at a subsystem level of detail compatible with the CM-CGSM design options, required inputs which were either generated in the CM-CGSM or could be easily supplied by the user, and showed sensitivity to missile design and performance parameters.

After the cost-estimating relationships (CERS) were selected, each was modified by the addition of three cost terms. One term allows for an inflation factor to be input for use in adjusting the cost for future years. Each CER was normalized to compute in 1974 dollars from whatever cost base the original cost estimate addressed so that the inflation factor adjusts cost from that base.

Figure 1 displays the factors used for these adjustments and factors to be used for future adjustments. The second term allows for input of miscellaneous costs which are added to each CER. The primary purpose for this term is to allow the user to control the cost estimate, if the cost of the subsystem is known or needs to be held at a constant level. The third term, a complexity factor, adjusts the cost values to allow for differential development or manufacturing complexities or state-of-the-art increase requirements.

The RCM is broken down into five general classes of subsystems: (1) airframe and integration, (2) propulsion, (3) guidance, (4) controls, and (5) warhead. The specifics of the costing equations within each class is discussed in the following text. Within this text, each equation is assigned a number which corresponds to the FORTRAN statement number within the specific RCM subroutine that costs that particular subsystem. For example, equation (5) under the liquid rocket propulsion system discussions in Section 2.3.2 is programmed as FORTRAN statement number 5 in the liquid rocket propulsion costing subroutine of the RCM.

FIGURE 1

PRICE INDICES FOR MILITARY SYSTEMS (U)

1974 Base

Fiscal Year	All Military Procurement Index	All Military RDT&E Index	Procurement Conversion Factor	RDT&E Conversion Factor
1963	0.71746	0.67531	1.393	1.481
1964	0.72213	0.68410	1.384	1.462
1965	0.74068	0.69662	1.350	1.436
1966	0.75588	0.71276	1.323	1.403
1967	0.77243	0.73552	1.295	1.360
1968	0.79242	0.76143	1.262	1.313
1969	0.81859	0.79576	1.222	1.257
1970	0.85968	0.84462	1.163	1.184
1971	0.90942	0.89205	1.100	1.121
1972	0.94418	0.92816	1.059	1.077
1973	0.97409	0.96404	1.027	1.037
1974	1.00000	1.00000	1.000	1.000
1975	1.067	1.068	0.937	0.936
1976	1.122	1.130	0.891	0.885
1977	1.176	1.190	0.850	0.840
1978	1.223	1.245	0.817	0.803
1979	1.272	1.302	0.786	0.768
1980	1.323	1.362	0.756	0.734
1981	1.376	1.424	0.727	0.702
1982	1.431	1.490	0.699	0.671
1983	1.488	1.558	0.672	0.642
Each Year Thereafter	4%	4.6%		

REFS:

1. August 31, 1973, Budget Guidance Memorandum, FY 74, Revised and FY 75 Guidance, OSD Controller's Office.
2. April, 1973, John Beach, OSD Controller's Office, via Art Yengling, OSD Cost Analysis.
3. March 19, 1973, Schneider, OSD Cost Analysis.

2.2 AIRFRAME AND INTEGRATION

2.2.1 Sources and Assumptions

Airframe and integration CER's were derived from results of the Rand studies documented in Reference 5. CER's presented in that document are *sensitive* to overall missile performance (design speed), to missile airframe weight (missile weight less warhead, guidance, control, and propulsion systems weights), and to the number of missiles developed and produced. The "airframe" component of airframe and integration cost includes engineering, development, tooling, manufacturing, testing and quality assurance cost terms for those missile subsystems and systems normally produced by the airframe contractor. The "integration" component includes those same cost terms as they apply to integration of the warhead, guidance, control, and propulsion systems into the missile airframe.

The RCM CER's were developed by adding inflation factors, complexity factors, and miscellaneous cost terms to the Rand cost equations. Reference 5 contains detailed descriptions of each CER's derivation, data source, regression analysis, uncertainty, and limitations. Rand CER's are based on aircraft airframe and integration costs but are widely applied to cruise missile costing and have been judged to be acceptable in the RCM due to the following considerations:

(1) CER's in Reference 5 are based on AMPR (Aeronautical Manufacturer's Planning Report) weight. AMPR weight is the dry aircraft weight less man-rating components, armament, fluids, power and electrical equipment, G&C equipment, propulsion subsystems, and wheels, tires, tubes, and brakes. AMPR weight thus includes *only aircraft structure*,

skin, wings, tails, inlets, ducting, and associated hardware. The complexity and cost of developing and producing those AMPR components for a cruise missile is assumed to be comparable to that for an aircraft with the same design speed.

(2) Rand CER's were developed using cost data on 29 post World War II aircraft from 10 airframe contractors. Those aircraft weighed from 5000 to 113,000 lb and were designed to speeds from Mach 0.5 to Mach 2.2. The RCM may encounter cruise missiles outside those bounds (less than 5,000 lb. in weight or greater than Mach 2.2 in speed); however, costs gained by extrapolations of the Rand CER's to those RCM configurations are assumed to be acceptable for relative cost screening.

Complexity factors and miscellaneous cost terms are provided for each RCM CER so that the cost output can be adjusted to account for exceptional design and performance problems or windfalls.

2.2.2 RDT&E CER's

The cost for airframe and integration RDT&E is separated into engineering, development, flight test operations, tooling, manufacturing labor, manufacturing material, and quality assurance. Airframe contractor profit is computed as a percent of the sum of those cost terms and is then added to the total RDT&E cost. Individual CER's are discussed in the following paragraphs. Results of a parametric variation of missile airframe weight and design speed on the cost output from each CER are shown on the figures at the end of Section 2.2. Each CER is assigned an equation number in this section which can be correlated to a FORTRAN statement number in the RCM subroutine which computes those cost terms. All multipliers and Rand CER coefficients are programmed into the RCM computer model as input variables and can be changed for special cases. All RDT&E CER's include a term for quantity of missiles developed (Q_D). Cost is then cumulative cost through Q_D units.

Engineering RDT&E cost is computed in the RCM using the following equation:

$$C_{RENG} = .001\, a\, b\, c\, d\, e\, A^f\, S^g\, Q_D^{\,h} + i\, d \qquad (1)$$

Fig. 2

where:

C_{RENG}	=	Engineering cost in thousands of dollars for the year of interest.
A	=	airframe weight (lb)
S	=	design speed (kts)
Q_D	=	number of airframe units produced during the development phase.
a	=	engineering rate in 1974 dollars per man hour
b	=	technology multiplier used to increase cost when advances are required in the state-of-the-art (SOA) for technology
c	=	development multiplier used to reduce cost when off-the-shelf components are available
d	=	inflation multiplier
e	=	0.0396
f	=	0.791
g	=	1.526
h	=	0.183
i	=	miscellaneous engineering cost in thousands of 1974 dollars.

The variables e through h were taken from Reference 5. Plotted results of this CER for a selected set of variables are presented in Figure 2. Each parameter in equation (1) is programmed into the RCM and can be changed for a given missile through a simple input procedure (including the coefficients e through h).

Development RDT&E cost is defined as:

$$C_{RDEV} = \frac{1.163}{1000} a\, b\, c\, A^{d} S^{e} Q_{D}^{f} + bg \qquad (2)$$

Fig. 3

where:

C_{RDEV}	=	development cost in thousands of dollars for the year of interest
a	=	complexity factor used to adjust cost for exceptional development problems or windfalls.
b	=	inflation multiplier
c	=	0.008325
d	=	0.873
e	=	1.89
f	=	0.346
g	=	miscellaneous cost in thousands of 1974 dollars.

The variables A, S, and Q_D are the same as in equation (1), while c through f are taken from Reference 5. Plotted output of this CER for variable A and S are presented in Figure 3. All variables are input to the RCM computer model.

Flight test operations RDT&E cost is defined by the CER:

$$C_{RFTO} = \frac{1.163}{1000} a\, b\, c\, A^{d} S^{e} Q_{D}^{f} + bg \qquad (3)$$

Fig. 4

where:

C_{RFTO}	=	flight test operations cost in thousands of dollars inflated to the year of interest
a	=	complexity factor used to adjust cost for exceptional flight test problems or windfalls.
b	=	inflation multiplier

c	=	0.001244
d	=	1.16
e	=	1.371
f	=	1.281
g	=	miscellaneous cost in thousands of 1974 dollars

The variables A, S, and Q_D are defined in the discussion of Equation (1), while c through f are derived in Reference 5. Plotted output of this CER for variable A and S are presented in Figure 4.

Tooling RDT&E cost is defined by the relationship:

$$C_{RTOOL} = .001\, a\, b\, c\, d\, e\, A^f S^g Q_D^{\ h} R^i + jd \qquad (4)$$

Fig. 5

where:

C_{RTOOL}	=	tooling cost in thousands of dollars
a	=	tooling labor rate in 1974 dollars per man hour
b	=	technology factor used to increase cost when advances are required to the SOA which increase tooling complexity
c	=	complexity factor used to decrease cost when existing tooling can be used
d	=	inflation multiplier
e	=	4.0127
f	=	0.764
g	=	0.899
h	=	0.178
i	=	0.066
j	=	miscellaneous tooling cost in thousands of 1974 dollars
R	=	production rate in missiles per month

The variables A, S, and Q_D are defined during the discussion of Equation (1), while e through i are developed in Reference 5. A plot of tooling cost for variable A and S is included as Figure 5.

Manufacturing labor RDT&E cost is computed in the as:

$$C_{RMFGL} = .001\, a\, b\, c\, d\, A^{e}\, S^{f}\, Q_{D}^{\ g} + ch \qquad (5)$$

Fig. 6

where:

C_{RMFGL} = manufacturing labor cost in thousands of dollars for year of interest

a = manufacturing labor rate in 1974 dollars per man hour

b = complexity factor used to adjust cost for exceptional manufacturing problems such as those caused by technology advances or material changes

c = inflation factor

d = 28.984

e = 0.74

f = 0.543

g = 0.524

h = miscellaneous manufacturing labor cost in thousands of 1974 dollars.

The variables A, S, and Q_D are defined in the discussion of Equation (1), while d through g are developed in the study of Reference 5. A plot of manufacturing labor cost is included for variable A and S (see Figure 6).

Manufacturing material RDT&E cost is computed by the CER:

$$C_{RMFGM} = \frac{1.163}{1000}\, a\, b\, c\, A^{d}\, S^{e}\, Q_{D}^{\ f} + bg \qquad (6)$$

Fig. 7

where:

C_{RMFGM} = manufacturing material cost in thousands of dollars

a = complexity factor used to adjust cost for changes in material used for airframe components

b = inflation factor

c = 37.632

d	=	0.689
e	=	0.624
f	=	0.792
g	=	miscellaneous manufacturing material cost in thousands of 1974 dollars.

The variables c through f were drawn from Reference 5. A and S are defined in the discussion of Equation (1). A plot of manufacturing material cost for variable A and S is included as Figure 7.

Airframe and integration quality assurance cost for RDT&E is defined by the CER:

$$C_{RQA} = a\, b\, C_{RMFGL} + cd \qquad (7)$$

Fig. 8

where:

C_{RQA}	=	quality assurance cost in thousands of dollars
C_{RMFGL}	=	manufacturing labor RDT&E cost (see Equation (5)).
a	=	complexity factor for quality assurance
b	=	0.13
c	=	inflation multiplier
d	=	miscellaneous quality assurance cost in thousands of 1974 dollars.

The parameter b was derived in Reference 5. A plot of quality assurance cost for variable A and S (variable manufacturing labor cost) is presented in Figure 8.

Total RDT&E cost is compiled in the RCM by summing all components and applying a profit margin, a complexity factor, and a miscellaneous cost term.

The CER for RDT&E total cost is:

$$C_{RAFI} = a\,(1 + p)\,(C_{RENG} + C_{RDEV} + C_{RFTO} + C_{RTOOL} + C_{RMFGL} + C_{RMFGM} + C_{RQA}) + b\,c \qquad (14)$$

where:

C_{RAFI}	=	total RDT&E cost in thousands of dollars
a	=	complexity factor for total cost
b	=	inflation factor
c	=	miscellaneous cost term for total RDT&E cost measured in thousands of 1974 dollars
p	=	profit margin (fraction) for the airframe contractor

2.2.3 Production CER's

The cost for airframe and integration first unit production is separated into engineering, tooling, manufacturing labor, manufacturing material, and quality assurance. Airframe contractor profit is computed as a per cent of the sum of those cost terms and is then added to the total production cost. Individual CER's are discussed in the following paragraphs. Results of a parametric variation of missile airframe weight and design speed on the cost output from each CER are shown on figures at the end of Section 2.2. Each CER is assigned an equation number in this section which can be correlated to a FORTRAN statement number in the RCM subroutine which computes those cost terms. All multipliers and Rand CER coefficients are programmed into the RCM computer model as input variables and can be changed for special cases.

The CER's documented in Reference 5 are based on cumulative cost through a set number of units. The first production unit is actually missile number $Q_D + 1$, where Q_D is the total number of missiles required for the RDT&E phase. Cost of the first production unit is then the cumulative cost for $Q_D + 1$ units minus the cumulative cost for Q_D units. That subtraction is present in all CER's in this section.

Engineering first unit production cost is computed in the RCTM using the following equation:

$$C_{PENG} = .001\, a\, b\, c\, d\, e\, A^{f} S^{g} ((Q_D + 1)^{h} - Q_D^{h}) + i\, d \qquad (8)$$

Fig. 9

where:

C_{PENG} = engineering cost in thousands of dollars for the year of interest.

A = airframe weight (lb)

S = design speed (kts)

Q_D = number of airframe units required for the development phase

a = engineering rate in 1974 dollars per man hour

b = technology multiplier used to adjust cost when advances are required in the SOA.

c = complexity factor used to reduce cost when off-the-shelf components are available.

d = inflation multiplier

e = 0.0396

f = 0.791

g = 1.526

h = 0.183

i = miscellaneous engineering cost in thousands of 1974 dollars.

Variables e through h were developed in Reference 5. A plot of engineering production cost for variable A and S is enclosed as Figure 9. Each CER parameter can be changed for a given RCM job through a simple input procedure.

Airframe and integration tooling first unit production cost is given by:

$$C_{PTOOL} = .001\, a\, b\, c\, d\, e\, A^{f} S^{g} ((Q_D + 1)^{h} - Q_D^{h}) R^{i} + j\, d \qquad (9)$$

Fig. 10

where:

C_{PTOOL} = tooling cost in thousands of dollars

a = tooling labor rate in 1974 dollars per man hour

b = technology factor used to increase cost when advances are required to the SOA which increase tooling complexity

c = complexity factor used to decrease cost when existing can be used.

d = inflation multiplier

e = 4.0127

f = 0.764

g = 0.899

h = 0.178

i = 0.066

j = miscellaneous tooling cost in thousands of 1974 dollars

R = production rate in missiles per month

Variables A, S, and Q_D are defined in the discussion of Equation (8), while e through i are derived from Reference 5. A plot of tooling cost for variable A and S is included as Figure 10.

Manufacturing labor cost for first unit production is:

$$C_{PMFGL} = .001\ a\ b\ c\ d\ A^e\ S^f\ ((Q_D + 1)^g - Q_D{}^g) + c\ h \qquad (10)$$

Fig. 11

where:

C_{PMFGL} = manufacturing labor cost in thousands of 1974 dollars

a = manufacturing labor rate in 1974 dollars per man hour

b = complexity factor used to adjust cost for exceptional manufacturing problems such as those caused by technology advances or material changes

c = inflation factor

d = 28.984

e = 0.74

f = 0.543

g = 0.524

h = miscellaneous manufacturing labor cost in thousands of 1974 dollars

The variables A, S, and Q_D are defined in the discussion of Equation (8), while d through g are developed in the study of Reference 5. A plot of manufacturing labor cost is included, for variable A and S, as Figure 11.

Manufacturing material first unit production cost is computed through the CER:

$$C_{PMFGM} = \frac{1.163}{1000} \, a \, b \, c \, A^d S^e \left((Q_D + 1)^f - Q_D^{\,f}\right) + b \, g \qquad (11)$$

Fig. 12

where:

C_{PMFGM} = manufacturing material cost in thousands of dollars of the year of interest

a = complexity factor used to adjust cost for changes in material used for airframe components.

b = inflation factor

c = 37.632

d = 0.689

e = 0.624

f = 0.792

g = miscellaneous manufacturing material cost in thousands of 1974 dollars

Variables e through f were developed in Reference 5. A and S are defined in the discussion of Equation (8). A plot of manufacturing material cost for variables A and S is included as Figure 12.

Quality assurance cost for first unit production is defined by:

$$C_{PQA} = a\, b\, C_{PMFGL} + c\, d \tag{12}$$

Fig. 13

where:

C_{PQA} = quality assurance cost in thousands of dollars

C_{PMFGL} = manufacturing labor first unit cost (see Equation (10)).

a = complexity factor for quality assurance

b = 0.13

c = inflation multiplier

d = miscellaneous quality assurance cost in thousands of 1974 dollars

The parameter b was derived in Reference 5. A plot of quality assurance cost for variables A and S (variable manufacturing labor cost) is presented in Figure 13.

Total first unit production cost is compiled in the RCM by summing all components and applying a profit margin, a complexity factor, and a miscellaneous cost term. The CER for that total cost is:

$$C_{PAFI} = a\,(1 + p)\,(C_{PENG} + C_{PTOOL} + C_{PMFGL} + C_{PMFGM} + C_{PQA}) + b\, c \tag{13}$$

where:

C_{PAFI} = total first unit production cost in thousands of dollars

a = complexity factor for total cost

b = inflation factor

c = miscellaneous cost term for total cost measured in thousands of 1974 dollars

p = profit margin (fraction) for the airframe contractor

FIGURE 2

AIRFRAME AND INTEGRATION ENGINEERING COST (U)

Reference: Equation 1 Section 2.2.2

$$C_{RENG} = a\ b\ c\ d\ \frac{(e\ A^{f}\ S^{g}\ Q_D^{\ h})}{1000} + i\ d$$

Assuming:

a = 26	f = .791
b = 1	g = 1.526
c = 1	h = .183
d = 1	i = 0
e = .0396	Q_D = 1

this becomes

$$C_{RENG} = 26\ \frac{.0396\ A^{.791}\ S^{1.526}\ Q_D^{\ .183}}{1000}$$

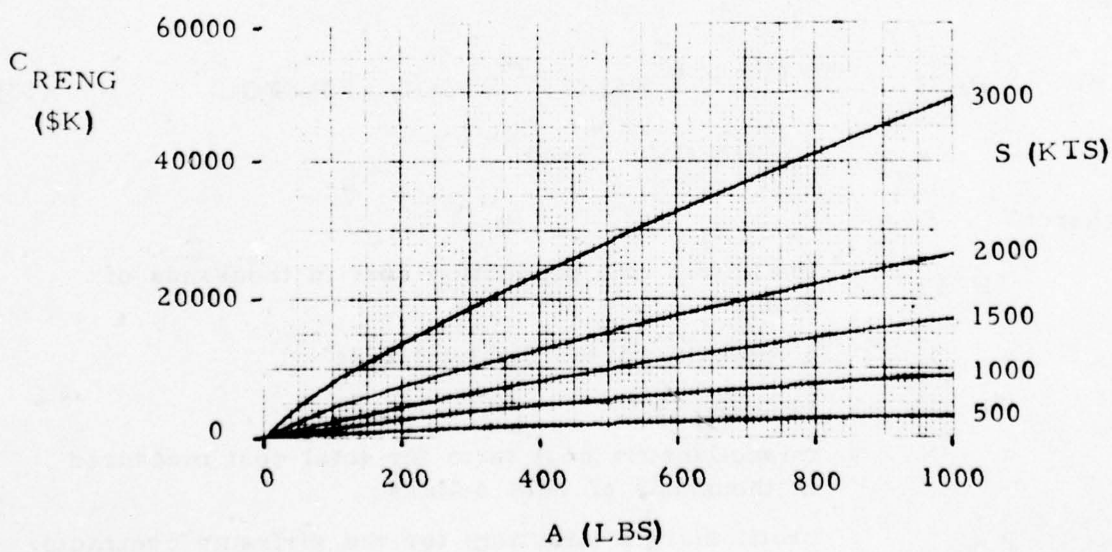


FIGURE 3

AIRFRAME AND INTEGRATION DEVELOPMENT COST (U)

Reference: Equation 2 Section 2.2.2

$$C_{RDEV} = 1.163\ a\ b\ \frac{c\ A^{d}\ S^{e}\ Q_D^{\ f}}{1000} + bg$$

Assuming:

a = 1	e = 1.89	Q_D = 1
b = 1	f = .346	
c = .008325	g = 0	
d = .873	h = 1	

this becomes

$$C_{RDEV} = 1.163\ \frac{.008325\ A^{.873}\ S^{1.89}\ Q_D^{\ .346}}{1000}$$

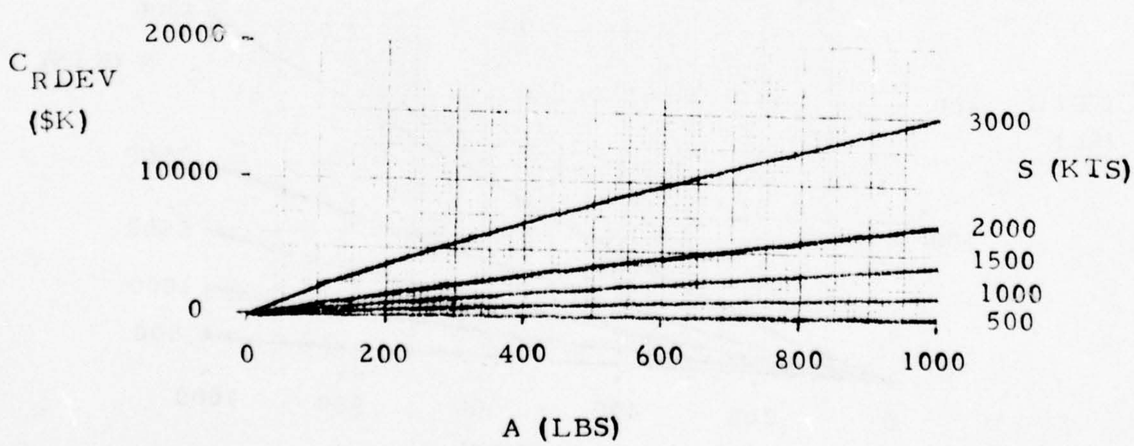


FIGURE 4

AIRFRAME AND INTEGRATION FLIGHT TEST OPERATIONS COST (U)

Reference: Equation 3 Section 2.2.2

$$C_{RFTO} = 1.163\ a\ b\ \frac{c\ A^{d}\ S^{e}\ Q_D^{\ f}}{1000} + b\ g$$

Assuming:

a = 1	e = 1.371
b = 1	f = 1.281
c = .001244	g = 0
d = 1.16	Q_D = 1

this becomes

$$C_{RFTO} = 1.163\ \frac{.001244\ A^{1.16}\ S^{1.371}\ Q_D^{\ 1.281}}{1000}$$

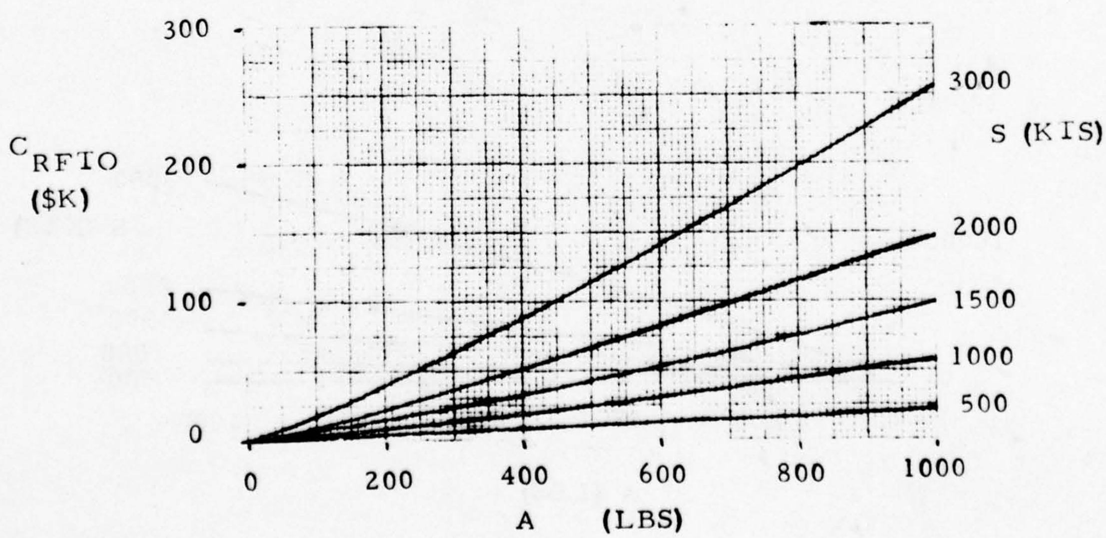


FIGURE 5
AIRFRAME AND INTEGRATION TOOLING COST (U)

Reference: Equation 4 Section 2.2.2

$$C_{RTOOL} = a\,b\,c\,d\,\frac{e\,A^{f}\,S^{g}\,Q_{D}^{h}\,R^{i}}{1000} + j\,d$$

Assuming:

a = 19	f = .764	Q_D = 1
b = 1	g = .899	R = 1
c = 1	h = .178	
d = 1	i = .066	
e = 4.0127	j = 0	

this becomes

$$C_{RTOOL} = 19\,\frac{4.0127\,A^{.764}\,S^{.899}\,Q_{D}^{.178}\,R^{.066}}{1000}$$

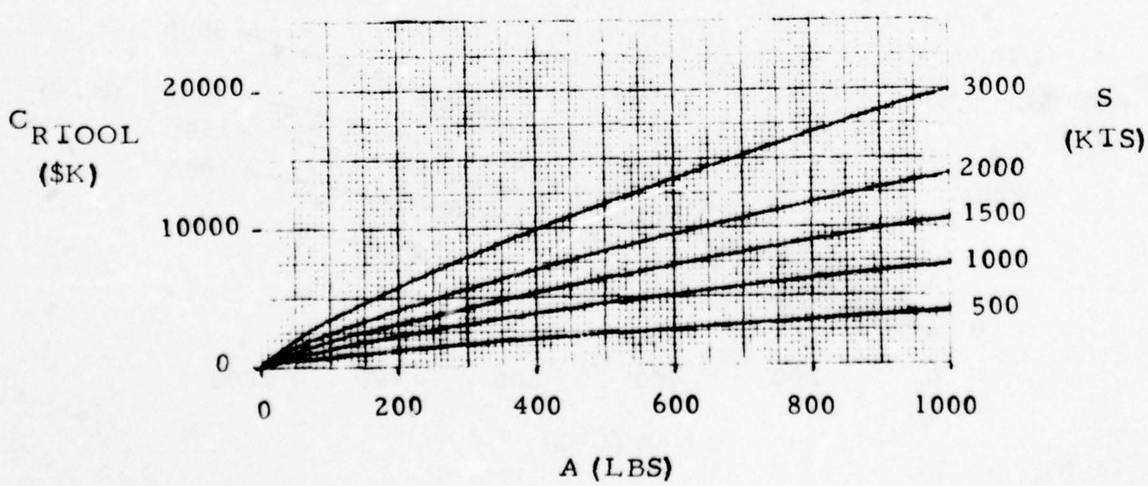


FIGURE 6
AIRFRAME AND INTEGRATION MANUFACTURING LABOR COSTS (U)

Reference: Equation 5 Section 2.2.2

$$C_{RMFGL} = a\,b\,c\,\frac{d\,A^e\,S^f\,Q_D^{\,g}}{1000} + c\,h$$

Assuming:

$a = 12$ $e = .74$

$b = 1$ $f = .543$

$c = 1$ $g = .524$

$d = 28.984$ $h = 0$

$Q_D = 1$

this becomes

$$C_{RMFGL} = 12\;\frac{28.984\,A^{.74}\,S^{.543}\,Q_D^{.524}}{1000}$$

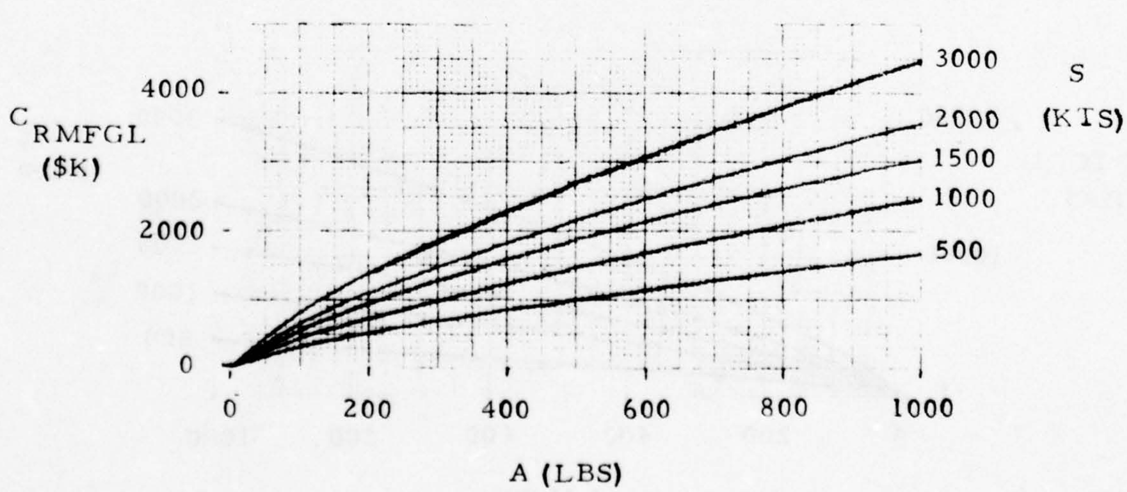


FIGURE 7

AIRFRAME AND INTEGRATION MANUFACTURING MATERIAL COST (U)

Reference: Equation 6 Section 2.2.2

$$C_{RMFGM} = 1.163 \; a \; b \; \frac{c \; A^{d} \; S^{e} \; Q_D^{\;f}}{1000} + b \; g$$

Assuming:

a = 1	e = .624	Q_D = 1
b = 1	f = .792	
c = 37.632	g = 0	
d = .689	h = 1	

this becomes

$$C_{RMFGM} = 1.163 \; \frac{37.632 \; A^{.689} \; S^{.624} \; Q_D^{.792}}{1000}$$

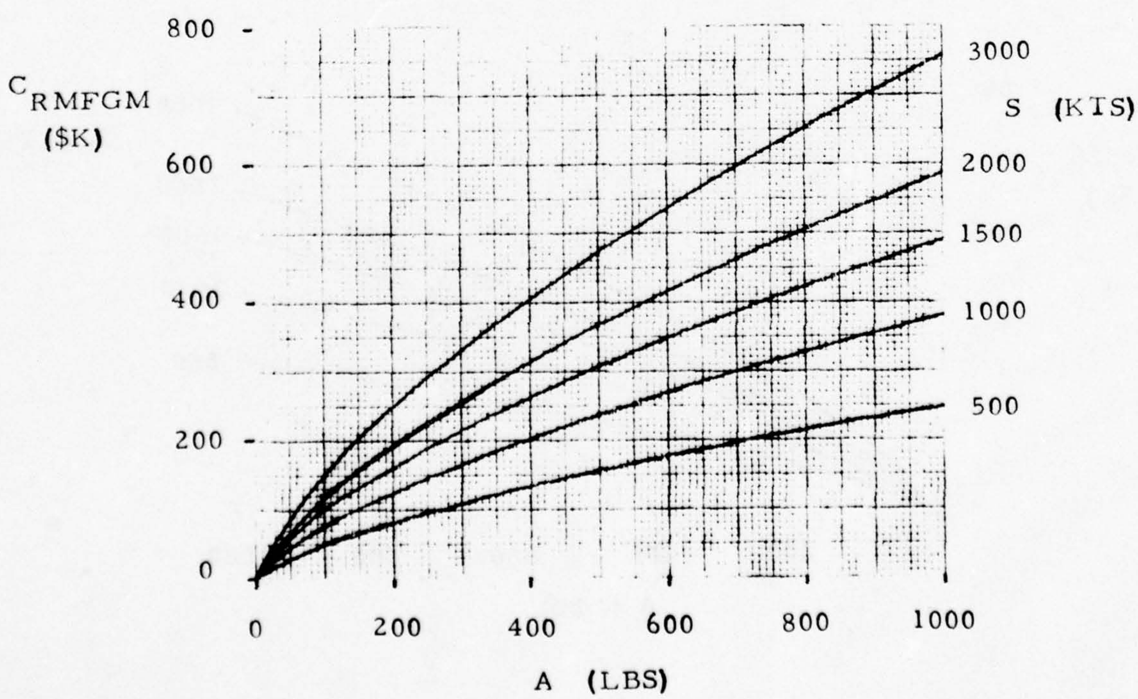


FIGURE 8

AIRFRAME AND INTEGRATION QUALITY ASSURANCE COST (U)

Reference: Equation 7 Section 2.2.2

$$C_{RQA} = a \cdot b\, C_{RMFGL} + c\, d$$

Assuming:

$a = 1$ $c = 1$

$b = .13$ $d = 0$

this becomes

$$C_{RQA} = .13\, C_{RMFGL}$$

$$C_{RMFGL} = f\,(A, S))$$

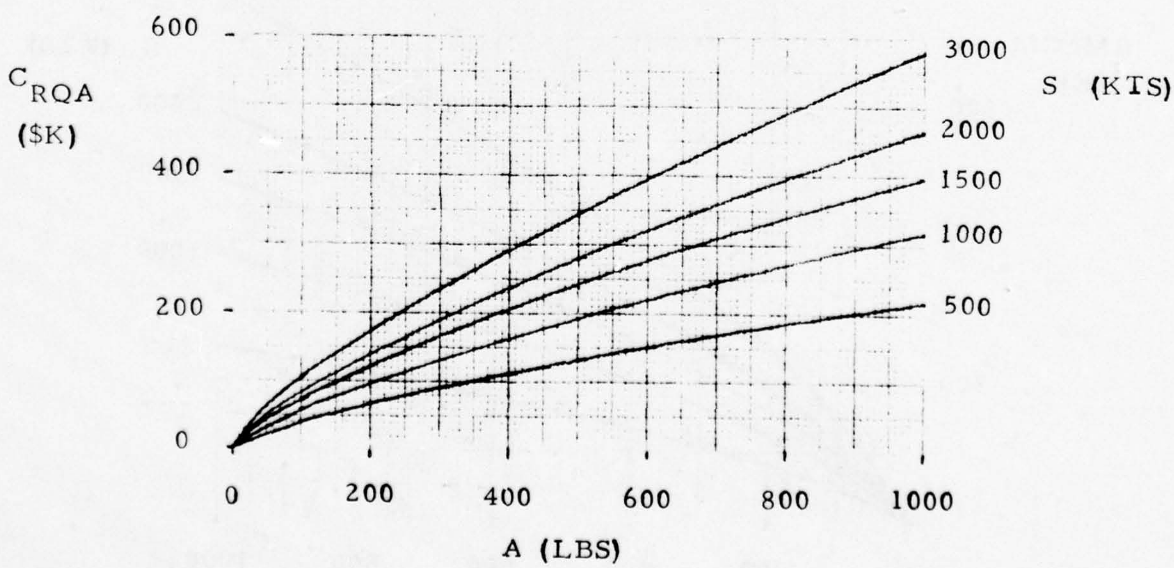


FIGURE 9

AIRFRAME AND INTEGRATION FIRST UNIT PRODUCTION ENGINEERING COST (U)

Reference: Equation 8 Section 2.2.3

$$C_{PENG} = \frac{abcd}{1000} \left[e\, A^{f}\, S^{g}\, ((Q_D + 1)^{h} - Q_D^{\;h})\right] + i\, d$$

Assuming:

a	= 26	f	= .791
b	= 1	g	= 1.526
c	= 1	h	= .183
d	= 1	i	= 0
e	= .0396	Q_D	= 20

this becomes:

$$C_{PENG} = \frac{26}{1000} \left[.0396\, A^{.791}\, S^{1.526}\, ((Q_D + 1)^{.183} - Q_D^{\;.183})\right]$$

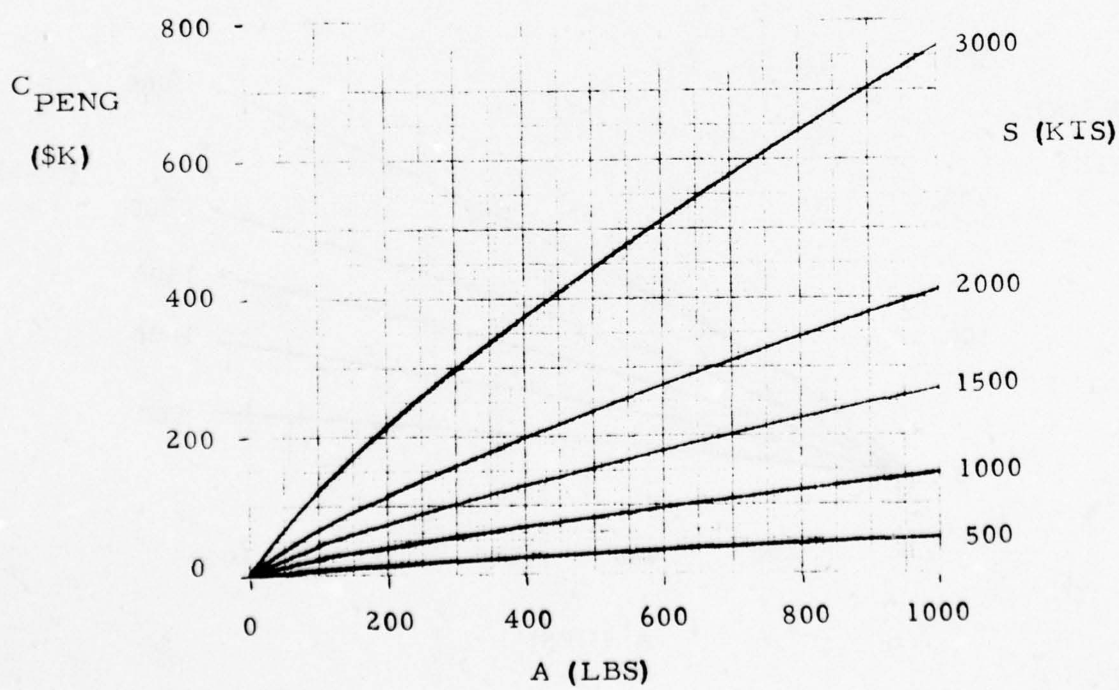


FIGURE 10

AIRFRAME AND INTEGRATION FIRST UNIT PRODUCTION TOOLING COST (U)

Reference: Equation 9 Section 2.2.3

$$C_{PTOOL} = \frac{abcd}{1000} \left[e\ A^{f}\ S^{g}\ ((Q_D + 1)^{h} - Q_D^{\ h})\ R^{i}\right] + jc$$

Assuming:

a = 19	e = 4.0127	i = .066
b = 1	f = .764	j = 0
c = 1	g = .899	Q_D = 20
d = 1	h = .178	R = 1

this becomes:

$$C_{PTOOL} = \frac{19}{1000} \left[4.0127\ A^{.764}\ S^{.899}\ ((Q_D + 1)^{.178} - Q_D^{\ .178})\ R^{.066}\right]$$

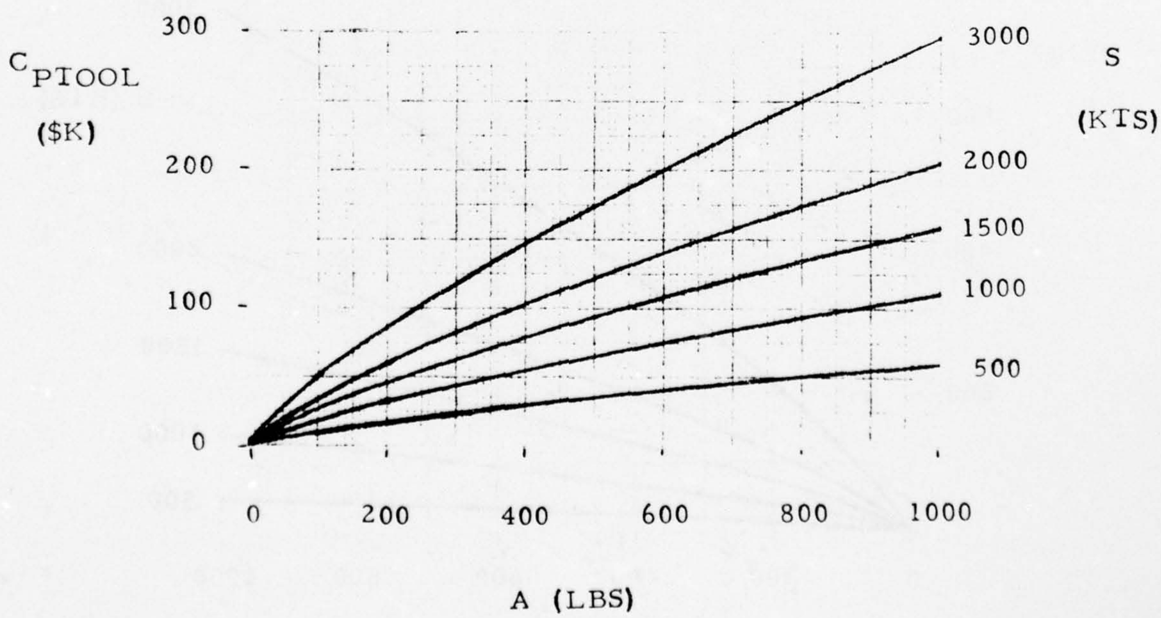


FIGURE 11
AIRFRAME AND INTEGRATION FIRST UNIT
PRODUCTION MANUFACTURING LABOR COST (U)

Reference: Equation 10 Section 2.2.3

$$C_{PMFGL} = \frac{abc}{1000} \left[d\, A^e S^f \left((Q_D + 1)^g - Q_D^{\,g}\right] + ch$$

Assuming:

a = 12	d = 28.984	g = .524
b = 1	e = .74	h = 0
c = 1	f = .543	Q_D = 20

this becomes:

$$C_{PMFGL} = \frac{12}{1000} \left[28.984\, A^{.74} S^{.543} \left((Q_D + 1)^{.524} - Q_D^{\,.524}\right)\right]$$

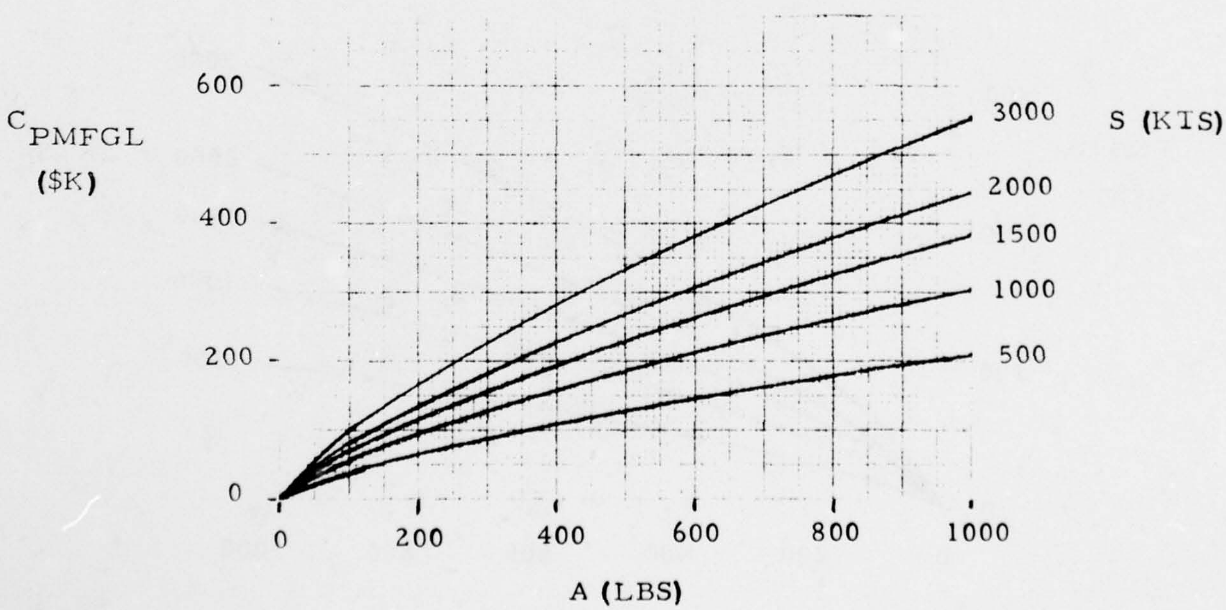


FIGURE 12

AIRFRAME AND INTEGRATION FIRST UNIT PRODUCTION MANUFACTURING MATERIAL COST (U)

Reference: Equation 11 Section 2.2.3

$$C_{PMFGM} = \frac{1.163\ a\ b}{1000} \left[c\ A^{d} S^{e} \left((Q_D + 1)^{.792} - Q_D^{\ .792} \right) \right] + b\ g$$

Assuming:

a = 1	d = .689	g = 0
b = 1	e = .624	Q_D = 20
c = 37.632	f = .792	

this becomes:

$$C_{PMFGM} = \frac{1.163}{1000} \left[37.632\ A^{.689} S^{.624} \left((Q_D + 1)^{.792} - Q_D^{\ .792} \right) \right]$$

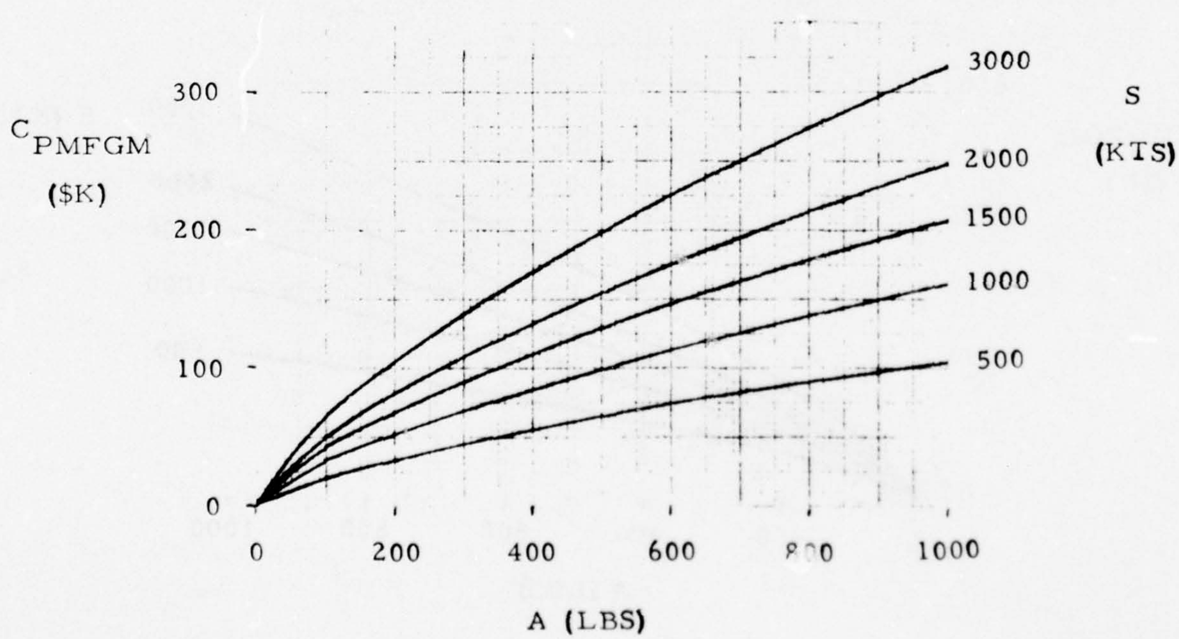


FIGURE 13

AIRFRAME AND INTEGRATION FIRST UNIT PRODUCTION QUALITY ASSURANCE COST (U)

Reference: Equation 12 Section 2.2.3

$$C_{PQA} = a\,b\,C_{PMFGL} + c\,d$$

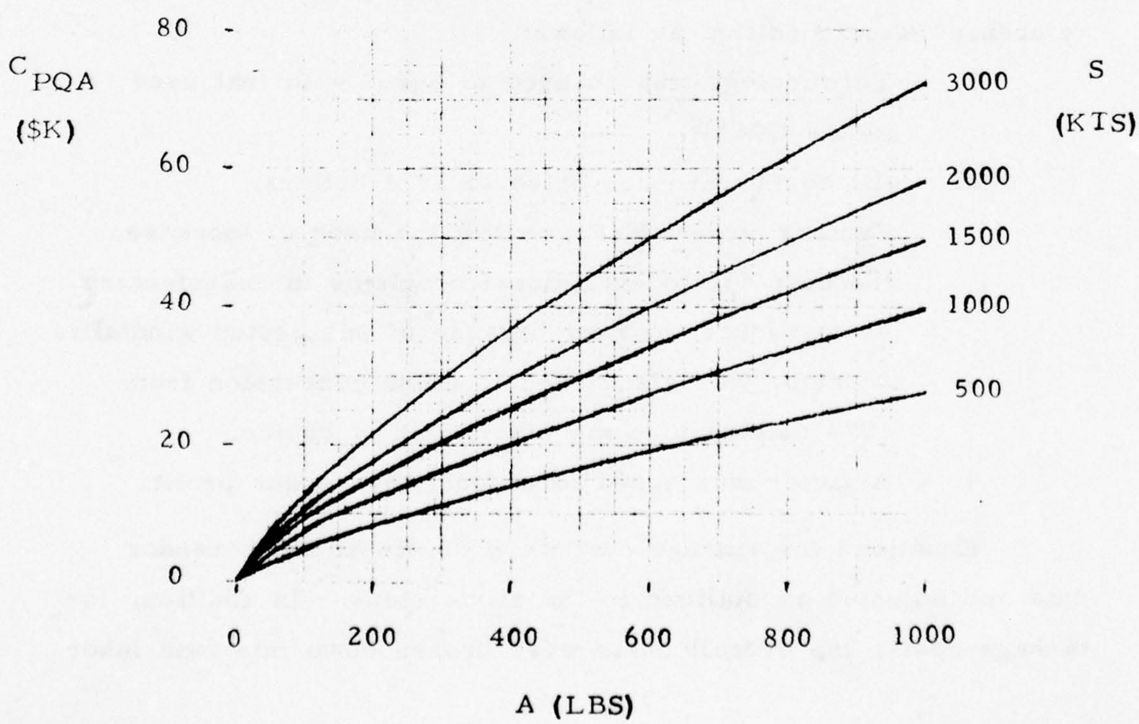
Assuming:

a = 1 c = 1
b = .13 d = 0

this becomes:

$$C_{PQA} = .13\,C_{PMFGL}$$

$$C_{PMFGL} = f(A, S)$$



2.3 PROPULSION

This section presents the cost equations (CER's) for the solid sustainer motor, liquid rocket, turbojet, integral ramjet, non-integral ramjet, and external booster propulsion systems. For each type of propulsion system, cost equations are first presented for system components. These are then combined to arrive at a propulsion system first unit cost. A CER is then given for system RDT&E cost and finally the total propulsion system cost (first unit plus RDT&E) is presented.

Where a CER contains a propulsion system parameter such as thrust, motor weight, etc., which is communicated from the CGSM, a range of typical values for the parameter is shown. Plots for most of the CER's using the typical values for propulsion system parameters are presented at the end of each propulsion system section. All of the equations used were obtained from references cited or from vendor data obtained by VSD on other contracts. Equations taken directly from cited references were modified as follows:

1. Terminology was changed to agree with that used in the CGSM.
2. All costs were converted to 1974 dollars.
3. Factors were added to allow the user to increase the cost due to exceptional problems in manufacture or to reduce the cost because of unexpected windfalls. A factor was also added to allow conversion from 1974 dollars to some other year of choice.
4. A factor was added to account for vendor profit.

Equations for tankage cost were developed from vendor data and adjusted as outlined in the above steps. In addition, for tankage costs, the overall costs were broken down into tank labor cost and tank material cost so that multiplying factors from Reference 1 could be applied to estimate costs for other tankage materials (the vendor data were for tanks constructed from 6Al4V Titanium). This procedure is discussed in Section 2.3.2, Liquid Propulsion System.

The details pertaining to each propulsion system are presented in the following sections.

2.3.1 SOLID PROPULSION SUSTAINER

2.3.1.1 Motor Case

The cost of the sustainer rocket motor case is given by the following three equations.

$$C_{BLC} = 1.1\, a \left(\frac{b}{W_{MC}}\right)^c W_{MC} \qquad (1)$$

Fig. 14

where

$a = 0.008166$

$b = 140$

$c = 0.333$

C_{BLC} = case labor cost, thousands of 1974 dollars

W_{MC} = weight of the motor case (75-1500), lbm.

The values for the constants b and c were taken directly from Reference 1. The coefficient, a, is a combination of coefficients appearing in the equation taken from Reference 1 and its derivations is explained below. A similar derivation of the final coefficients was done for other equations taken from Reference 1. However, the derivations are similar in all cases and the details of the derivations will not be repeated for any of the subsequent equations reported herein. Thus, the original equation for the motor case labor cost is given below:

$$BLC = (AC \times CF(I)) \left(\frac{140}{W_C}\right)^{0.333} (W_C) \left(\frac{6000}{Q}\right)^{0.0291}$$

where:

BLC = case labor cost, thousands of dollars

AC = labor rate in dollars/lb = 0.00634

CF(I) = fabrication complexity factor = 1

W_C = case weight, lbm

Q = number of units manufactured

The term $\left(\frac{6000}{Q}\right)^{0.02491}$, is a learning curve expression.

Since all cost equations reported herein are for the first unit, the above expression results in a value of 1.288. The factor, 1.1 in Equation 1, converts the cost obtained from the original Reference 1 equation from 1971 to 1974 dollars. A plot or typical case labor cost appears in Figure 14 at the end of this section.

The case material cost is given by:

$$C_{BMC} = 1.1\, a \left(\frac{b}{W_{MC}}\right)^{c} W_{MC} \qquad (2)$$

Fig. 15

where:

$a = 0.02022$

$b = 140$

$c = 0.333$

C_{BMC} = case material cost, thousands of 1974 dollars.

Figure 15 is a plot of typical case material cost.

The total case cost then becomes:

$$C_{CASE} = a\,(C_{BLC} + C_{BMC}) + b \qquad (3)$$

where:

a = factor used to adjust for exceptional problems or windfalls.

b = miscellaneous cost, thousands of 1974 dollars

C_{CASE} = case cost, thousands of 1974 dollars.

The case insulation cost is given by:

$$C_{LI} = a\, b\, (1.1) \left(\frac{c}{D_P}\right)^{d} D_P + e \qquad (4)$$

Fig. 16

where:

a = factor used to adjust insulation cost for exceptional problems or windfalls

$b = 0.001039$

$c = 198$

$d = 0.333$

e	=	miscellaneous cost term in thousands of 1974 dollars.
C_{LI}	=	insulation cost in thousands of 1974 dollars
D_P	=	insulation volume (250-5000), cubic inches

The value for the constant, b is the product of the base cost per cubic inch of insulation and liner and the value of the learning curve term, $\left(\frac{1000}{Q}\right)^{0.069}$. The constant, 1.1 converts from 1971 to 1974 dollars.

Typical case insulation cost is shown in Figure 16.

2.3.1.2 Nozzle

The nozzle cost is given by:

$$C_{NOZ} = a\, b\, (3.3)\, (W_N)\, (c + d\, D_{THRT} + e\, R_{NOZI}) + f \quad (5)$$

Fig. 17

where:

a	=	factor used to adjust nozzle cost for exceptional problems or windfalls.
b	=	0.001755
c	=	4.6788
d	=	1.4045
e	=	1.5487
f	=	miscellaneous cost term in thousands of 1974 dollars.
C_{NOZ}	=	nozzle cost in 1974 thousands of dollars
W_N	=	nozzle weight (15-300), lbm
D_{THRT}	=	nozzle throat diameter (1.13-5.04), inches
R_{NOZI}	=	nozzle inlet radius (1.70-7.56), inches

The constant, 3.3 is the product of the 1971 to 1974 inflation factor (1.1) and a complexity factor (3) for a pintle nozzle. The constant, b is the product of the learning curve term, $\left(\frac{2000}{Q}\right)^{0.074}$ and the conversion to thousands of dollars (10^{-3}).

Figure 17 is a plot of typical nozzle cost.

2.3.1.3 Propellant

The mixed propellant cost is given by:

$$C_{PRC} = a\,(W_P)\left(\frac{b}{c\;W_P}\right)^d \left(\frac{f}{e}\right) + g \qquad (6)$$

Fig. 18

where:

a	=	factor used to adjust propellant cost for exceptional problems or windfalls.
b	=	100,000
c	=	32.006
d	=	0.069
e	=	1000
f	=	cost per pound of propellant in 1974 dollars.
g	=	miscellaneous cost term in thousands of 1974 dollars.
C_{PRC}	=	mixed propellant cost in thousands of 1974 dollars.
W_P	=	propellant weight (425-8500), lbm

The factor c was derived from the factor, AMR appearing in Reference 1 which is the average monthly rate expressed in terms of number of missiles as follows:

$$AMR = 0.2587 + 37.0680Q - 5.8389Q^2 + 0.5185Q^3$$

which reduces to a value of 32.006 for Q = 1.

Typical propellant cost is shown in Figure 18.

The propellant loading cost is given by:

$$C_{PLC} = a\,(1.1)\,b\,W_P\left(\frac{c}{d\;W_P}\right)^e + f \qquad (7)$$

Fig. 19

where:

a	=	factor used to adjust propellant loading cost for exceptional problems or windfalls.

b = 0.00343

c = 100000.

d = 32.006 (see explantion for equation 6)

e = 0.387

f = miscellaneous cost term in thousands of 1974 dollars.

C_{PLC} = propellant loading cost in thousands of 1974 dollars

Figure 19 illustrates typical propellant loading cost.

2.3.1.4 Safe/Arm and Igniter

The cost of the safe and arm system is given by:

$$C_{SA} = a \quad (8)$$

where:

a = an assigned value for safe and arm cost in thousands of 1974 dollars. A value of .175 is used.

The igniter cost is given by:

$$C_{IGN} = a \quad (9)$$

where:

a = an assigned value for igniter cost in thousands of 1974 dollars. A value of .350 is used.

2.3.1.5 Motor First Unit Cost

The first unit cost for the solid motor is given by:

$$C_{SRFU} = a\,(1 + P_{SPC})\left\{ b\,(1.15)\left[C_{CASE} + C_{LI} + C_{NOZ} + C_{PRC} + C_{PLC} + C_{SA} + C_{IGN}\right] + c \right\} \quad (10)$$

where:

a = inflation factor used to adjust cost from 1974 dollars to year of interest.

b = factor used to adjust first unit cost for exceptional problems or windfalls.

c = miscellaneous cost term in thousands of 1974 dollars.

C_{SRFU} = total solid motor cost in thousands of 1974 dollars.

P_{SPC} = contractors percent profit

The factor, 1.15 is for a 15% cost of integrating the motor components.

2.3.1.6 RDT&E Cost

The solid motor RDT&E cost equation was obtained by curve fitting data from Reference 6. This graph is shown in Figure 20 and the equation for the curve is:

$$COST = 14392 \left[(D)\,(W_M)\right]^{0.4263}$$

where:

COST = motor RDT&E cost in 1964 dollars

D = motor diameter, inches

W_M = motor weight, lbm

After adjusting the equation for use in the cost model, it becomes:

$$C_{SRRD} = a\,(1 + P_{SPC})\left\{bc\left[(D)\,(W_M)\right]^{d}(1.462) + e\right\} \qquad (11)$$

Fig. 20

where:

a = inflation factor used to adjust cost from 1974 dollars to year of interest.

b = factor used to adjust RDT&E cost for exceptional problems or windfalls

c = 16.551

d = 0.4263

e = miscellaneous cost term in thousands of 1974 dollars.

C_{SRRD} = RDT&E cost in thousands of 1974 dollars.

P_{SPC} = contractors profit margin (fraction)

D = motor diameter (12-36), inches

W_M = motor weight (500-10,000), lbm

The factor, c is derived from the original coefficient, 14392, by multiplying by the factor for converting to 1974 dollars dividing by 1000 to convert to thousands of dollars and multiplying by a factor of 1.15 to account for the added complexity of developing a pintle nozzle.

Figure 20 shows typical RDT&E cost.

2.3.1.7 Total Motor Cost

The total motor cost is the sum of the First Unit Cost and the RDT&E cost. Thus:

$$C_{SRT} = C_{SRFU} + C_{SRRD} \qquad (12)$$

FIGURE 14
SOLID ROCKET CASE LABOR COST (U)

Reference: Equation 1 Section 2.3.1

$$C_{BLC} = 1.1\, a \left(\frac{b}{W_{MC}}\right)^{c} W_{MC}$$

Assuming:

a =.008166 c = .333

b = 140

this becomes

$$C_{BLC} = 1.1\, (.008166) \left(\frac{140}{W_{MC}}\right)^{.333} W_{MC}$$

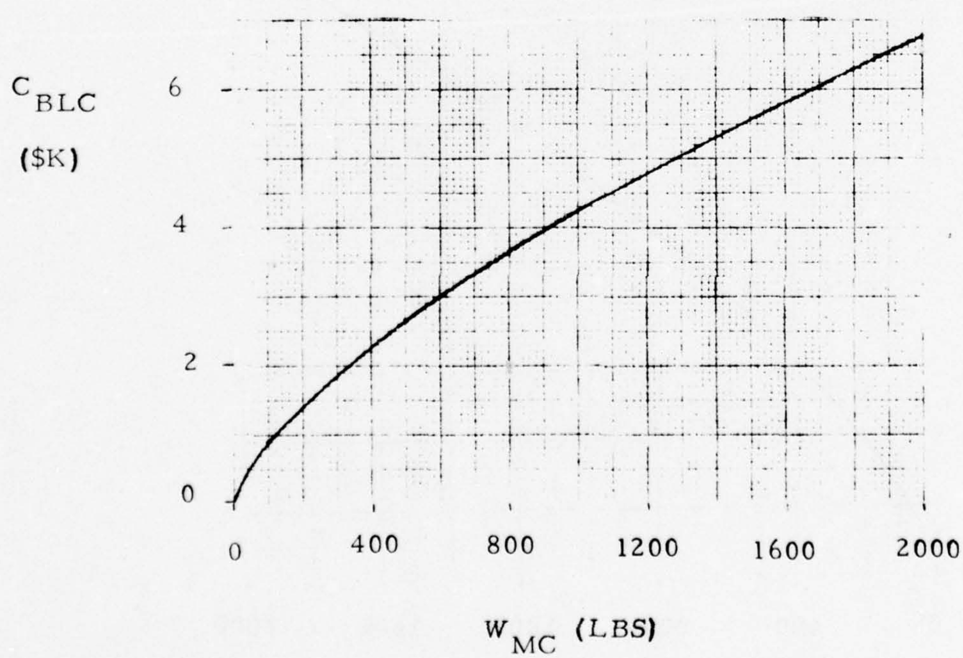


FIGURE 15

SOLID ROCKET CASE MATERIAL COST (U)

Reference: Equation 2 Section 2.3.1

$$C_{BMC} = 1.1\, a \left(\frac{b}{W_{MC}}\right)^{c} W_{MC}$$

Assuming:

a = .02022 c = .333

b = 140

this becomes:

$$C_{BMC} = 1.1\,(.02022) \left(\frac{140}{W_{MC}}\right)^{.333} W_{MC}$$

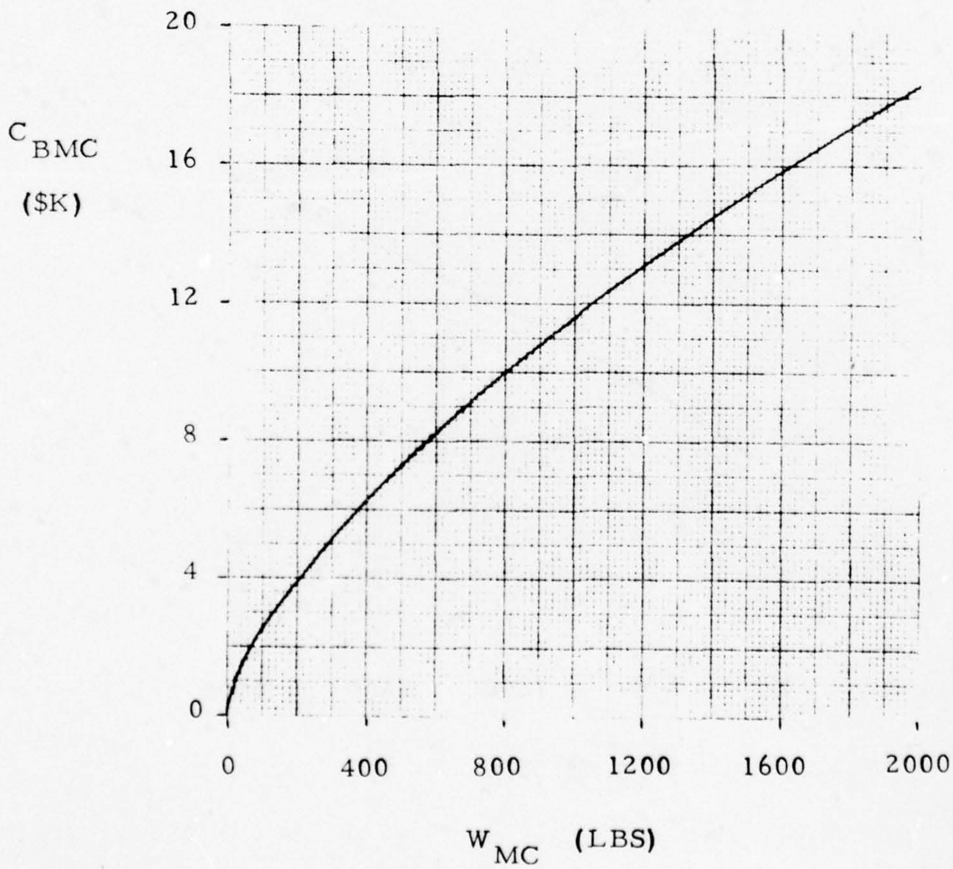


FIGURE 16
SOLID ROCKET INSULATION COST (U)

Reference: Equation 4 Section 2.3.1

$$C_{LI} = 1.1\ a\ b\ \left(\frac{c}{D_P}\right)^{d} D_P + e$$

Assuming:

$a = 1$ $d = .333$

$b = .001039$ $e = 0$

$c = 198$

this becomes

$$C_{LI} = 1.1\ (.001039)\ \left(\frac{198}{D_P}\right)^{.333} D_P$$

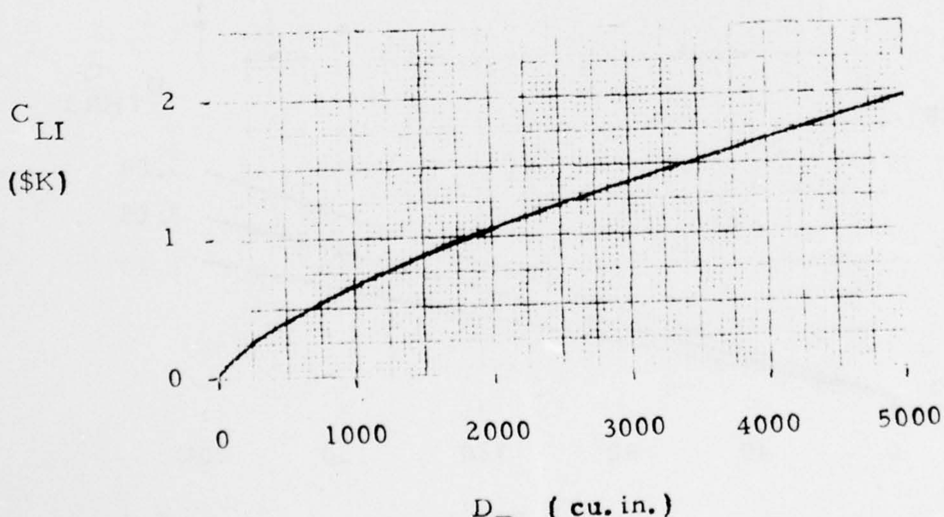


FIGURE 17
SOLID ROCKET NOZZLE COST (U)

Reference: Equation 5 Section 2.3.1

$$C_{NOZ} = 3.3\ a\ b\ W_N\ (c + d\ D_{THRT} + e\ R_{NOZI}) + f$$

Assuming:

$a = 1$	$d = 1.4045$	$R_{NOZI} = 1.7$
$b = .001755$	$e = 1.5487$	
$c = 4.6788$	$f = 0$	

this becomes

$$C_{NOZ} = 3.3\ (.001755)\ W_N\ (4.6788 + 1.4045\ D_{THRT} + 2.633)$$

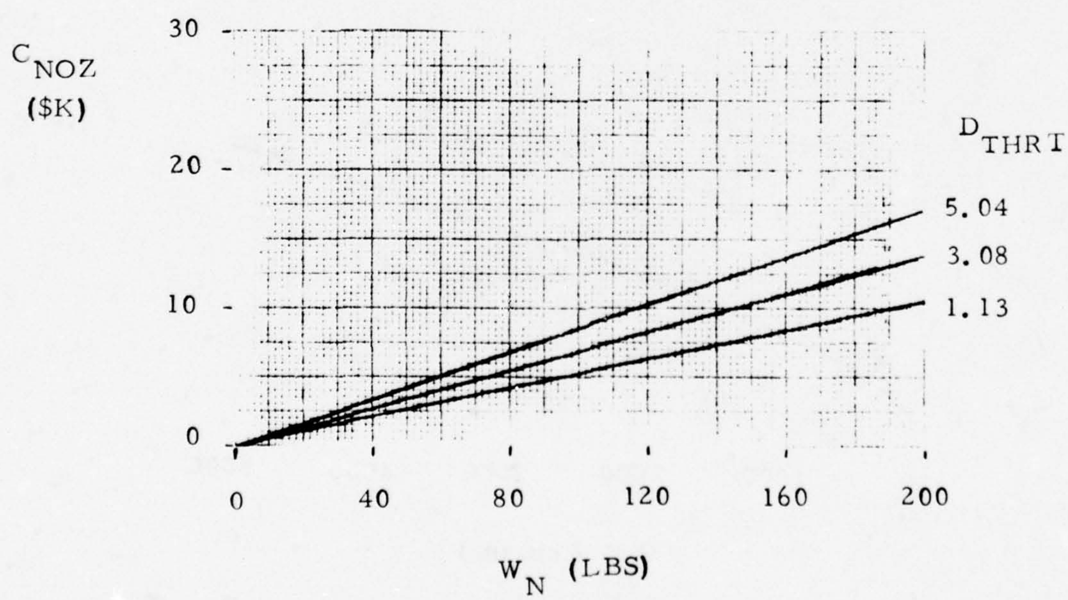


FIGURE 18

SOLID ROCKET RAW PROPELLANT COST (U)

Reference: Equation 6 Section 2.3.1

$$C_{PRC} = a\, W_P \left(\frac{b}{c\, W_P}\right)^d \left(\frac{f}{e}\right) + g$$

Assuming:

a = 1 e = 1000

b = 100000 f = 1

c = 32.006 g = 0

d = .069

this becomes

$$C_{PRC} = \frac{W_P}{1000} \left(\frac{100000}{32.006\, W_P}\right)^{.069}$$

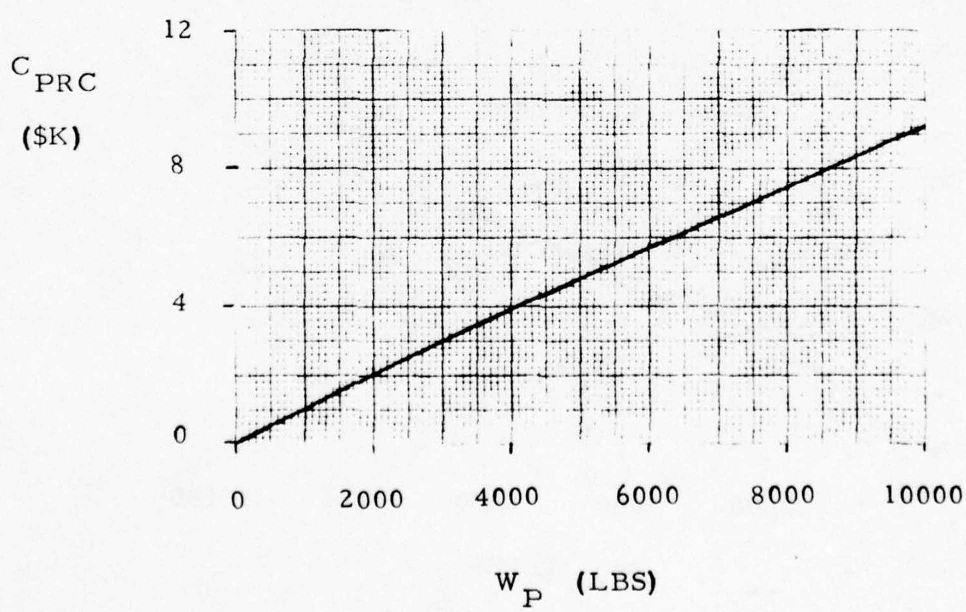


FIGURE 19
SOLID ROCKET PROPELLANT LOADING COST (U)

Reference: Equation 7 Section 2.3.1

$$C_{PLC} = 1.1\ a\ b\ W_P \left(\frac{c}{d\ W_P}\right)^e + f$$

Assuming:

a = 1 d = 32.006

b = .00343 e = .387

c = 100000 f = 0

this becomes

$$C_{PLC} = 1.1\ (.00343)\ W_P \left(\frac{100000}{32.006\ W_P}\right)^{.387}$$

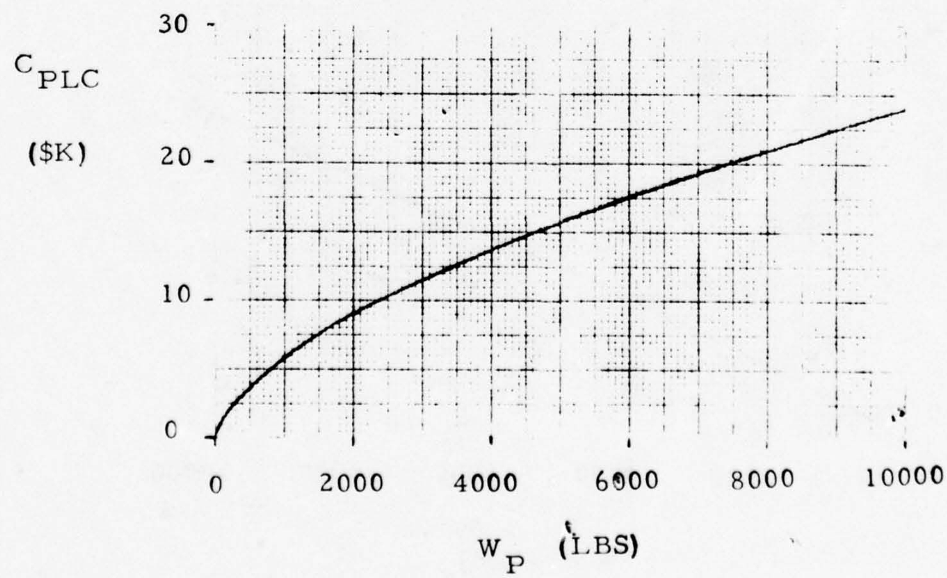


FIGURE 20
SOLID ROCKET RDT&E COST (U)

Reference: Equation 11 Section 2.3.1

$$C_{SRRD} = a\,(1 + P_{SPC})\left[b\,c\,(D \cdot W_M)^d\ 1.462 + e\right]$$

Assuming:

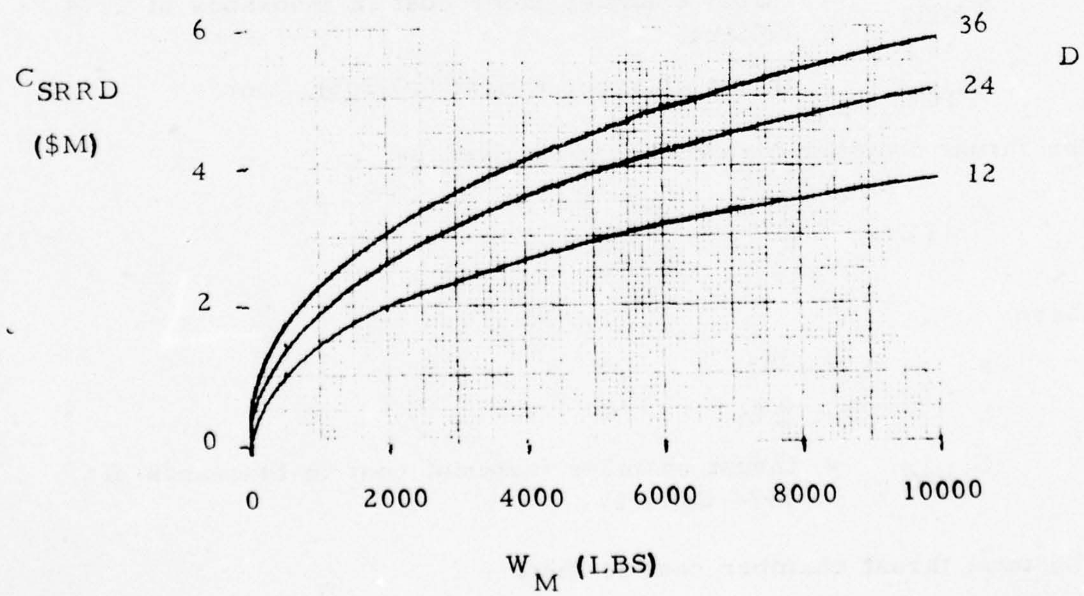
a = 1 d = .4263

b = 1 e = 0

c = 16.551 P_{SPC} = .1

this becomes

$$C_{SRRD} = (1.1)\ 16.551\ (D \cdot W_M)^{.4263}\ 1.462$$



2.3.2 Liquid Propulsion System

The following equations are for the liquid propulsion system which consists of a pump-fed engine and a regeneratively cooled thrust chamber. Tank pressurization for providing the necessary pump net positive suction head is provided by stored nitrogen gas. All equations except where indicated were taken from Reference 8. All equations in Reference 8 are for the 100th unit. They were converted to first unit costs by multiplying by the factor, 3.85 as recommended in the reference.

2.3.2.1 Thrust Chamber

The thrust chamber labor cost is given by:

$$C_{LTC} = \frac{a\, b\, (W_{TC})^{c}}{1000} \qquad (1)$$

where:

a = the labor rate, dollars/hour

b = 639.1

c = 0.5

C_{LTC} = thrust chamber labor cost in thousands of 1974 dollars.

W_{TC} = thrust chamber weight (20-200), lbm

The thrust chamber material cost is given by:

$$C_{MTC} = 1.35\, \frac{a\, (W_{TC})^{b}}{1000} \qquad (2)$$

where:

a = 201

b = 0.75

C_{MTC} = thrust chamber material cost in thousands of 1974 dollars.

The total thrust chamber cost is then:

$$C_{TC} = a\,(C_{LTC} + C_{MTC}) + b \qquad (3)$$

Fig. 21

where:

a	=	factor to adjust thrust chamber cost for exceptional problems or windfalls.
b	=	miscellaneous cost in thousands of 1974 dollars.
C_{TC}	=	total thrust chamber cost, thousands of dollars

Figure 21 is a plot of thrust chamber cost for typical chamber weights.

2.3.2.2 Turbopump

The turbopump labor cost is given by:

$$C_{LTP} = \frac{a\,b}{1000}\,(W_{TP} - W_{GG} - W_{SC})^{c} \qquad (4)$$

Fig. 22

where

a	=	labor rate, dollars per hour
b	=	234.9
c	=	0.63
C_{LTP}	=	turbopump cost in thousands of 1974 dollars.
W_{TP}	=	turbopump weight (70-150), lbm
W_{GG}	=	gas generator weight (2-20), lbm
W_{SC}	=	start cartridge weight (5-10), lbm

The weights of the gas generator and start cartridge are subtracted from W_{TP} in equation (4) because the value of W_{TP} as it is calculated in the CGSM includes the gas generator and start cartridge weights whereas the cost equation from Reference 8 is for just the bare turbopump. The costs of the gas generator and start cartridge are calculated in later equations.

Figure 22 is a plot of turbopump labor costs using the above equation.

The turbopump material costs are calculated by:

$$C_{MTP} = \frac{1.35\,a}{1000}(W_{TP} - W_{GG} - W_{SC})^{b} \qquad (5)$$

Fig. 23

where:

$a = 340.7$

$b = 0.81$

C_{MTP} = turbopump material cost, thousands of 1974 dollars.

Turbopump material cost is plotted in Figure 23. The gas generator and start cartridge labor cost is given by:

$$C_{LGG} = \frac{a\, b}{1000} (W_{GG} + W_{SC})^c \qquad (6)$$

Fig. 24

where:

a = labor rate, dollars per hour

$b = 361.9$

$c = 0.5$

C_{LGG} = gas generator and start cartridge cost, thousands of 1974 dollars.

A plot of equation (6) is shown in Figure 24. The gas generator and start cartridge material cost is given by:

$$C_{MGG} = \frac{1.35\, a}{1000} (W_{GG} + W_{SC})^b \qquad (7)$$

Fig. 25

where:

$a = 174.8$

$b = 0.86$

C_{MGG} = gas generator and start cartridge cost in thousands of 1974 dollars.

Figure 25 is a plot of gas generator and start cartridge material cost.

And finally the cost of the turbopump delivery system, including gas generator and start cartridge is:

$$C_{TP} = a\,(C_{LTP} + C_{MTP} + C_{LGG} + C_{MGG}) + b \qquad (8)$$

where:

a = factor to adjust turbopump system costs for exceptional problems or windfalls.

b = miscellaneous cost in thousands of 1974 dollars.

C_{TP} = turbopump system cost, thousands of 1974 dollars.

2.3.2.3 Engine Miscellaneous Equipment

The engine miscellaneous labor costs is given by:

$$C_{LM} = \frac{a\,b}{1000} (W_{LV})^c \qquad (9)$$

where:

a = factor to adjust thrust chamber cost for exceptional problems or windfalls.

b = 125.9

c = 0.7

C_{LM} = miscellaneous labor cost, thousands of 1974 dollars.

W_{LV} = miscellaneous hardware weight (0), lbm

and the engine miscellaneous material cost is:

$$C_{MM} = \frac{1.35\, a\, (W_{LV})^b}{1000} \qquad (10)$$

where:

a = 1355

b = 0.63

C_{MM} = material cost, thousands of 1974 dollars

The engine total miscellaneous cost is then:

$$C_M = a\,(C_{LM} + C_{MM}) + b$$

where:

a = factor to adjust engine miscellaneous cost for exceptional problems or windfalls

b = miscellaneous cost in thousands of 1974 dollars.

2.3.2.4 Pressurization System

As indicated previously, the propellant tanks are pressurized by nitrogen from a high pressure storage bottle. The cost equation for the storage bottle were obtained by curve fitting vendor data (Reference 7) as shown in the following table.

GAS TANK COST DATA

Tank Volume, cubic inches	Cost
185	$ 1650
445	2800
650	3300
870	3500

The final cost equation for the storage bottle is:

$$C_{GT} = \frac{1.059\, a\, (V_{GT})^{b}}{1000} \qquad (12)$$

where:

a = 122.83

b = 0.4949

V_{GT} = storage bottle volume (100-1000), cubic inches

The factor, 1.059 converts from 1970 to 1974 dollars.

The cost equation for the entire pressurization system is given by:

$$C_{PS} = a\,(C_{GT} + b + c) + d \qquad (13)$$

Fig. 26

where:

a = factor to adjust the pressurization system cost for exceptional problems or windfalls.

b = regulator cost in thousands of 1974 dollars (0.275)

c = miscellaneous valves cost in thousands of 1974 dollars (0.275).

d = miscellaneous cost term in thousands of 1974 dollars.

C_{PS} = pressurization system cost in thousands of 1974 dollars.

Figure 26 is a plot of pressurization system cost.

2.3.2.5 Propellant Tankage

For the cost equations for the liquid propulsion system tankage, vendor cost data (Reference 9) shown below were combined with cost equations from Reference 1. This approach was taken in order to take advantage of recent vendor data and yet maintain the flexibility in regard to material selection provided by the type of cost equations presented in Reference 1. The approach taken in combining the actual cost data with the CAMS equations is outlined below.

First the cost data were plotted in order to obtain an equation for cost as a function of tank weight. The plot of the data are shown in the table below.

PROPELLANT TANK COST DATA

Tank Weight, lbm	Cost
7.2	$ 24,200
7.2	30,000
7.9	24,200
7.9	29,000
8.7	29,000
10.09	33,000
10.97	30,000
12.17	31,000
15.75	31,000

The resulting equation is:

$$C = 16500\ W^{0.2608}$$

where:

C = tank cost, dollars

W = tank weight, lbs

Breaking this equation into two equations for labor cost and material cost using the ratio from Reference 1 of:

$$\frac{AC}{BC} = 0.4535$$

where:

AC = reference labor cost per pound

BC = reference material cost per pound

The two equations become:

$$C_L = 5148\ W^{0.2608}$$

$$C_M = 11352\ W^{0.2608}$$

where:

C_L = tank labor cost, dollars

C_M = tank material cost, dollars

Since the above equations are for titanium, they were adjusted back to the base equations for 300 maraging steel (which has, by definition has a complexity factor of unity for both the labor cost and material cost equations) by dividing the coefficient of each of the two equations by its respective complexity factor for titanium (1.0 for labor cost and 2.571 for material cost). This then gives a set of tankage cost equations which can use the complexity factors for a number of different tankage materials to arrive at tank cost.

Since there are only three materials out of the list of options presented in Reference 1 suitable for liquid propellant tankage, the labor cost and material cost equations were combined for each material for convenience and are presented below.

$$C_T = \frac{a\, b\, (1.1)}{1000} (W_T)^c + d \qquad (14)$$

Fig. 27

where:

a = factor used to adjust tankage cost for exceptional problems or windfalls.

b = 7191 (stainless steel)

= 2165 (aluminum)

= 16499 (titanium)

c = 0.2608

d = miscellaneous tank cost in thousands of 1974 dollars

C_T = tank cost in thousands of 1974 dollars.

W_T = tank weight (20-150), lbm

Propellant tankage cost is plotted in Figure 27.

2.3.2.6 Propellants

The fuel and oxidizer cost is given by:

$$C_P = \frac{a}{1000}\left[b \left(\frac{c}{W_O}\right)^d W_O + e \left(\frac{c}{W_F}\right)^d W_F \right] + f \qquad (15)$$

Fig. 28

where:

a = factor used to adjust propellant cost for exceptional problems or windfalls.

b = oxidizer cost, dollars per pound

c = 3125

d = 0.069

e = fuel cost, dollars per pound

f = miscellaneous propellant cost in thousands of 1974 dollars.

C_P = propellant cost, thousands of 1974 dollars.

W_O = oxidizer weight (100-1000), lbm

W_F = fuel weight (50-500), lbm

Figure 28 is a plot of propellant cost.

The propellant loading cost is given by:

$$C_{PL} = a\,b\,(1.1)\left(\frac{c}{W_P}\right)^d W_P + e \qquad (16)$$

Fig. 29

where:

a = factor used to adjust propellant loading cost for exceptional problems or windfalls.

b = 10^{-4}

c = 3125

d = 0.029

e = miscellaneous propellant loading cost in thousands of 1974 dollars.

C_{PL} = propellant loading cost, thousands of 1974 dollars.

W_P = propellant weight (150-1500), lbm

Propellant loading cost is shown in Figure 29.

2.3.2.7 Safe and Arm

The cost of the safe and arm system is given by:

$$C_{SA} = a \qquad (17)$$

where

a = safe and arm cost in thousands of 1974 dollars.

2.3.2.8 First Unit Cost

The first unit cost of the liquid propulsion system then becomes:

$$C_{LRFU} = \left[1.15\,a\,b\,(C_{TC} + C_{TP} + C_M + C_{PS} + C_T + C_P + C_{PL} + C_{SA}) + a\,c\right](1 + P_{LPC}) \quad (18)$$

where:

a = factor used to adjust cost from 1974 dollars to year of interest

b = factor used to adjust first unit cost for exceptional problems or windfalls.

c = miscellaneous cost term in thousands of 1974 dollars

C_{LRFU} = propulsion system first unit cost in thousands of 1974 dollars.

P_{LPC} = contractors profit margin (fraction)

2.3.2.9 RDT&E Cost

The RDT&E cost for the liquid propulsion system was obtained from Reference 6 by fitting on equation to the curve in that figure. It should be noted that the RDT&E cost is only for the engine and does not include the cost for tankage which is included on the airframe RDT&E cost. The equation for the curve in Reference 6 is:

$$C = 2.3 \times 10^{-4} F + 3$$

where:

C = liquid engine RDT&E cost

F = engine thrust, lbf

The resulting equation is:

$$C_{LRRD} = a\left[b\,(1.462\,d\,F_{MAX} + e) + c\right](1 + P_{LPC}) \qquad (19)$$

Fig. 30

where:

a = factor to adjust from 1974 dollars to year of interest.

b = factor used to adjust cost for exceptional problems or windfalls.

c = miscellaneous cost term in thousands of 1974 dollars.

d = 0.231

e = 3000

C_{LRRD} = liquid engine RDT&E cost in thousands of 1974 dollars.

F_{MAX} = maximum engine thrust (1000-10,000), lbf

P_{LPC} = contractors profit fraction

Figure 30 is a plot of liquid propulsion system RDT&E cost.

2.3.2.10 Total System Cost

The total liquid propulsion system cost (excluding tankage RDT&E cost as explained above) is given by:

$$C_{LRT} = C_{LRRD} + C_{LRFU}$$

where:

C_{LRF} = liquid propulsion system cost in thousands of 1974 dollars.

FIGURE 21

LIQUID ROCKET THRUST CHAMBER FIRST UNIT COST (U)

Reference: Equation 3 Section 2.3.2

$$C_{TC} = a \left\{ \frac{b\, c\, (W_{TC})^{d}}{1000} + \frac{1.35\, e\, (W_{TC})^{f}}{1000} \right\} + g$$

Assuming:

a = 1	e = 201
b = 10	f = .75
c = 639.1	g = 0
d = .5	

this becomes

$$C_{TC} = \frac{10\,(639.1)\,(W_{TC})^{.5} + 1.35\,(201)\,(W_{TC})^{.75}}{1000}$$

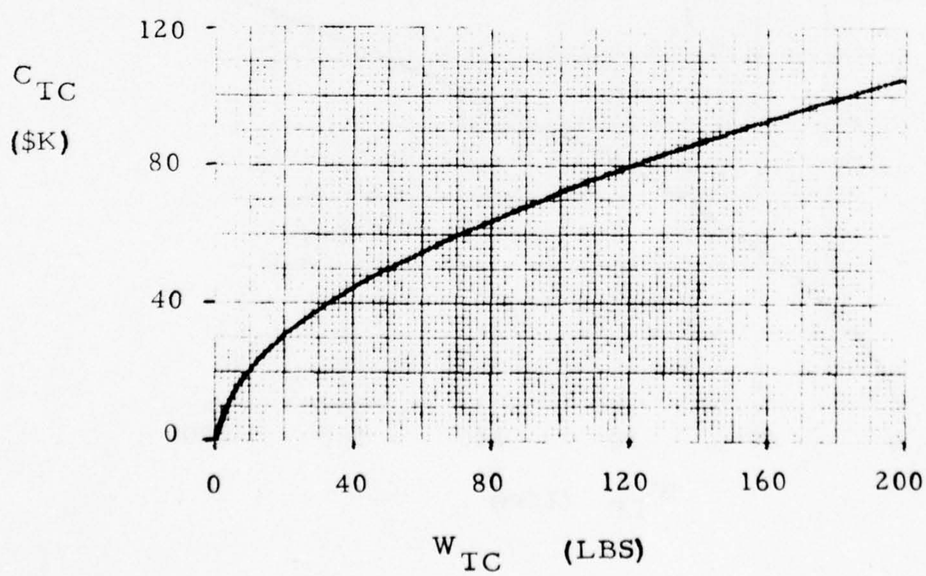


FIGURE 22
LIQUID ROCKET TURBOPUMP FIRST UNIT COST (LABOR) (U)

Reference: Equation 4 Section 2.3.2

$$C_{LTP} = \frac{a\,b\,(W_{TP} - W_{GG} - W_{SC})^{c}}{1000}$$

Assuming:

$a = 10$ $\quad W_{GG} = .1\,W_{TP}$

$b = 234.9$ $\quad W_{SC} \approx .3\,W_{GG}$

$c = .63$

this becomes

$$C_{LTP} = \frac{10\,(234.9)\,(W_{TP} - W_{GG} - W_{SC})^{.63}}{1000}$$

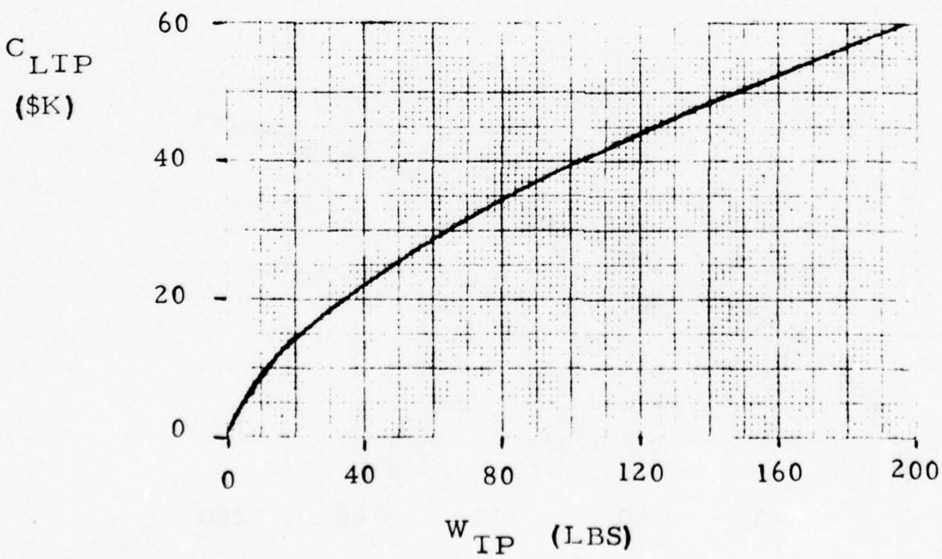


FIGURE 23
LIQUID ROCKET TURBOPUMP FIRST UNIT COST (MATERIAL) (U)

Reference: Equation 5 Section 2.3.2

$$C_{MTP} = \frac{1.35\, a\, (W_{TP} - W_{GG} - W_{SC})^{b}}{1000}$$

Assuming:

$a = 340.7$ $\quad W_{GG} = .1\, W_{TP}$

$b = .81$ $\quad W_{SC} \approx .3\, W_{GG}$

this becomes

$$C_{MTP} = \frac{1.35\,(340.7)\,(W_{TP} - W_{GG} - W_{SC})^{.81}}{1000}$$

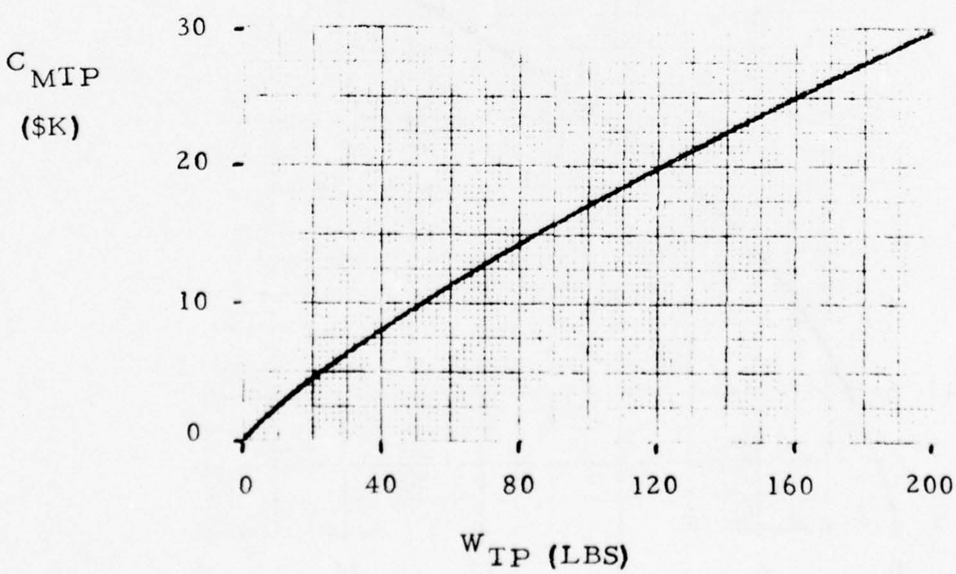


FIGURE 24
LIQUID ROCKET GAS GENERATOR FIRST UNIT COST (LABOR) (U)

Reference: Equation 6 Section 2.3.2

$$C_{LGG} = \frac{a\,b\,(W_{GG} + W_{SC})^{c}}{1000}$$

Assuming:

$a = 10$ $\qquad W_{SC} \approx .3\,W_{GG}$

$b = 361.9$

$c = .5$

this becomes

$$C_{LGG} = \frac{10\,(361.9)\,(W_{GG} + W_{SC})^{.5}}{1000}$$

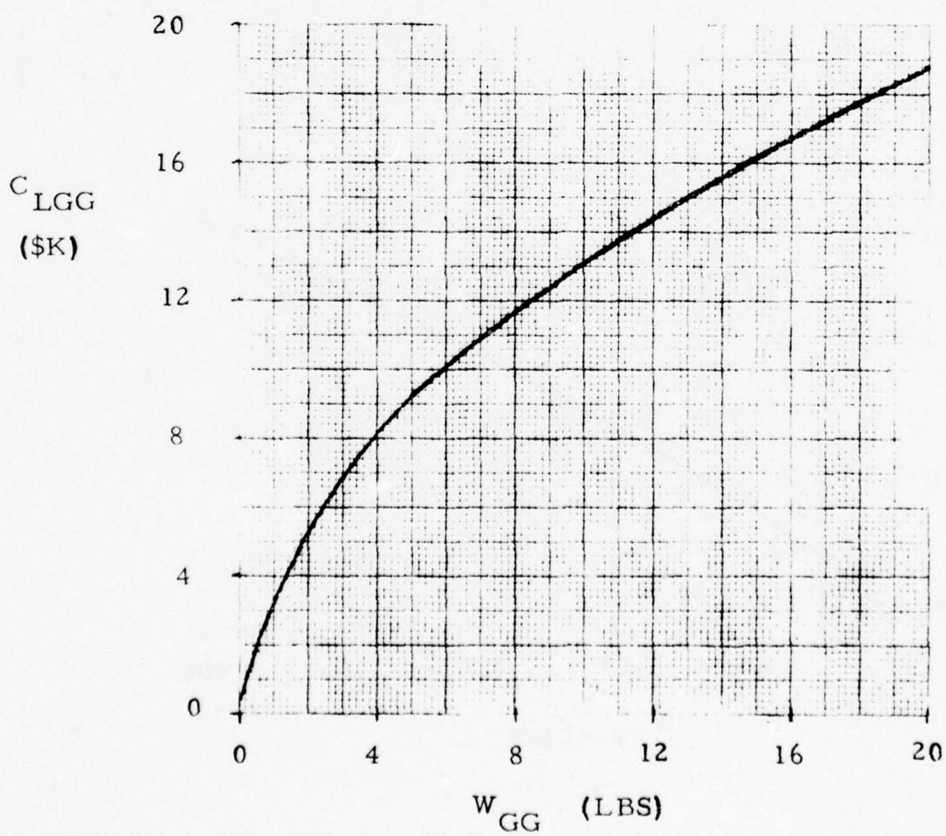


FIGURE 25
LIQUID ROCKET GAS GENERATOR FIRST UNIT COST (MATERIAL) (U)

Reference: Equation 7 Section 2.3.2

$$C_{MGG} = \frac{1.35a(W_{GG} + W_{SC})^{b}}{1000}$$

Assuming:

a = 174.8 $\quad W_{SC} \approx .3\, W_{GG}$

b = .86

this becomes

$$C_{MGG} = \frac{1.35\ (174.8)\ (W_{GG} + W_{SC})^{.86}}{1000}$$

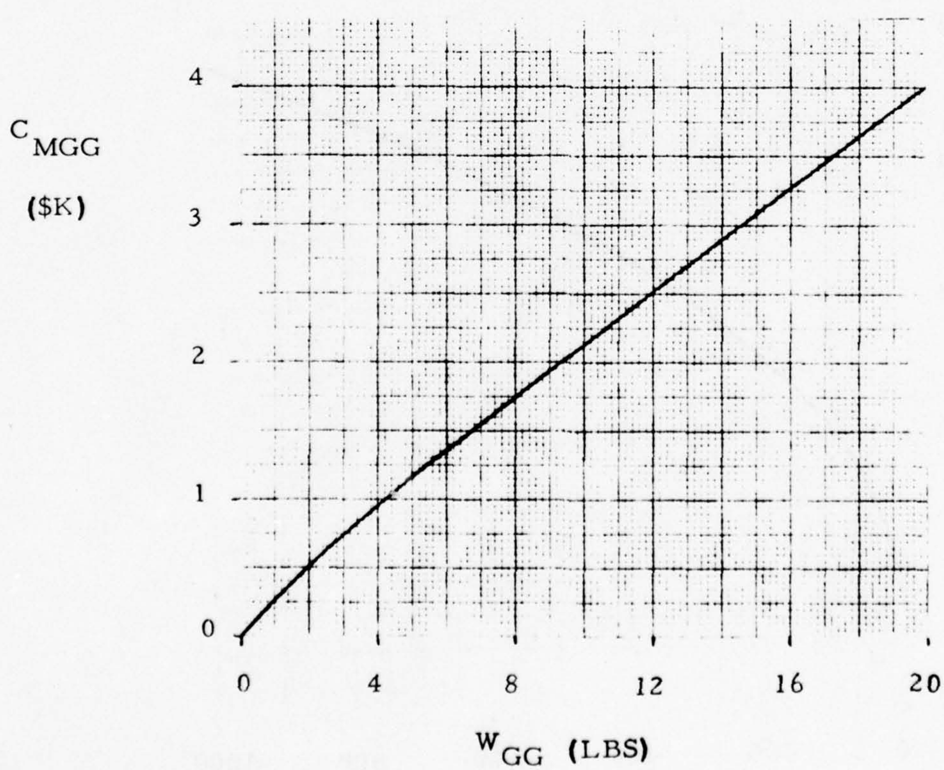


FIGURE 26

LIQUID ROCKET PRESSURIZATION SYSTEM FIRST UNIT COST (U)

Reference: Equation 13 Section 2.3.2

$$C_{PS} = a\left(\frac{1.059\ b\ V_{GT}^{\ c}}{1000} + d + e\right) + f$$

Assuming:

a	=	1	d	=	.275
b	=	122.83	e	=	.275
c	=	.4949	f	=	0

this becomes:

$$C_{PS} = \frac{1.059\ (122.83)\ V_{GT}^{\ .4949}}{1000} + .275 + .275$$

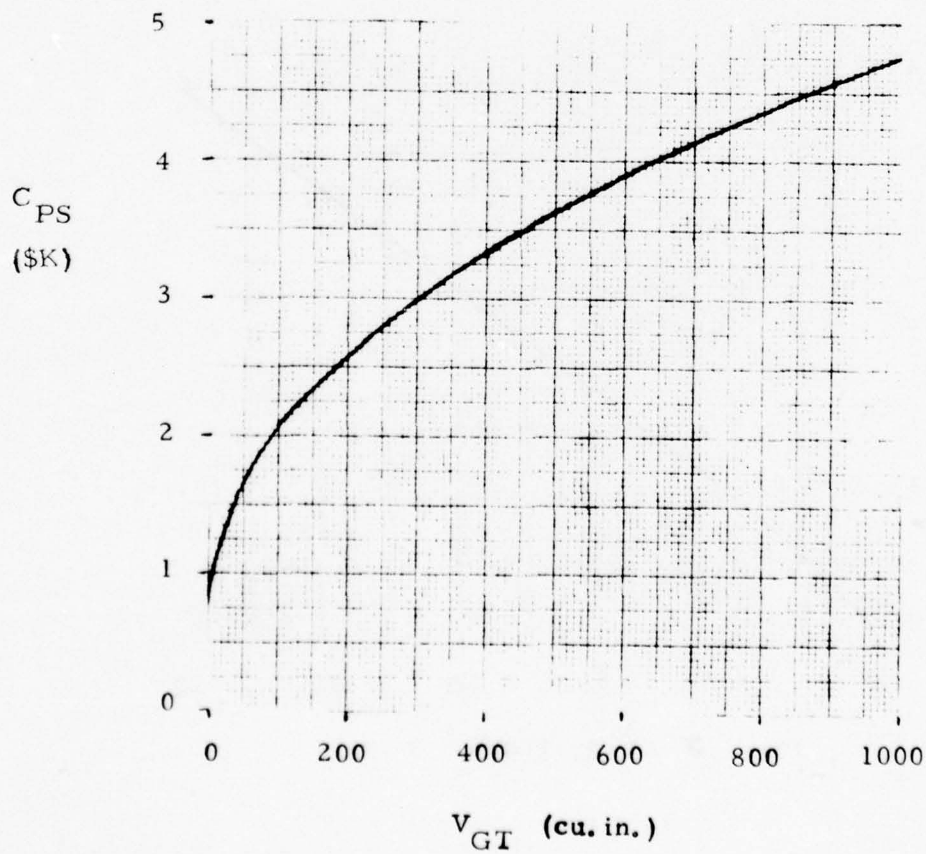


FIGURE 27
LIQUID ROCKET TANKAGE FIRST UNIT COST (U)

Reference: Equation 14 Section 2.3.2

$$C_T = 1.1 \frac{a\,b\,W_T^{\,c}}{1000} + d$$

Assuming:

a = 1 c = .2608

b = 7191 d = 0

this becomes:

$$C_T = \frac{1.1\,(7191)\,W_T^{\,.2608}}{1000}$$

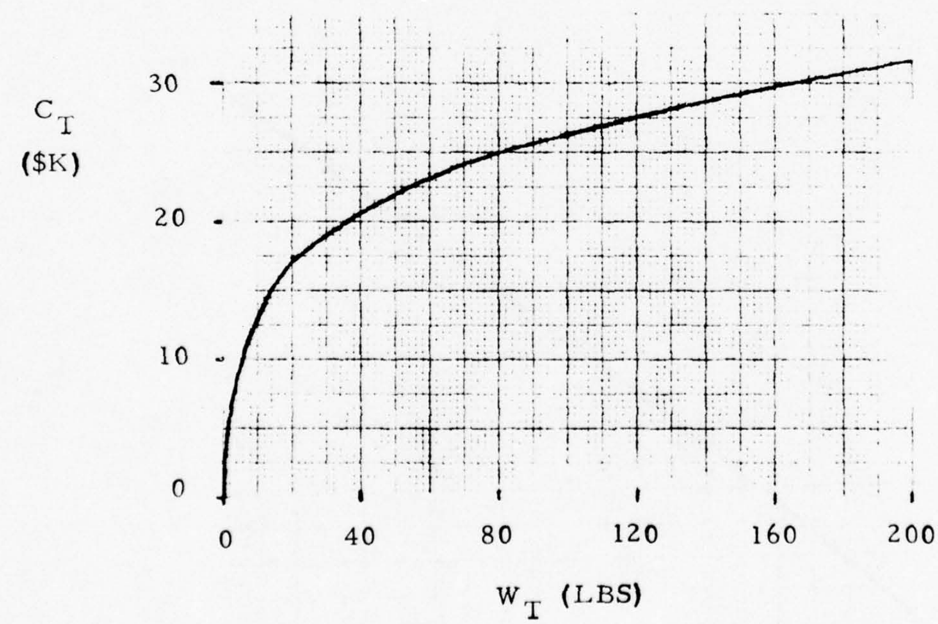


FIGURE 28

LIQUID ROCKET FUEL/OXIDIZER FIRST UNIT COST (U)

Reference: Equation 15 Section 2.3.2

$$C_P = \frac{a\left(b\left(\frac{c}{W_o}\right)^d W_o + e\left(\frac{c}{W_F}\right)^d W_F\right)}{1000} + f$$

Assuming:

$a = 1$	$d = .069$	$W_o = 2\,W_F$
$b = .11$	$e = 1.18$	
$c = 3125$	$f = 0$	

this becomes:

$$C_P = \frac{.11\left(\frac{3125}{W_o}\right)^{.069} W_o + 1.18\left(\frac{3125}{W_F}\right)^{.069} W_F}{1000}$$

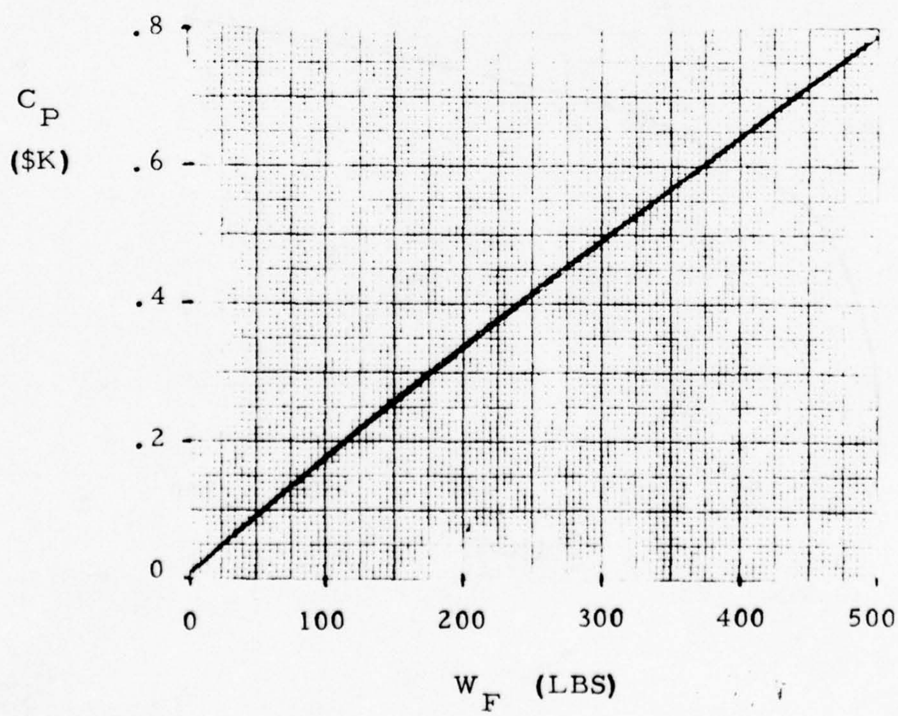


FIGURE 29

LIQUID ROCKET PROPELLANT LOADING FIRST UNIT COST (U)

Reference: Equation 16 Section 2.3.2

$$C_{PL} = 1.1\, a\, b\left(\frac{c}{W_P}\right)^{d} W_P + e$$

Assuming:

$a = 1$ $d = .029$

$b = 10^{-4}$ $e = 0$

$c = 3125$

this becomes

$$C_{PL} = 1.1\,(10^{-4})\left(\frac{3125}{W_P}\right)^{.029} W_P$$

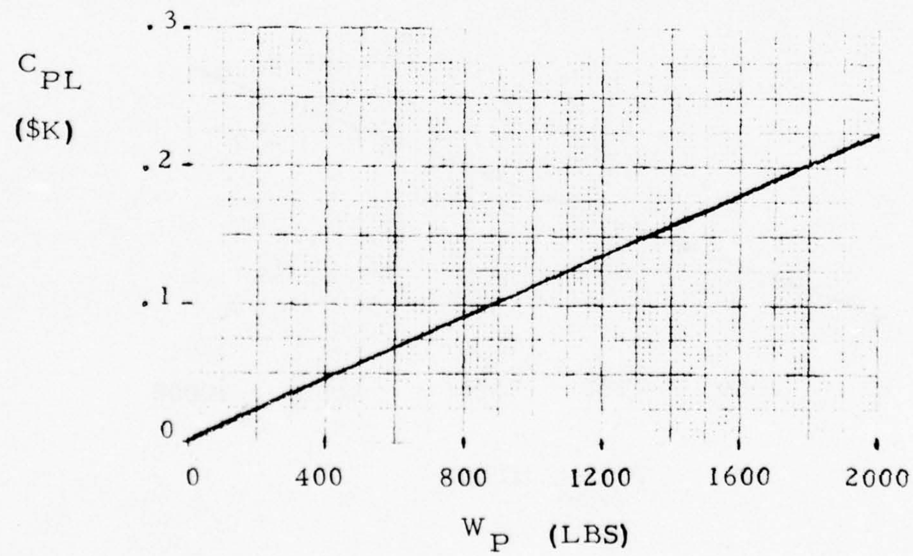


FIGURE 30
LIQUID ROCKET RDT&E COST (U)

Reference: Equation 19 Section 2.3.2

$$C_{LRRD} = (a_1 b_1 (a_2 b_2\ 1.462\ F_{MAX} + c_2) + c_1)(1 + P_{LPC})$$

Assuming:

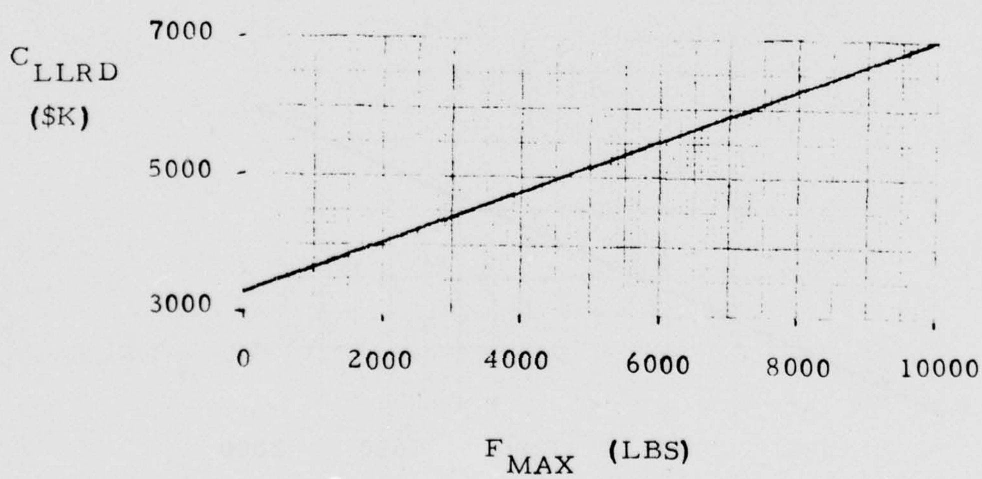
$a_1 = 1$ $a_2 = 1$ $P_{LPC} = .1$

$b_1 = 1$ $b_2 = .231$

$c_1 = 0$ $c_2 = 3000$

this becomes:

$$C_{LRRD} = (1.462\ (.231)\ F_{MAX} + 3000\ )\ 1.1$$



2.3.3 TURBOJET PROPULSION SYSTEM

The following Cost Estimating Relationships are for the turbojet propulsion system which consists of engine, tankage and fuel. All accessory equipment such as fuel pump, lubrication systems, etc., are included as a part of the engine.

2.3.3.1 Turbojet Engine

The CER for the turbojet engine first unit cost was taken from Reference 4. It covers three different cost bands, depending upon the sophistication of the engine which is defined in terms of turbine inlet temperatures. In general, a higher turbine inlet temperature requires the use of more exotic (and more expensive) materials and a more complex design.

The cost of the engine is given by:

$$C_{ETJ} = a\, b\, (F_{NET})^{c}\, (1.222) + d \qquad (1)$$

Fig. 31

where:

- a = factor used to adjust engine cost for exceptional problems or windfalls.
- b = 1.52 for $T_4 < 2060^\circ R$
  - = 3.08 for $2060 \leq T_4 \leq 2360^\circ R$
  - = 5.64 for $T_4 > 2360^\circ R$
- c = 0.6
- d = miscellaneous cost term in thousands of 1974 dollars.
- C_{ETJ} = turbojet engine cost in thousands of 1974 dollars.
- F_{NET} = engine design net thrust (2000-8000), lbf

A plot of typical turbojet engine cost is shown in Figure 31.

2.3.3.2 Tankage

The equations for the fuel tank are the same as those developed for the liquid propulsion system and their development is described completely in that section of the report.

The tankage labor cost is given by:

$$C_{TL} = 1.222\, a\, C_{FT} (W_T)^b \qquad (2)$$

Fig. 32

where:

$a = 5.148$

$b = 0.2608$

C_{TL} = tank labor cost in thousands of 1974 dollars.

C_{FT} = 0.2 for aluminum

= 1.0 for steel

= 1.0 for titanium

W_T = tank weight(25-100), lbm.

The factor, C_{FT} is a tank fabrication complexity factor which reflects the relative difficulty in fabricating the different materials.

The tank material cost is given by:

$$C_{TM} = 1.059\, a\, P_{FT} (W_T)^b \qquad (3)$$

Fig. 33

where:

$a = 4.415$

$b = 0.2608$

C_{TM} = tank material cost in thousands of 1974 dollars.

P_{FT} = 0.257 for aluminum

= 1.0 for steel

= 2.571 for titanium

The factor, P_{FT} reflects the relative difference in material cost.

The total tank cost is then:

$$C_T = a\,(C_{TL} + C_{TM}) + b \qquad (4)$$

where:

a = factor used to adjust tank cost for exceptional problems or windfalls.

b = miscellaneous tank cost in thousands of 1974 dollars.

C_T = total tank cost in thousands of 1974 dollars.

Typical tankage labor cost and material cost are shown in Figures 32 and 33.

2.3.3.3 Fuel

The fuel cost is given by:

$$C_{TJLF} = a\,b\left(\frac{c}{W_F}\right)^d W_F + e \qquad (5)$$

Fig. 34

where:

a = factor used to adjust fuel cost for exceptional problems or windfalls

b = fuel cost in thousands of 1974 dollars per pound

c = 3125

d = 0.069

e = miscellaneous cost term in thousands of 1974 dollars

C_{TJLF} = fuel cost in thousands of 1974 dollars.

W_F = fuel weight, lbm

Figure 34 is a plot of typical fuel cost.

The fuel loading cost is given by:

$$C_{TJLFL} = 1.1\,a\,b\left(\frac{c}{W_F}\right)^d (W_F) + e \qquad (6)$$

Fig. 35

where:

a	=	factor used to adjust fuel loading cost for exceptional problems or windfalls.
b	=	0.0001
c	=	3125
d	=	0.029
e	=	miscellaneous cost in terms of thousands of 1974 dollars.
C_{TJLFL}	=	fuel loading cost in thousands of 1974 dollars

Figure 35 is a plot of typical fuel loading cost.

2.3.3.4 First Unit Cost

The CER for the first unit cost is :

$$C_{TJFU} = a\,(1 + P_{TJC})\left[1.15\, b\,(C_{ETJ} + C_T + C_{TJLF} + C_{TJLFL}) + c\right] \qquad (7)$$

where

a	=	inflation factor used to adjust from 1974 dollars to year of interest
b	=	factor used to adjust first unit cost for exceptionaly problems or windfalls.
c	=	miscellaneous cost in thousands of 1974 dollars
C_{TJFU}	=	turbojet propulsion system first unit cost in terms of thousands of 1974 dollars.
P_{TJC}	=	contractors profit margin (fraction)

2.3.3.5 RDT&E Cost

The CER for the turbojet propulsion system RDT&E was obtained from Reference 4 and is given by:

$$C_{TJRD} = a\left\{b\left[1.462\, d\,(F_{MAX})^{e}\right] + c\right\}(1 + P_{TJC}) \qquad (10)$$

where:

a	=	factor used to adjust from 1974 dollars to year of interest
b	=	factor used to adjust RDT&E costs for exceptional problems or windfalls
c	=	miscellaneous costs in thousands of 1974 dollars

d = 16.22

e = 0.7436

C_{TJRD} = turbojet propulsion system RDT&E cost in thousands of 1974 dollars.

F_{MAX} = design maximum thrust, lbf

P_{TJC} = contractors profit margin (fraction)

Figure 36 is a plot of typical turbojet propulsion system RDT&E cost.

2.3.3.6 Total Propulsion System Cost

The total propulsion system cost is given by:

$$C_{TJT} = C_{TJFU} + C_{TJRD}$$

where:

C_{TJT} = total turbojet propulsion system cost in thousands of 1974 dollars.

FIGURE 31
TURBOJET ENGINE COST (U)

Reference: Equation 1 Section 2.3.3

$$C_{ETJ} = a\ b\ 1.222\ F_{NET}^{\ c} + d$$

Assuming:

a = 1 c = .6

b = 3.08 d = 0

this becomes

$$C_{ETJ} = 3.08\ (1.222)\ F_{NET}^{\ .6}$$

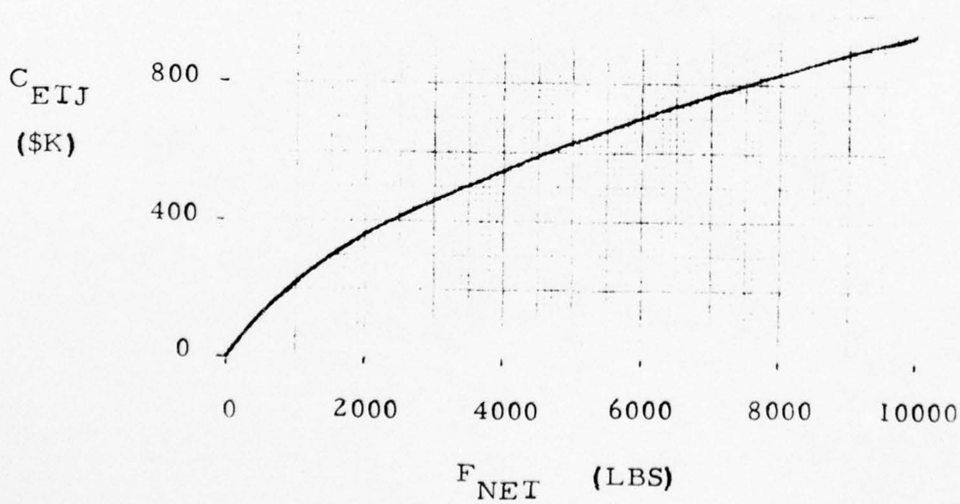


FIGURE 32
TURBOJET TANKAGE LABOR COST (U)

Reference: Equation 2 Section 2.3.3

$$C_{TL} = 1.059\ a\ C_{FT}\ W_T^{\ b}$$

Assuming:

$a = 5.148 \qquad C_{FT} = 1$

$b = .2608$

this becomes

$$C_{TL} = 1.059\ (5.148) W_T^{\ .2608}$$

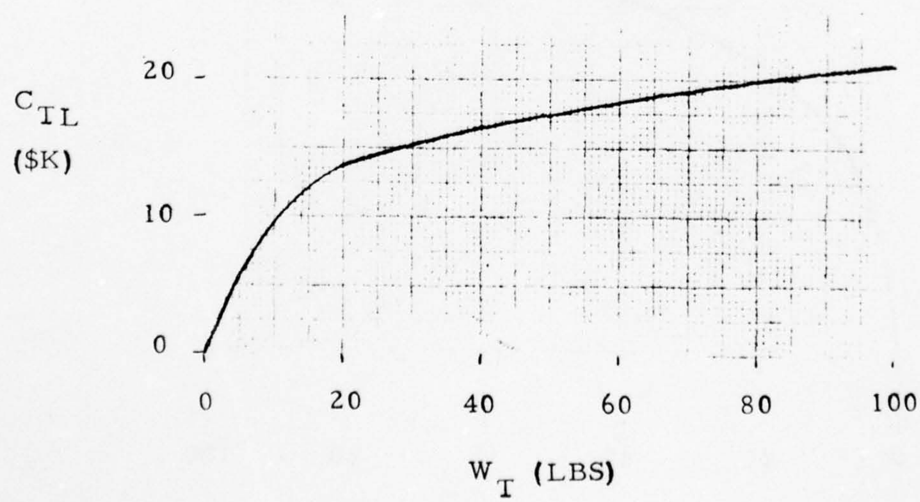


FIGURE 33
TURBOJET TANKAGE MATERIAL COST (U)

Reference: Equation 3 Section 2.3.3

$$C_{TM} = 1.059\ a\ P_{FT}\ W_T^{\ b}$$

Assuming:

$a = 4.415$ $P_{FT} = 1$

$b = .2608$

this becomes

$$C_{TM} = 1.059\ (4.415) W_T^{\ .2608}$$

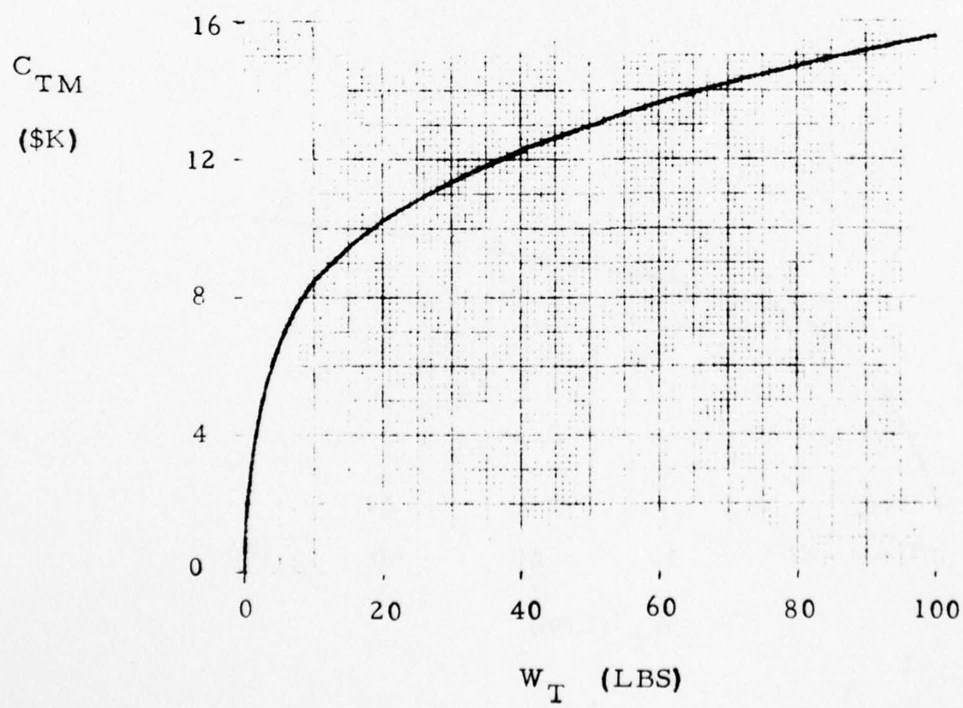


FIGURE 34

INTEGRAL AND NON-INTEGRAL RAMJET AND TURBOJET LIQUID FUEL COST (U)

Reference: Equation 5 Section 2.3.3
and Equation 12 Section 2.3.4
and Equation 12 Section 2.3.5

$$C_{TJLF} = a\, b \left(\frac{c}{W_F}\right)^{d} W_F + e$$

Assuming:

a = 1 d = .069

b = .00002 e = 0

c = 3125

this becomes

$$C_{TJLF} = .00002 \left(\frac{3125}{W_F}\right)^{.069} W_F$$

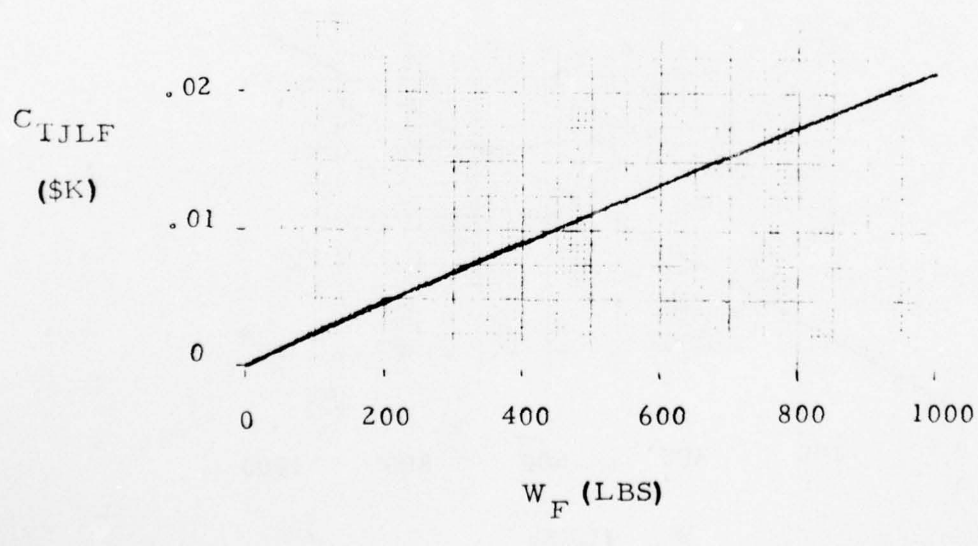


FIGURE 35
TURBOJET FUEL LOADING COST (U)

Reference: Equation 6 Section 2.3.3

$$C_{TJLFL} = 1.1\, a\, b \left(\frac{c}{W_F}\right)^{d} W_F + e$$

Assuming:

a = 1 d = .029

b = .0001 e = 0

c = 3125

this becomes

$$C_{TJLFL} = 1.1\,(.0001)\left(\frac{3125}{W_F}\right)^{.029} W_F$$

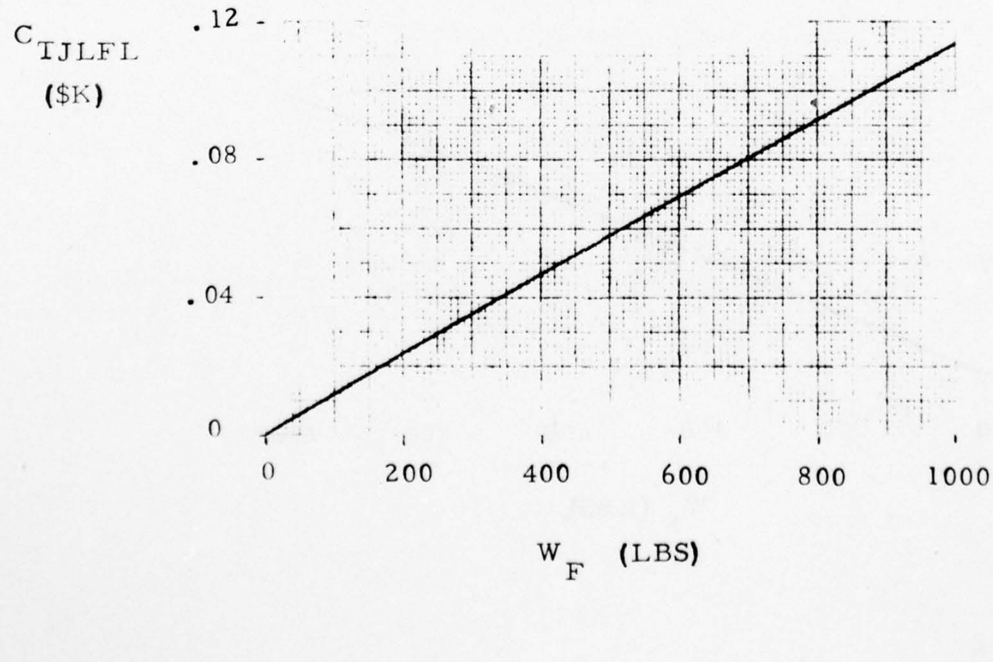


FIGURE 36
TURBOJET RDT&E COST (U)

Reference: Equation 10 Section 2.3.3

$$C_{TJRD} = a \left[b \left(1.462\, d\, F_{max}^{\,e} \right) + c \right] \left(1 + P_{TJC} \right)$$

Assuming:

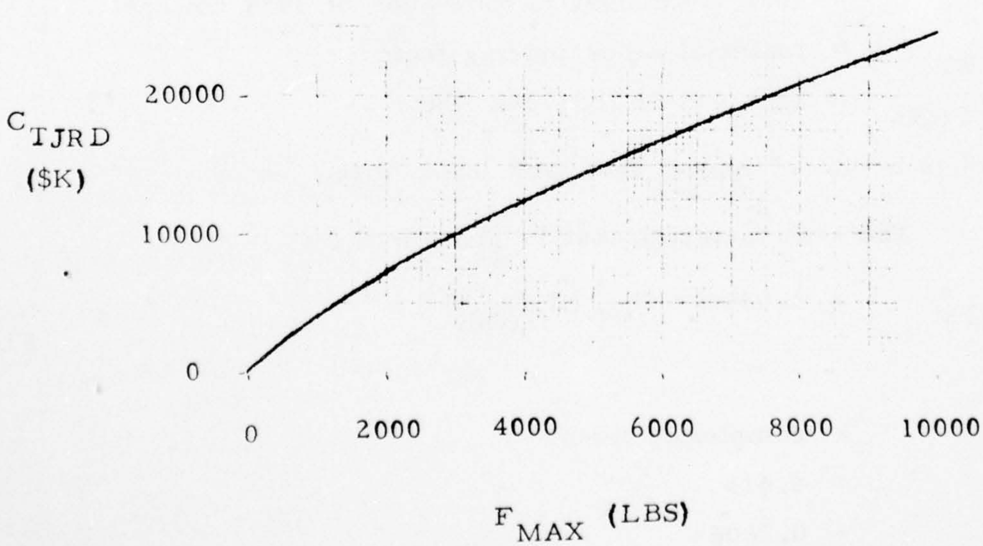
$a = 1$

$b = 1$ $d = 16.22$ $P_{TJC} = .1$

$c = 0$ $e = .7436$

this becomes

$$C_{TJRD} = 16.22\,(1.462)\,F_{max}^{\,.7436}\,(1.1)$$



2.3.4 Integral Ramjet

The following Cost Estimating Relationships are for the integral rocket-ramjet propulsion system. In this system, the case of the solid rocket booster becomes the combustion chamber for the ramjet subsequent to booster burnout. All of the equations except where noted were taken from Reference 1.

2.3.4.1 Fuel Tankage

The CER's for the fuel tankage are the same as those used for the liquid propulsion except that a larger number of tank materials are available since the ramjet fuel is compatible with a larger variety of materials.

The tank labor cost is given by:

$$C_{TL} = 1.059\ a\ b\ C_{FT}\ (W_{TANK}) \qquad (1)$$

Fig. 37

where:

- a = complexity factor
- b = 5.148
- c = 0.2608
- C_{TL} = tank labor cost in thousands of 1974 dollars
- C_{FT} = material labor pricing factor
- W_{TANK} = tank weight (25-100), lbm

Figure 37 is a plot of typical fuel tank labor cost.

The tank material cost is given by:

$$C_{TM} = 1.059\ a\ b\ P_{FT}\ (W_{TANK})^{c} \qquad (2)$$

Fig. 38

where:

- a = complexity factor
- b = 4.415
- c = 0.2608
- P_{FT} = material pricing factor
- C_{TM} = tank material cost in thousands of 1974 dollars

Typical fuel tank material cost is shown in Figure 38.

The total tank cost is then:

$$C_T = a\,(C_{TL} + C_{TM}) + b$$

where:

a = complexity factor

b = miscellaneous cost in thousands of 1974 dollars

C_T = total tank cost in thousands of 1974 dollars

The values for C_{FT}, material labor pricing factor and for P_{FT}, material pricing factor for the ramjet fuel tankage are listed below:

Material	C_{FT}	P_{FT}
300 Grade Maraging Steel	1.0	1.0
4130 Steel	0.6	0.229
4340 Steel	1.0	0.274
17-4 PH Stainless Steel	0.6	0.929
2014-T6 Aluminum	0.2	0.257
AZ-31B-0 Magnesium	2.5	0.723
6A14V Titanium	1.0	2.571
Rene' 41 Alloy	1.0	1.386
Columbium Alloy WC-1294	0.6	22.857
Glass cloth	3.241	1.281

It should be noted that the above material list applies to solid motor case, integral rocket-ramjet combustor and fuel tankage. In the case of tankage, however, exotic materials such as Columbium alloy which are suitable for high temperature applications such as combustion chambers, would not be a logical choice for a tankage material because of its high cost as compared to that of 17-4 PH Stainless Steel or 2014-T6 Aluminum. Therefore, some discretion should be used in selection of tankage materials from the available options.

The cost of the tankage external insulation is given by:

$$C_{EXIN} = 1.1\, a\, b \left(\frac{c}{V_{EXIN}} \right)^{d} (V_{EXIN}) + e \qquad (4)$$

Fig. 39

where:

a = complexity factor

b = 0.001039

c = 198.0

d = 0.333

e = miscellaneous cost in thousands of 1974 dollars

C_{EXIN} = cost of insulation in thousands of 1974 dollars

V_{EXIN} = volume of insulation (2000-3000), in^3

The volume of the insulation is not calculated in the CGSM so it must be calculated at this point using the insulation weight and density which are calculated in the CGSM. Thus:

$$V_{EXIN} = \frac{EXINWT}{RHOX}$$

where:

EXINWT = external insulation weight, lbm

RHOX = external insulation density, lbm/in^3

Figure 39 is a plot of typical external insulation cost.

The fuel delivery systems are: stored nitrogen, monopropellant gas generator, solid propellant gas generator, and ram-air turbopump.

For the stored nitrogen system the cost equation for the gas tank is the same as for the liquid propulsion system.

$$C_{GT} = 1.059\, a\, b\, (V_{REQ})^{c} \qquad (5)$$

Fig. 40

where:

a	=	complexity factor
b	=	122.83
c	=	0.4949
C_{GT}	=	gas tank cost in thousands of 1974 dollars
V_{REQ}	=	gas tank volume (450-750), in^3

Typical gas tank cost is shown in Figure 40.

The regulator cost is:

$$C_{REG} = a \quad (6)$$

where:

a	=	gas regulator cost in thousands of 1974 dollars

The cost of miscellaneous values, etc is given by:

$$C_{MV} = a \quad (7)$$

where:

a	=	cost of miscellaneous valves in thousands of 1974 dollars.

The cost of the complete N2 pressurization system is:

$$C_{PSN2} = a\,(C_{GT} + C_{REG} + C_{MV}) + b \quad (8)$$

where:

a	=	complexity factor
b	=	miscellaneous cost in thousands of 1974 dollars
C_{PSN2}	=	pressurization system cost in thousands of 1974 dollars

The cost of the solid gas generator pressurization system is given by:

$$C_{PSSGG} = 1.1\, a\, b \left[c \left(\frac{d}{G_{GW}} \right)^{e} (G_{GW}) + f \right] + g \qquad (9)$$

Fig. 41

where:

a = complexity factor

b = 3.086

c = 0.0577

d = 4.0

e = 0.36

f = 0.075

g = miscellaneous cost in thousands of 1974 dollars

C_{PSSGG} = solid propellant gas generator cost in thousands of 1974 dollars

G_{GW} = solid propellant gas generator weight (5-10), lbm

Typical cost for a solid propellant gas generator is shown in Figure 41.

The cost of the monopropellant gas generator pressurization system is given by:

$$C_{PSMGG} = a \qquad (10)$$

where:

a = cost of monopropellant gas generator in thousands of 1974 dollars.

The cost of the ram-air turbine fuel delivery system is given by:

$$C_{PSRAM} = 1.1\, a \left[b\, (c + d\, H_{PPUMP}) - e\, (H_{PPUMP})^{f} \right] + g \qquad (11)$$

Fig. 42

where:

a = complexity factor

b = 1.08

c = 2.543

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SEATIDE ANALYSIS PROCESS. VOLUME V. RELATIVE COST MODEL (RCM), (U)

FEB 75 R K MCDONOUGH DAAB09-72-C-0062

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d = 0.014

e = 2×10^{-5}

f = 2.0

g = miscellaneous cost in thousands of 1974 dollars

C_{PSRAM} = ram-air turbine cost in thousands of 1974 dollars

Figure 42 shows the typical cost for a ram-air turbine pressurization system.

H_{PPUMP} = pump horsepower (2-3), HP

2.3.4.3 Ramjet Fuel

The ramjet fuel cost is given by:

$$C_{LF} = \frac{a\,b}{1000}\left(\frac{c}{W_{TFUEL}}\right)^{d}(W_{TFUEL}) + e \qquad (12)$$

where:

a = complexity factor

b = fuel cost per pound in 1974 dollars

c = 3125

d = 0.069

e = miscellaneous fuel cost in thousands of 1974 dollars

C_{LF} = fuel cost in thousands of 1974 dollars

W_{TFUEL} = fuel weight (600-1000), lbm

and the fuel loading cost is given by:

$$C_{LFL} = 1.1\,a\,b\left(\frac{c}{W_{TFUEL}}\right)^{d}(W_{TFUEL}) + e \qquad (13)$$

Fig. 43

where:

a = complexity factor

b = 10^{-4}

c = 3125.0

d = 0.029

e = miscellaneous fuel loading cost in thousands of 1974 dollars.

C_{LFL} = fuel loading cost in thousands of 1974 dollars

Typical fuel loading cost is plotted in Figure 43.

2.3.4.4 Booster Motor/Ramjet Combustor

The CER's for the solid propellant booster motor which also serves as the ramjet combustion chamber and nozzle are listed below. The motor case labor cost is given by:

$$C_{BLC} = 1.1\, a\, b\, C_{FCASE}\left(\frac{c}{W_{MC}}\right)^{d} (W_{MC}) + e \qquad (14)$$

Fig. 44

where:

- a = complexity factor
- b = 0.0096
- c = 140.0
- d = 0.333
- e = miscellaneous cost in thousands of 1974 dollars
- C_{BLC} = motor case cost in thousands of 1974 dollars
- C_{FCASE} = material pricing labor factor similar to C_{FT} defined previously
- W_{MC} = weight of motor case (50-80), lbm

Figure 44 is a plot of typical case labor cost.

The motor case is given in terms of the following variables solved for in the CGSM:

$$W_{MC} = CASEWT + WBOSS + TOMIS$$

where:

- CASEWT = case structure weight, lbm
- WBOSS = boss weights, lbm
- TOMIS = skirt weight, lbm

The case material is given by:

$$C_{BMC} = 1.1\, a\, b\, P_{FCASE}\left(\frac{c}{W_{MC}}\right)^{d} (W_{MC}) + e \qquad (15)$$

Fig. 45

where:

a	=	complexity factor
b	=	0.02378
c	=	140.0
d	=	0.333
e	=	miscellaneous cost in thousands of 1974 dollars
C_{BMC}	=	case material cost in thousands of 1974 dollars
P_{FCASE}	=	material pricing factor similar to P_{FT} described previously.

Typical case material cost is plotted in Figure 45.

The case insulation cost is determined by:

$$C_{LI} = 1.1\, a\, b \left(\frac{c}{V_{BI}}\right)^d (V_{BI}) + e \qquad (16)$$

Fig. 46

where:

a	=	complexity factor
b	=	0.001195
c	=	198.0
d	=	0.33
e	=	miscellaneous cost in thousands of 1974 dollars
C_{LI}	=	insulation cost in thousands of 1974 dollars
V_{BI}	=	insulation volume (400-600), in^3

Case insulation volume air are calculated in the CGSM. Therefore, the calculation must be performed in the Cost Model using the following expression.

$$V_{BI} = \frac{FWDWTI + WCYLI + ADWTI}{RHOIN} + \frac{EXTI}{RHOX}$$

where:

FWDWTI	=	forward closure insulation weight, lbm
WCYLI	=	cylinder insulation weight, lbm
ADWTI	=	aft dome insulation weight, lbm
RHOIN	=	internal insulation density, lbm/in^3
EXTI	=	external insulation weight, lbm
RHOX	=	external insulation density, lbm/in^3

Figure 46 is a plot of typical case insulation cost.

The nozzle cost is given by:

$$C_{NOZ} = 1.1\, a\, b\, (c + 2d\,(R_5) + e\, Y_1)\,(N_{OZWT}) + f \qquad (17)$$

Fig. 47

where:

a = complexity factor

b = 0.0026234

c = 4.6788

d = 1.4045

e = 1.5487

f = miscellaneous nozzle cost in thousands of 1974 dollars

C_{NOZ} = nozzle cost in thousands of 1974 dollars

R_5 = nozzle throat radius (2-3), inches

Y_1 = nozzle inlet radius (5-8), inches

N_{OZWT} = nozzle weight (25-100), lbm

Figure 47 is a plot of typical nozzle cost.

The booster solid propellant cost is given by:

$$C_{PRC} = \frac{a\, b}{1000} \left(\frac{c}{M_P}\right)^d (M_P) + e \qquad (18)$$

Fig. 48

where:

a = complexity factor

b = propellant cost per pound in thousands of 1974 dollars

c = 3125.0

d = 0.069

e = miscellaneous propellant cost in thousands of 1974 dollars

C_{PRC} = propellant cost in thousands of 1974 dollars

M_P = propellant weight (200-800), lbm

Typical booster propellant cost is shown in Figure 48 and the propellant loading cost is given by:

$$C_{PLC} = 1.1\, a\, b \left(\frac{c}{M_P}\right)^d (M_P) + e \qquad (19)$$

Fig. 49

where:

a = complexity factor

b = 0.00343

c = 3125.0

d = 0.387

e = miscellaneous propellant cost in thousands of 1974 dollars

Figure 49 is a plot of typical propellant loading cost.

The equation for the igniter cost is:

$$C_{IGN} = a \qquad (20)$$

where:

a = igniter cost in thousands of 1974 dollars

and the safe and arm system cost is given by:

$$C_{SA} = a \qquad (21)$$

where:

a = safe and arm systems cost in thousands of 1974 dollars

The total booster/combustor first unit cost becomes:

$$C_{BOOC} = a\,(C_{BLC} + C_{BMC} + C_{LI} + C_{NOZ} + C_{PRC} + C_{PLC} + C_{IGN} + C_{SA}) + b \qquad (22)$$

where:

a = complexity factor

b = miscellaneous cost in thousands of 1974 dollars

The total ramjet propulsion system first unit cost becomes:

$$C_{IRJFU} = a\,(1 + P_{RJC})\; 1.15\, b\, (C_T + C_{EXIN} + C_{PS} + C_{LF} + C_{LFL} + C_{BOOC}) + c \qquad (23)$$

where:

- a = inflation factor to adjust cost from 1974 dollars to year of interest
- b = complexity factor
- c = miscellaneous cost
- C_{IRJFU} = integral ramjet propulsion system first unit cost in thousands of 1974 dollars
- P_{RJC} = contractors profit margin

2.3.4.5 RDT&E Cost

The integral ramjet propulsion RDT&E cost is given by:

$$C_{IRJRD} = (1 + P_{RJC})\, a \left[1.18\, b\, d\, (D_{COM}) + c \right] \qquad (26)$$

Fig. 50

where:

- a = inflation factor to convert RDT&E cost from 1974 dollars to year of interest
- b = complexity factor
- c = miscellaneous total RDT&E cost in thousands of 1974 dollars
- d = 2422
- C_{IRJRD} = integral ramjet propulsion system RDT&E cost in thousands of 1974 dollars
- P_{RJC} = contractors profit margin
- D_{COM} = combustor diameter (12), inches

A plot of typical integral ramjet propulsion system RDT&E cost appears in Figure 50.

FIGURE 37
INTEGRAL AND NON-INTEGRAL RAMJET TANK LABOR COST (U)

Reference: Equation 1 Section 2.3.4
and Equation 1 Section 2.3.5

$$C_{TL} = 1.059\, a\, b\, C_{FT}\, W_{TANK}^{\;c}$$

Assuming:

$a = 1$ $c = .2608$

$b = 5.148$ $C_{FT} = 1$

this becomes

$$C_{TL} = 1.059\,(5.148)\, W_{TANK}^{\;.2608}$$

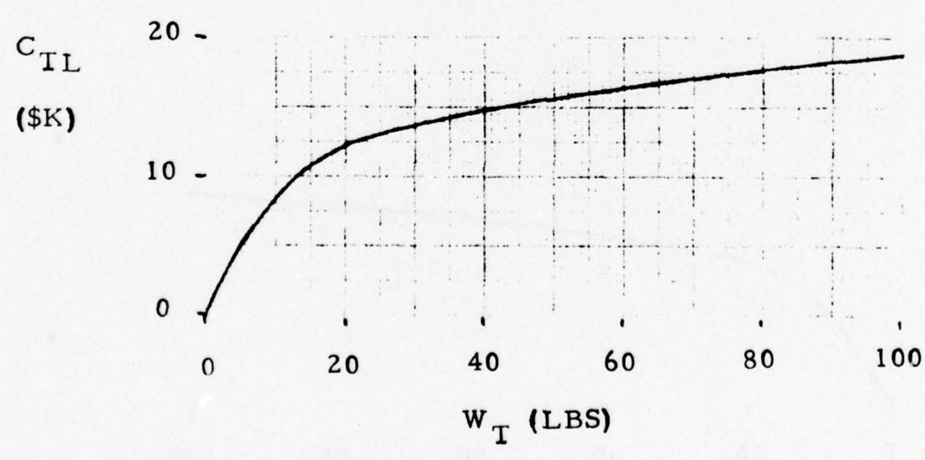


FIGURE 38
INTEGRAL AND NON-INTEGRAL RAMJET TANK MATERIAL COST (U)

Reference: Equation 2 Section 2.3.4
and Equation 2 Section 2.3.5

$$C_{TM} = 1.059\ a\ b\ P_{FT}\ W_{TANK}^{\ c}$$

Assuming:

$a = 1$ $c = .2608$

$b = 4.415$ $P_{FT} = 1$

this becomes

$$C_{TM} = 1.059\ (4.415)\ W_{TANK}^{\ .2608}$$

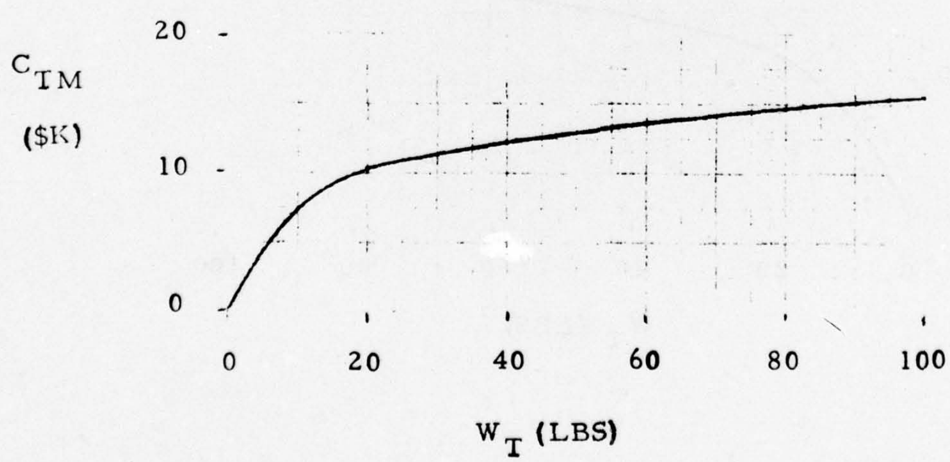


FIGURE 39
INTEGRAL AND NON-INTEGRAL RAMJET EXTERNAL INSULATION COST (U)

Reference: Equation 4 Section 2.3.4
and Equation 4 Section 2.3.5

$$C_{EXIN} = 1.1\ a\ b \left(\frac{c}{V_{EXIN}}\right)^{d} V_{EXIN} + e$$

Assuming:

a = 1   c = 198

b = .001039   d = .333

e = 0

this becomes

$$C_{EXIN} = 1.1\ (.001039) \left(\frac{198}{V_{EXIN}}\right)^{.333} V_{EXIN}$$

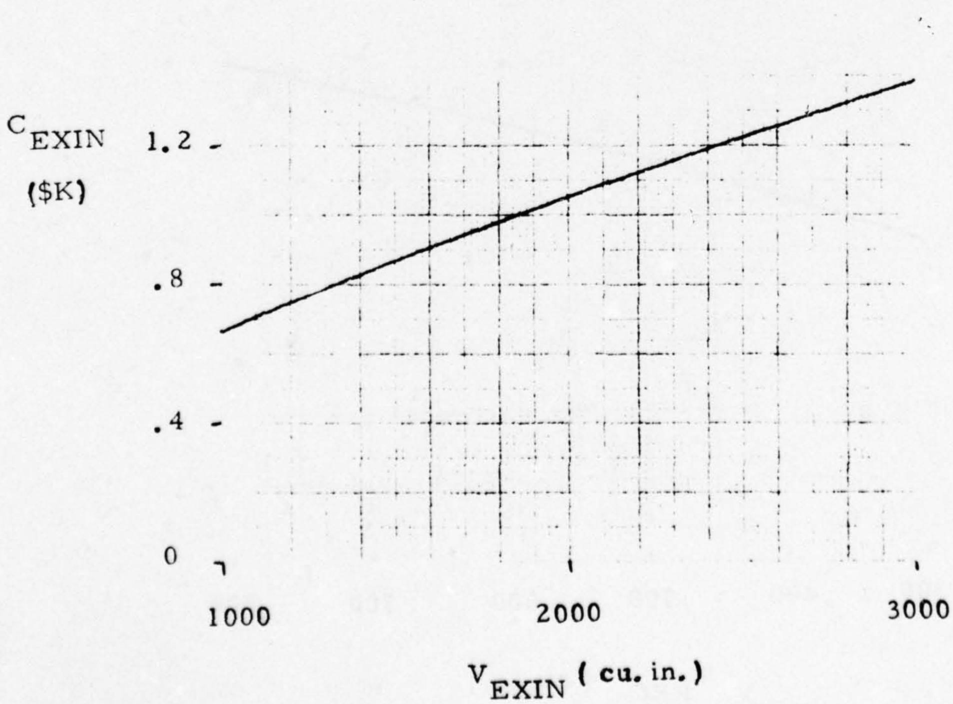


FIGURE 40
INTEGRAL AND NON-INTEGRAL GAS TANK COST (U)

Reference: Equation 5 Section 2.3.4
and Equation 5 Section 2.3.5

$$C_{GT} = 1.059 \; a \; b \; (V_{REQ})^{c}$$

Assuming:

$a = 1$ $c = .4949$

$b = .12283$

this becomes

$$C_{GT} = 1.059 \; (.12283) \; V_{REQ}^{\;.4949}$$

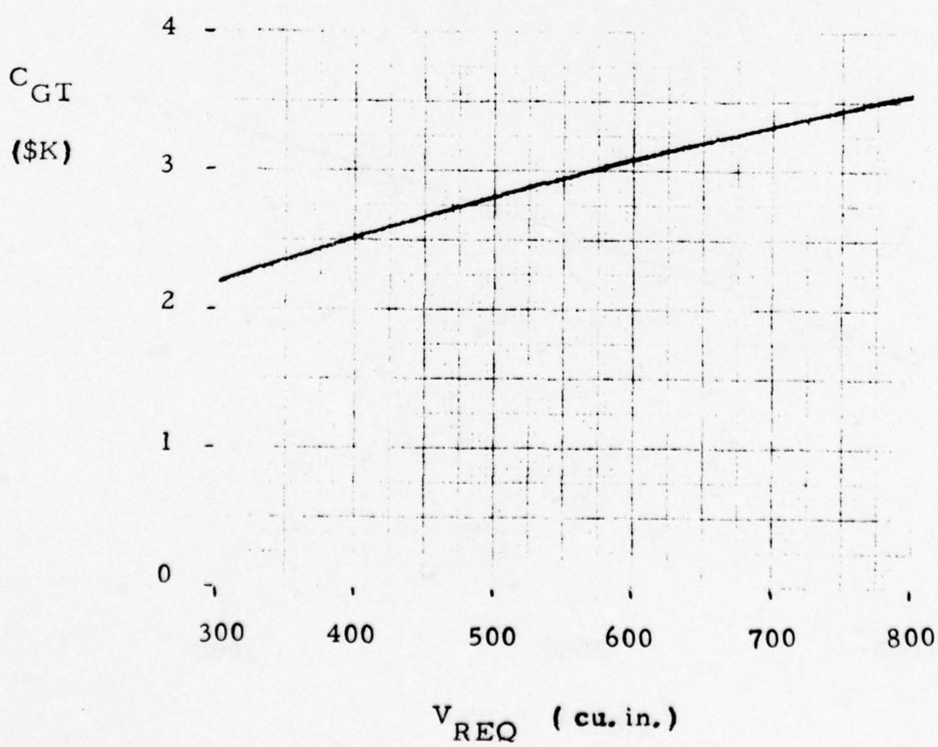


FIGURE 41
INTEGRAL AND NON-INTEGRAL RAMJET SOLID
GAS GENERATOR PRESSURIZATION SYSTEM COST (U)

Reference: Equation 9 Section 2.3.4
and Equation 9 Section 2.3.5

$$C_{PSSGG} = 1.1\ a\ b \left[c \left(\frac{d}{G_{GW}}\right)^{e} G_{GW} + f \right] + g$$

Assuming:

a = 1 e = .36

b = 3.086 f = .075

c = .0577 g = 0

d = 4

this becomes

$$C_{PSSGG} = 1.1\ (3.086) \left[.0577 \left(\frac{4}{G_{GW}}\right)^{.36} G_{GW} + .075 \right]$$

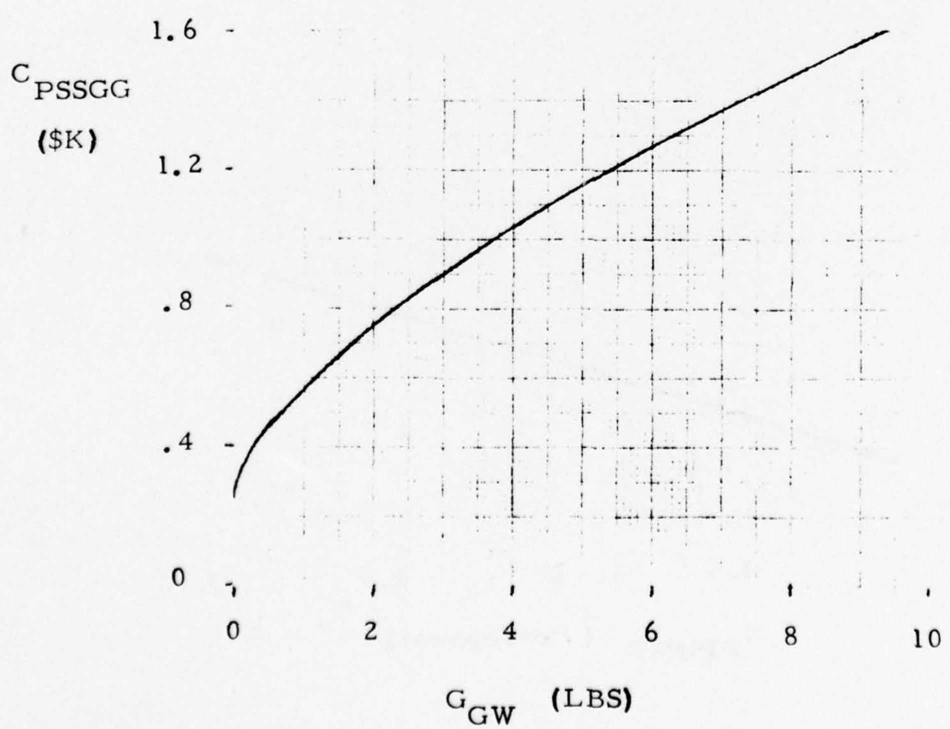


FIGURE 42
INTEGRAL AND NON-INTEGRAL RAMJET
RAM AIR TURBINE PRESSURIZATION SYSTEM
COST (U)

Reference: Equation 11 Section 2.3.4
and Equation 11 Section 2.3.5

$$C_{PSRAM} = 1.1\, a \left[b\,(c + d\, H_{ppump}) - e\, H_{ppump}^{\,f} \right] + g$$

Assuming:

a = 1   e = .00002

b = 1.08   f = 2

c = 2.543   g = 0

d = .014

this becomes

$$C_{PSRAM} = 1.1 \left[1.08\,(2.543 + .014\, H_{ppump}) - .00002\, H_{ppump}^{\,2} \right]$$

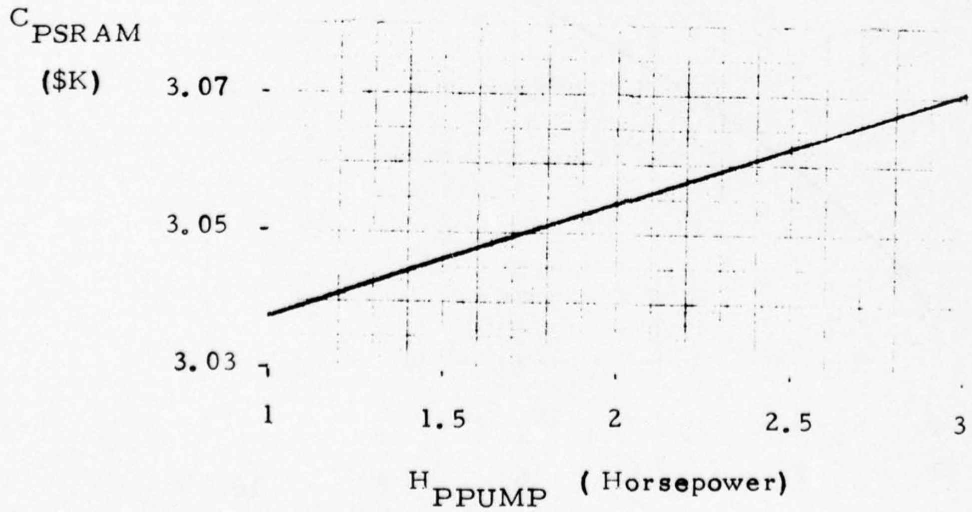


FIGURE 43
INTEGRAL AND NON-INTEGRAL RAMJET FUEL LOADING COST (U)

Reference: Equation 13 Section 2.3.4
and Equation 13 Section 2.3.5

$$C_{LFL} = 1.1\, a\, b \left(\frac{c}{W_{TFUEL}}\right)^{d} W_{TFUEL} + e$$

Assuming:

a = 1 d = .029

b = .0001 e = 0

c = 3125

this becomes

$$C_{LFL} = 1.1\,(.0001)\left(\frac{3125}{W_{TFUEL}}\right)^{.029} W_{TFUEL}$$

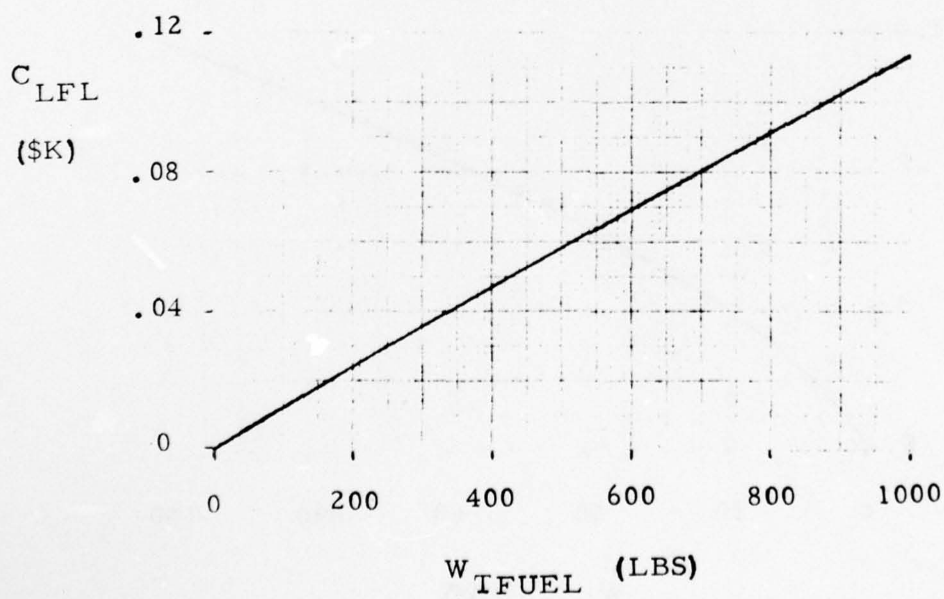


FIGURE 44
INTEGRAL RAMJET CASE LABOR COST (U)

Reference: Equation 14 Section 2.3.4

$$C_{BLC} = 1.1\ a\ b\ C_{FCASE} \left(\frac{c}{W_{MC}}\right)^{d} W_{MC} + e$$

Assuming:

$a = 1$ $d = .333$

$b = .0096$ $e = 0$

$c = 140$ $C_{FASE} = 1$

this becomes

$$C_{BLC} = 1.1\ (.0096) \left(\frac{140}{W_{MC}}\right)^{.333} W_{MC}$$

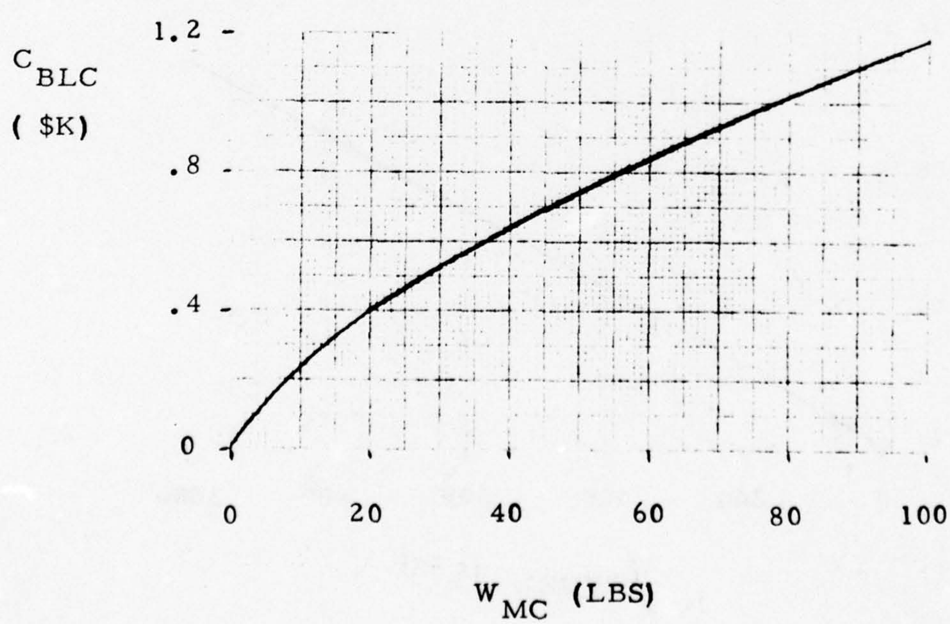


FIGURE 45
INTEGRAL RAMJET CASE MATERIAL COST (U)

Reference: Equation 15 Section 2.3.4

$$C_{BMC} = 1.1\ a\ b\ P_{FCASE} \left(\frac{c}{W_{MC}}\right)^{d} W_{MC} + e$$

Assuming:

$a = 1$ $d = .333$

$b = .02378$ $e = 0$

$c = 140$ $P_{FCASE} = 1$

this becomes

$$C_{BMC} = 1.1\ (.02378) \left(\frac{140}{W_{MC}}\right)^{.333} W_{MC}$$

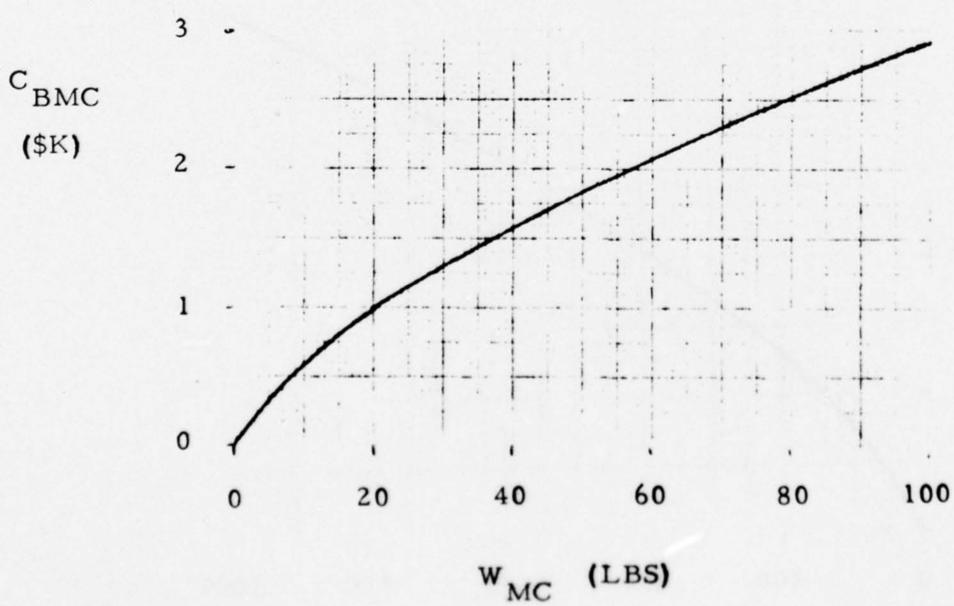


FIGURE 46
INTEGRAL RAMJET CASE INSULATION COST (U)

Reference: Equation 16 Section 2.3.4

$$C_{LI} = 1.1\, a\, b \left(\frac{c}{V_{BI}}\right)^{d} V_{BI} + e$$

Assuming:

a = 1 d = .333

b = .001195 e = 0

c = 198

this becomes

$$C_{LI} = 1.1\,(.001195)\left(\frac{198}{V_{BI}}\right)^{.333} V_{BI}$$

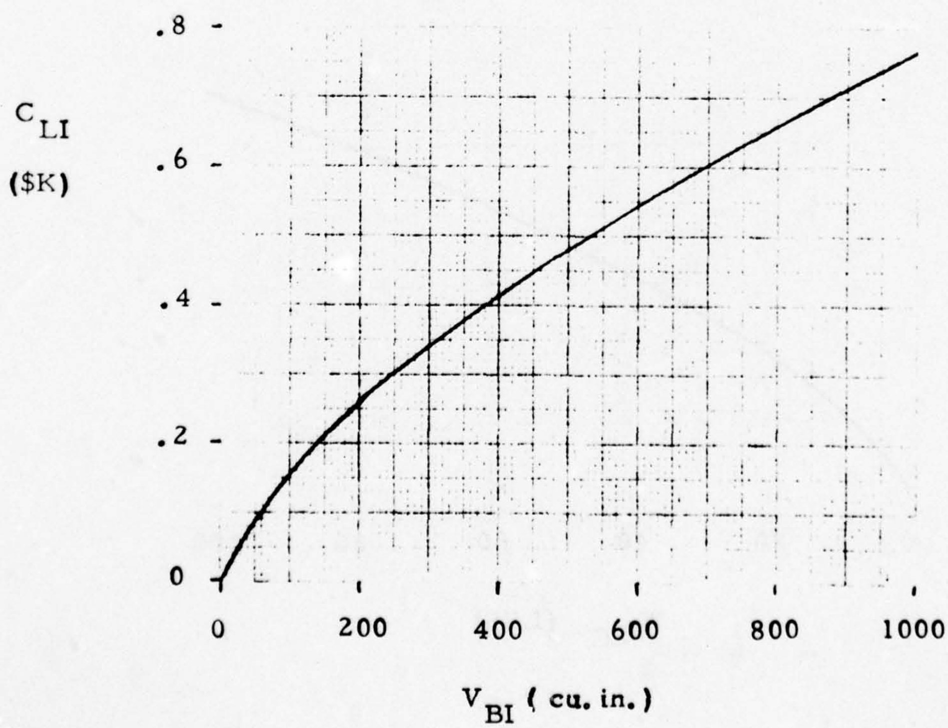


FIGURE 47
INTEGRAL RAMJET NOZZLE COST (U)

Reference: Equation 17 Section 2.3.4

$$C_{NOZ} = 1.1\ a\ b\ (c + d\ R + e\ Y)\ N_{OZWT} + f$$

Assuming:

a = 1	e = 1.5487
b = .0026234	f = 0
c = 4.6788	R = 3
d = 2.809	Y = 8

this becomes

$$C_{NOZ} = 1.1\ (.0026234)\ (4.6788 + 2.809\ R + 1.5487\ Y)\ N_{OZWT}$$

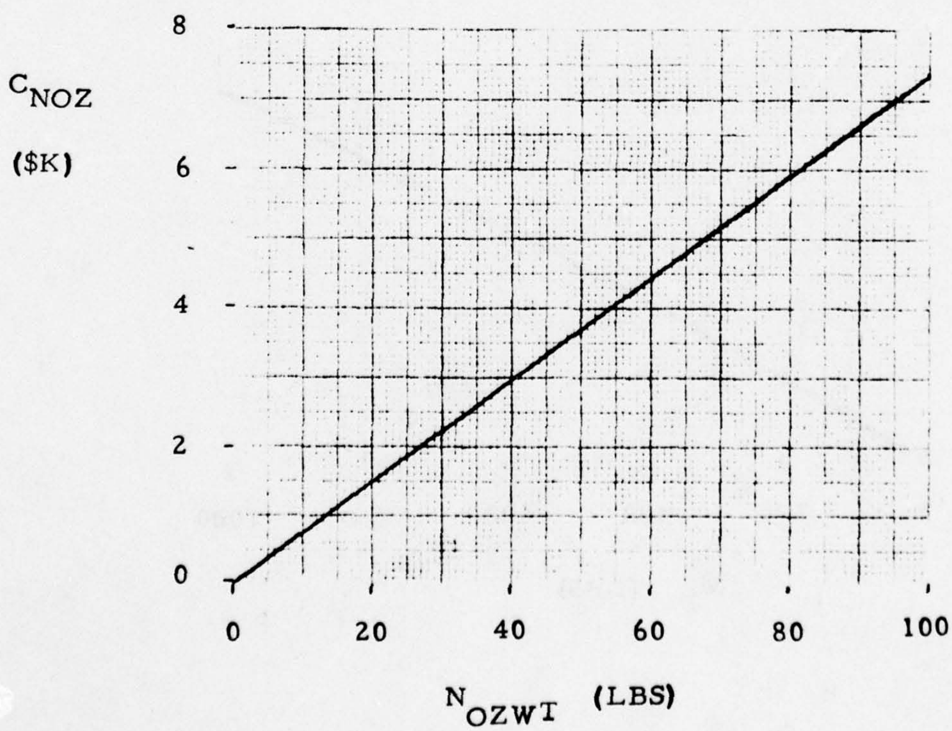


FIGURE 48
EXTERNAL BOOSTER AND INTEGRAL RAMJET SOLID PROPELLANT COST (U)

Reference: Equation 18 Section 2.3.4; and Equation 6 Section 2.3.6

$$C_{PR} = \frac{a\ b\ M_P}{1000}\left(\frac{c}{M_P}\right)^d + e$$

Assuming:

a = 1 d = .069

b = 1 e = 0

c = 3125

this becomes

$$C_{PR} = \frac{M_P}{1000}\left(\frac{3125}{M_P}\right)^{.069}$$

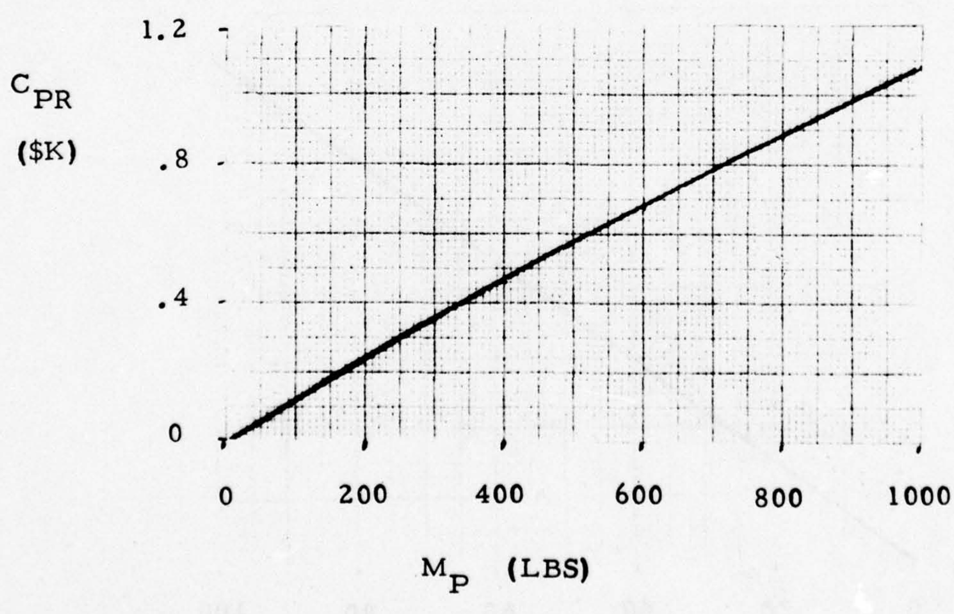


FIGURE 49
EXTERNAL BOOSTER PROPELLANT AND
INTEGRAL RAMJET PROPELLANT LOADING COST (U)

Reference: Equation 19 Section 2.3.4
and Equation 7 Section 2.3.6

$$C_{PL} = 1.1\ a\ b\ M_P \left(\frac{c}{M_P}\right)^d + e$$

Assuming:

$a = 1$ $d = .387$

$b = .00343$ $e = 0$

$c = 3125$

this becomes

$$C_{PL} = 1.1\ (.00343)\ M_P \left(\frac{3125}{M_P}\right)^{.387}$$

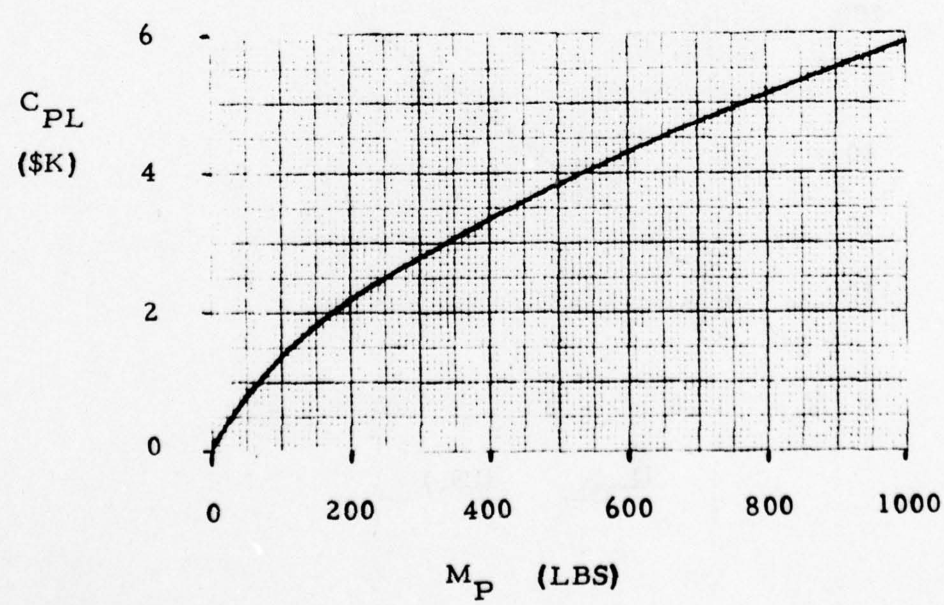


FIGURE 50
INTEGRAL RAMJET RDT&E COST (U)

Reference: Equation 26 Section 2.3.4

$$C_{IRJRD} = (1 + P_{RJC})\, a\, [b \quad (1.18\ )(d)(D_{COM}) + c]$$

Assuming:

$a = 1$

$b = 1$

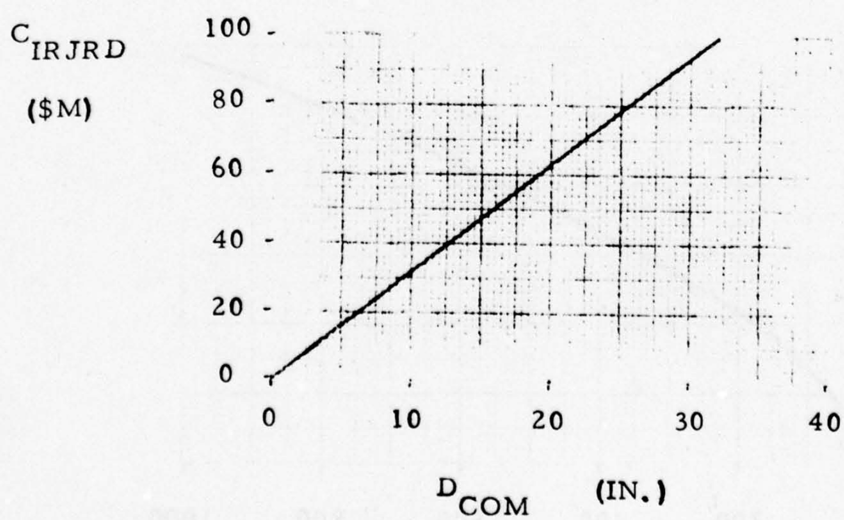
$d = 2422$

$c = 0$

$P_{RJC} = .1$

this becomes:

$$C_{IRJRD} = 1.1\,[1.184)(2422)(D_{COM})]$$



2.3.5 Non-Integral Ramjet

The following CER's are for the non-integral ramjet propulsion system. This system consists of a ramjet engine, fuel tankage, fuel and pressurization system. The booster, which is normally associated with this system is discussed in Section 2.3.6. The CER's for the fuel tankage, fuel and various pressurization system options are identical to those used for the integral ramjet system and were presented along with the illustrative plots in Section 2.3.4. They will not be repeated in this section.

2.3.5.1 Ramjet Combustor

The ramjet combustor labor cost is given by:

$$C_{COML} = a\, b\, C_{FC} \left(\frac{c}{W_{COMM}}\right)^{d} (W_{COMM}) \qquad (14)$$

Fig. 51

where:

a = complexity factor

b = 0.008166

c = 140.0

d = 0.333

C_{COML} = ramjet combustor labor cost in thousands of 1974 dollars.

C_{FC} = material labor pricing factor for combustor case and having the same values of C_{FT} and C_{FCASE} described previously.

W_{COMM} = combustor metal weight (20-30), lbm

For the combustor, the combustor metal weight is defined as:

$$W_{COMM} = BOSDMP + SKTS + FWDWTS + WCMS + ADWTS + FTFNG$$

where:

BOSDMP	=	boss weight, lbm
SKTS	=	skirts weight, lbm
FWDWTS	=	forward closure weight, lbm
WCMS	=	cylinder weight, lbm
ADWTS	=	aft dome weight, lbm
FTFNG	=	fittings weight, lbm

Typical combustor labor cost is shown in Figure 51.

The combustor material cost is given by:

$$C_{COMM} = 1.1\, a\, b\, P_{FC} \left(\frac{c}{W_{COMM}}\right)^d (W_{COMM}) \qquad (15)$$

Fig. 52

where:

a	=	complexity factor
b	=	0.02022
c	=	140.0
d	=	0.333
C_{COMM}	=	combustor material cost in thousands of 1974 dollars
P_{FC}	=	material pricing factor, having the same values as P_{FT} and P_{FCASE} described previously.

Figure 52 is a plot of typical combustor material cost.

The combustor insulation cost is given by:

$$C_{COMI} = 1.1\, a\, b \left(\frac{c}{V_{COMI}}\right)^d (V_{COMI}) \qquad (16)$$

Fig. 53

where:

a	=	complexity factor
b	=	0.001039
c	=	198.0
d	=	0.333
C_{COMI}	=	combustor insulation cost in thousands of 1974 dollars
V_{COMI}	=	combustor insulation volume, in^3

The value for V_{COMI} is obtained using the various insulation weights and densities as described in Section 2.3.4.

Typical combustor insulation cost is shown in Figure 53.

2.3.5.2 Nozzle

The cost of the ramjet nozzle is given by:

$$C_{NOZ} = 1.1\, a\, b\, (c + d\, R_5 + e\, Y_1)\,(W_{NOZ}) \quad (17)$$

Fig. 54

where:

a	=	complexity factor
b	=	0.001755
c	=	4.6788
d	=	2.809
e	=	1.5487
C_{NOZ}	=	nozzle cost in thousands of 1974 dollars
R_5	=	nozzle throat radius, inches
Y_1	=	nozzle inlet radius, inches
W_{NOZ}	=	nozzle weight, lbm

A plot of typical ramjet nozzle cost is shown in Figure 54.

The total combustor cost is given by:

$$C_{RJC} = a\,(C_{COML} + C_{COMM} + C_{COMI} + C_{NOZ}) + b \quad (18)$$

where:

a	=	complexity factor
b	=	miscellaneous combustor cost in thousands of 1974 dollars

The non-integral ramjet propulsion system first unit cost is given by:

$$C_{NRJFU} = a\,(1 + P_{RJC})\left[1.15\, b\,(C_T + C_{EXIN} + C_{PS} + C_{LF} + C_{LFL} + C_{RJC}) + c\right] \quad (19)$$

where:

a	=	inflation factor to adjust cost from 1974 dollars to year of interest
b	=	complexity factor
c	=	miscellaneous first unit cost in thousands of 1974 dollars
C_{NRJFU}	=	non-integral ramjet propulsion system first unit cost in thousands of 1974 dollars
P_{RJC}	=	contractors profit margin.

The equation for the RDT&E cost is given below:

$$C_{NRJRD} = (1 + P_{RJC})\, a \left[b\,(1.184\, d\, D_{COM}) + c \right] \qquad (22)$$

Fig. 55

where:

a	=	inflation factor to convert RDT&E cost from 1974 dollars to year of interest.
b	=	complexity factor
c	=	miscellaneous RDT&E cost in thousands of 1974 dollars.
d	=	2040.
C_{NRJRD}	=	RDT&E cost in thousands of 1974 dollars
P_{RJC}	=	contractors profit margin
D_{COM}	=	combustor diameter, inches

Figure 55 is a plot of typical RDT&E cost for the non-integral ramjet system.

FIGURE 51
EXTERNAL BOOSTER CASE AND NON-INTEGRAL RAMJET COMBUSTOR LABOR COST (U)

Reference: Equation 14 Section 2.3.5
and Equation 1 Section 2.3.6

$$C_{COML} = 1.1 \; a \; C_{FC} \left(\frac{b}{W_{COMM}}\right)^{c} W_{COMM}$$

Assuming:

$a = .008166 \qquad c = .333$

$b = 140 \qquad C_{FC} = 1$

this becomes

$$C_{COML} = 1.1 \; (.008166) \left(\frac{140}{W_{COMM}}\right)^{.333} W_{COMM}$$

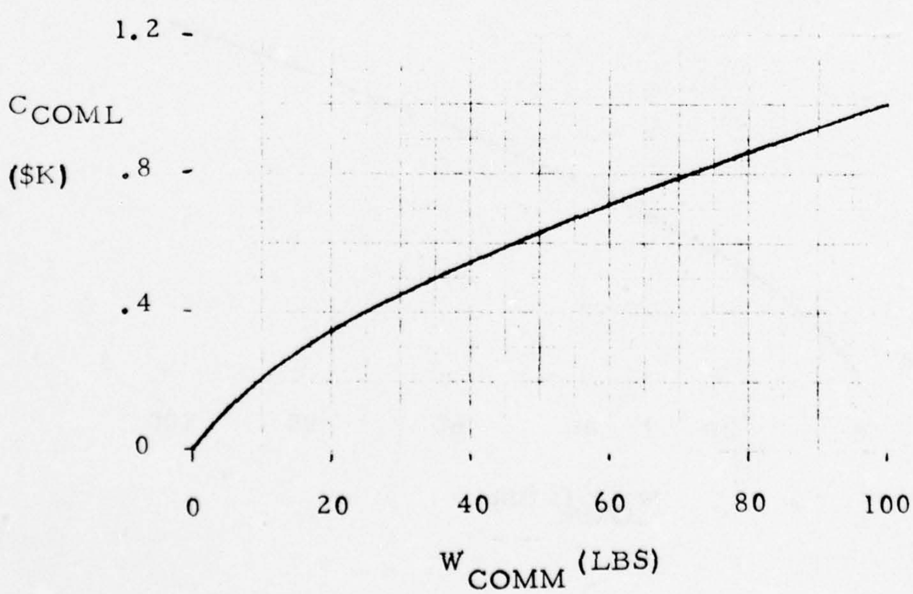


FIGURE 52
EXTERNAL BOOSTER CASE AND NON-INTEGRAL RAMJET COMBUSTOR MATERIAL COST (U)

Reference: Equation 15 Section 2.3.5
and Equation 2 Section 2.3.6

$$C_{COMM} = 1.1\ a\ P_{FC} \left(\frac{b}{W_{COMM}}\right)^{c} W_{COMM}$$

Assuming:

$a = .02022$ $c = .333$

$b = 140$ $P_{FC} = 1$

this becomes

$$C_{COMM} = 1.1\ (.02022) \left(\frac{140}{W_{COMM}}\right)^{.333} W_{COMM}$$

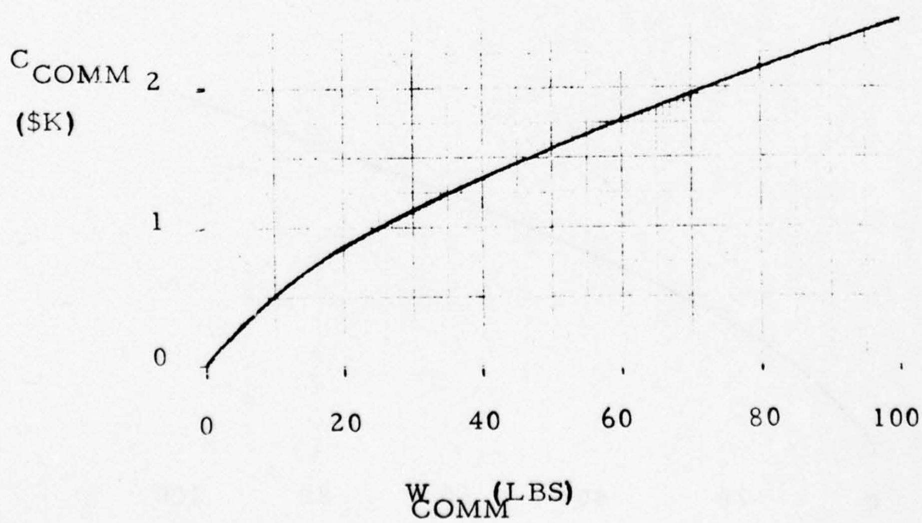


FIGURE 53
EXTERNAL BOOSTER AND NON-INTEGRAL RAMJET
COMBUSTOR INSULATION COST (U)

Reference: Equation 16 Section 2.3.5
and Equation 4 Section 2.3.6

$$C_{COMI} = 1.1\ a\ b\ \left(\frac{c}{V_{COMI}}\right)^{d} V_{COMI}$$

Assuming:

a = 1 d = .333

b = .001039

c = 198

this becomes

$$C_{COMI} = 1.1\ (.001039)\ \left(\frac{198}{V_{COMI}}\right)^{.333} V_{COMI}$$

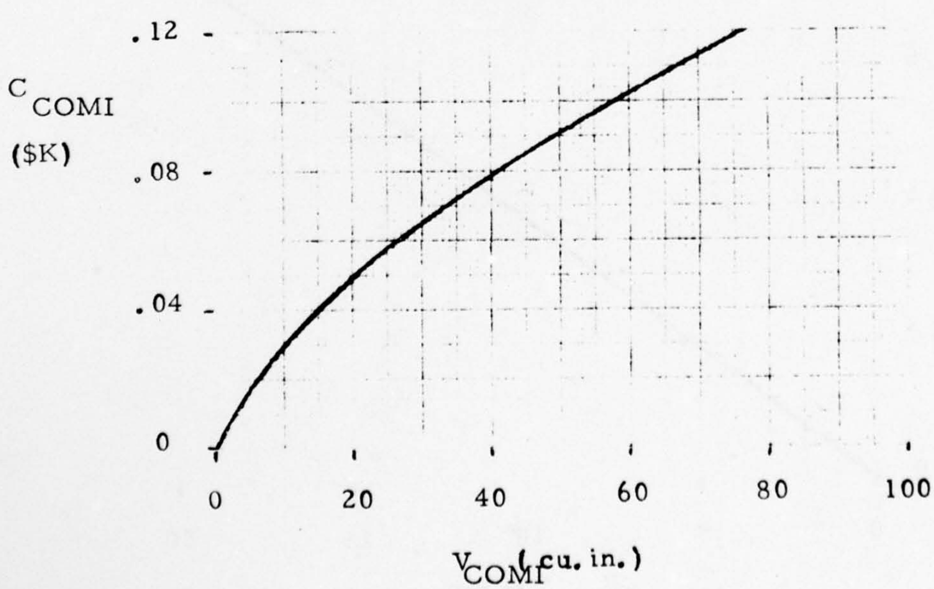


FIGURE 54
NON-INTEGRAL RAMJET NOZZLE COST (U)

Reference: Equation 17 Section 2.3.5.2

$$C_{NOZ} = 1.1\ a\ b\ (c + d\ R + e\ Y)\ W_{NOZ}$$

Assuming:

a = 1 e = 1.5487

b = .001755 R = 2

c = 4.6788 Y = 6

d = 2.809

this becomes

$$C_{NOZ} = 1.1\ (.001755)\ (4.6788 + 2.809R + 1.5487Y)\ W_{NOZ}$$

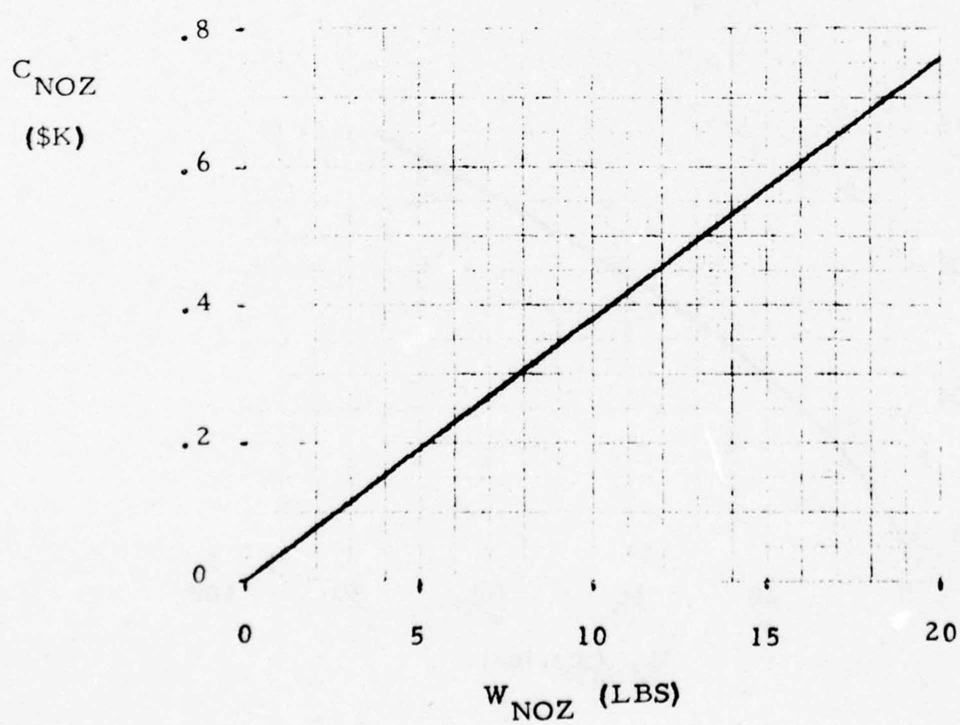


FIGURE 55
NON-INTEGRAL RAMJET RDT&E COST (U)

Reference: Equation 22 Section 2.3.5

$$C_{NRJRD} = (1 + P_{RJC})\, a\, [b \quad (1.184)(d)\,(D_{COM}) \quad + c]$$

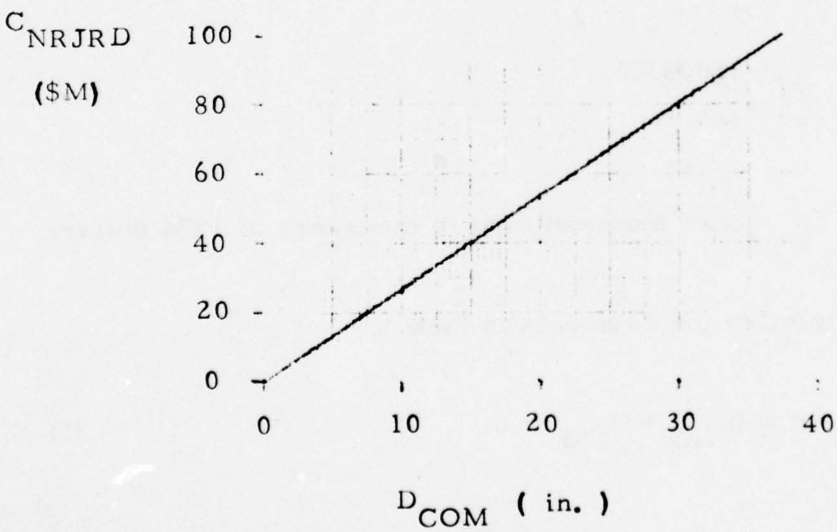
Assuming:

$a = 1$
$b = 1$
$c = 0$
$d = 2040$

$P_{RJC} = .1$

this becomes:

$$C_{NRJRD} = 1.1\,[(1.184)(2040)(D_{COM})]$$



2.3.6 EXTERNAL BOOSTER

The following CER's are for the external booster which is used in conjunction with the non-integral ramjet or turbojet engines.

2.3.6.1 Motor Case

The case labor cost is given by

$$C_{CL} = 1.1\, a\, C_{FM} \left(\frac{b}{W_{MC}}\right)^{c} (W_{MC}) \qquad (1)$$

where:

$a = 0.008166$

$b = 140.0$

$c = 0.333$

C_{CL} = case labor cost in thousands of 1974 dollars

W_{MC} = booster case weight (25-100), lbm

The case material cost is given by

$$C_{CM} = 1.1\, a\, P_{FM} \left(\frac{b}{W_{MC}}\right)^{c} (W_{MC}) \qquad (2)$$

where:

$a = 0.008166$

$b = 140.0$

$c = 0.333$

C_{CM} = case material cost in thousands of 1974 dollars

The total motor case cost is then

$$C_{TC} = a\,(C_{CL} + C_{CM}) + b \qquad (3)$$

where: a = complexity factor

b = miscellaneous case cost in thousands of 1974 dollars

The motor internal insulation cost is given by

$$C_{LI} = 1.1\,ab \left(\frac{c}{V_{BI}} \right)^{d} (V_{BI}) + e \quad (4)$$

where: a = complexity factor

b = 0.001039

c = 198.0

d = 0.333

e = miscellaneous cost in thousands of 1974 dollars

C_{LI} = insulation cost in thousands of 1974 dollars

V_{BI} = insulation volume (65-250), in^3

The insulation was obtained from the insulation weight and density as described in 2.3.1.

2.3.6.2 Nozzle

The external booster nozzle cost is given by

$$C_{NOZ} = 1.1\,ab \left[c + (D_{THRT}) + e\,(R_{NOZ}) \right] (N_{OZWT}) \quad (5)$$

Fig. 56

where: a = complexity factor

b = 0.001755

c = 4.6788

d = 1.4045

e = 1.5487

f = miscellaneous cost in thousands of 1974 dollars

C_{NOZ} = nozzle cost in thousands of 1974 dollars

D_{THRT} = nozzle throat diameter (3-4), inches

R_{NOZ} = nozzle inlet radius (5-6), inches

N_{OZWT} = nozzle weight (25-100), lbm

Figure 56 is a plot of typical booster nozzle cost.

2.3.6.3 Propellant

The propellant cost is given by

$$C_{PR} = \frac{abM_P}{1000} \left(\frac{c}{M_P} \right)^d + e \tag{6}$$

where:

a = complexity factor

b = propellant cost in 1974 dollars per pound

c = 3125.0

d = 0.069

e = miscellaneous nozzle cost in thousands of 1974 dollars

C_{PR} = propellant cost in thousands of 1974 dollars

M_P = propellant weight (200-800), lbm

and the propellant loading cost is

$$C_{PL} = 1.1 \text{ ab } M_P \left(\frac{c}{M_P} \right)^d + e \tag{7}$$

where: a = complexity factor

b = 0.00343

c = 3125.0

d = 0.387

e = miscellaneous cost in thousands of 1974 dollars

C_{PL} = propellant loading cost in thousands of 1974 dollars

2.3.6.4 Igniter and Safe/Arm

The igniter cost and safe and arm system cost are given below.

$$C_{IGN} = 0.3861$$

$$C_{SA} = 0.19305$$

where: C_{IGN} = igniter cost in thousands of 1974 dollars

C_{SA} = safe and arm system cost in thousands of 1974 dollars

2.3.6.5 First Unit Cost

The booster first unit cost is given by

$$C_{EBFU} = Z_{XNB} \left\{ a \left[b(C_{TC} + C_{LI} + C_{NOZ} + C_{PR} + C_{PL} + C_{IGN} + C_{SA}) + c \right] (1 + P_{EBC}) \right\} \quad (10)$$

where: a = factor used to convert from 1974 dollars to year of interest

b = complexity factor

c = miscellaneous production cost in thousands of 1974 *dollars*

C_{EBFU} = first unit cost in thousands of 1974 dollars

Z_{XNB}	=	number of boosters
P_{EBC}	=	contractor's profit margin

2.3.6.6 RDT&E Cost

The booster RDT&E cost is given by

$$C_{EBRD} = a \left\{ bc \left[(D)(W_M) \right]^d (1.462) + e \right\} (1 + P_{EBC}) \quad (11)$$

Fig. 57

where:

a	=	factor used to convert RDT&E cost from 1974 dollars to year of interest
b	=	complexity factor
c	=	14.392
d	=	0.4263
e	=	miscellaneous cost in thousands of 1974 dollars
C_{EBRD}	=	RDT&E cost in thousands of 1974 dollars
D	=	motor diameter (10-20), inches
W_M	=	motor weight (250-1000), lbm
P_{EBC}	=	contractor's profit margin

Figure 57 is a plot of typical booster motor RDT&E cost.

FIGURE 56
EXTERNAL BOOSTER NOZZLE COST (U)

Reference: Equation 5 Section 2.3.6

$$C_{NOZ} = 1.1\ a\ b\ (c + d\ D_{THRT} + e\ R_{NOZ})\ N_{OZWT} + f$$

Assuming:

$a = 1$ $d = 1.4045$ $D_{THRT} = 4$

$b = .001755$ $e = 1.5487$ $R_{NOZ} = 6$

$c = 4.6788$ $f = 0$

this becomes

$$C_{NOZ} = 1.1\ (.001755)\ (4.6788 + 1.4045\ D_{THRT} + 1.5487\ R_{NOZ})\ N_{OZWT}$$

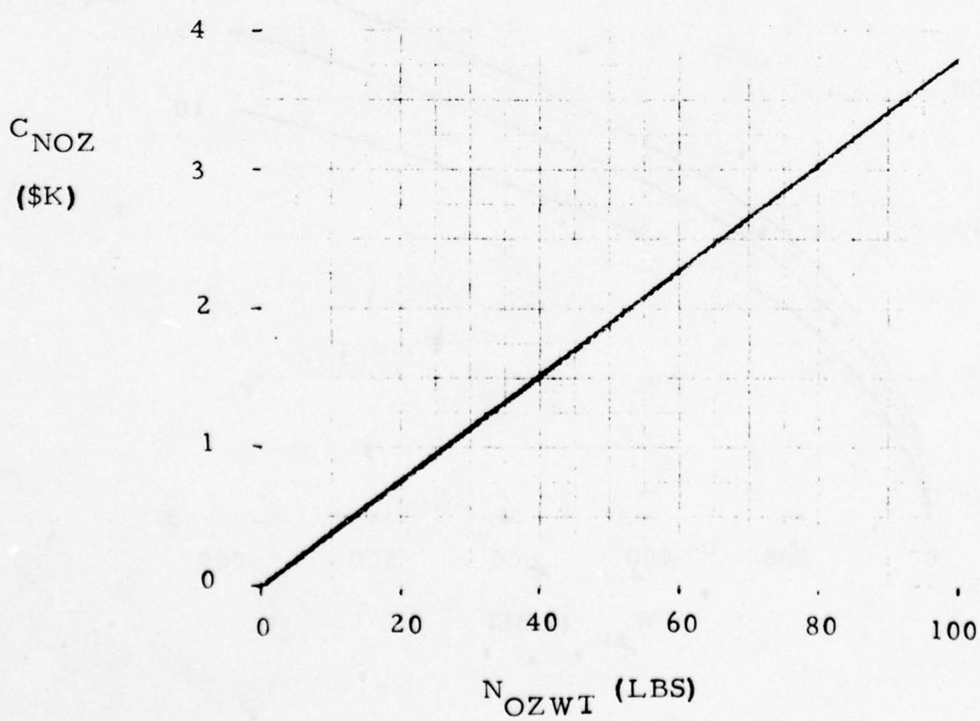


FIGURE 57
EXTERNAL BOOSTER RDT&E COST (U)

Reference: Equation 11 Section 2.3.6

$$C_{EBRD} = a\left[b\ c\ (D \cdot W_M)^d\ 1.462 + e\right](1 + P_{EBC})$$

Assuming:

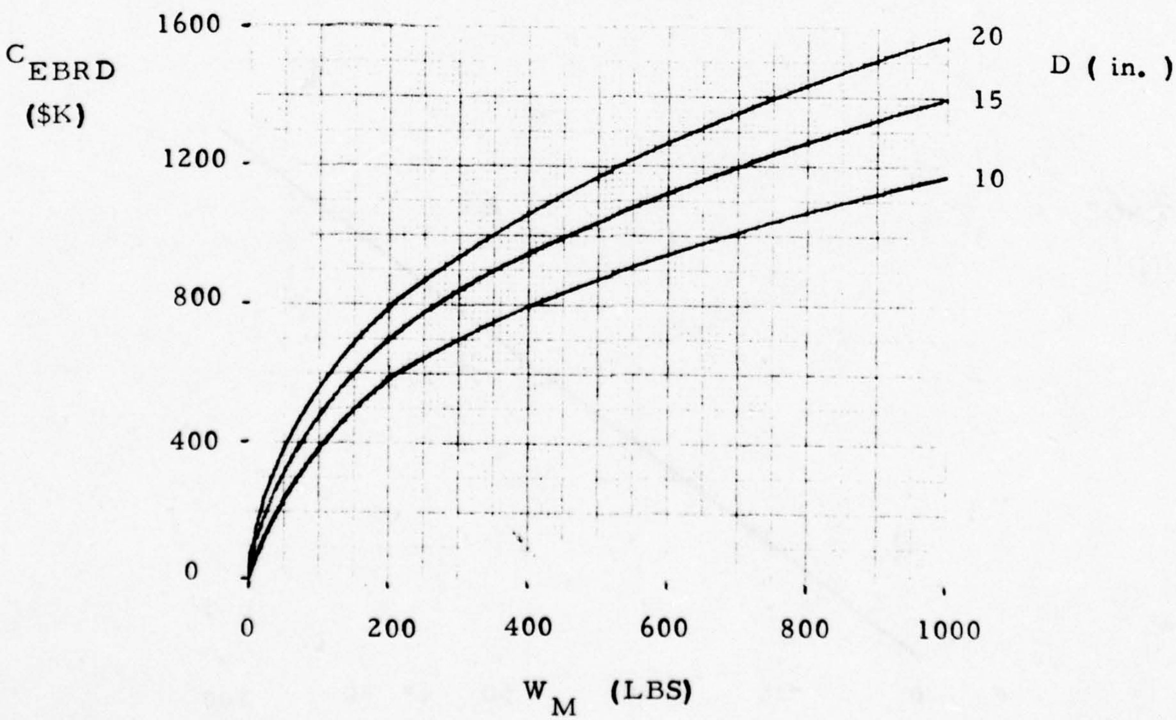
$a = 1$ $d = .4263$

$b = .1$ $e = 0$

$c = 14.392$ $P_{EBC} = .1$

this becomes

$$C_{EBRD} = 1.1\ (1.462)\ (14.392)\ (D \cdot W_M)^{.4263}$$



2.4 GUIDANCE AND CONTROLS

2.4.1 Sources and Assumptions

Guidance and Control costing methodologies were obtained from two basic sources: (1) Cost Estimating Relationships for Tactical Missile RDT&E (Reference 3), (2) the ADTC Air Launched Weapon System Cost Model (Reference 2). Three types of missile guidance systems are costed: (1) passive/semi-active, (2) active, and (3) infrared. Control Systems are costed with and without autopilot. Both guidance and controls are costed at the system level and no subsystem cost details on such items as gyros, computers, radomes are available. Both RDT&E and Production first unit costing methodologies were derived.

2.4.2 RDT&E CERS

2.4.2.1 Guidance

The Guidance System RDT&E costing methodology was lifted directly from Reference 3. It covers the three missile guidance types of interest and is computed as a function of guidance system first unit cost. The RDT&E costs include all costs necessary to develop a guidance system from conceptual design to the point of manufacture. The CER used is described as follows:

$$C_{GRD} = a\left(b\left(e^{\left(c + d\, C_{GFU}{}^{f}\right)}\right) + g\right) \qquad (1)$$

Fig. 58

where:

C_{GRD} = guidance system RDT&E cost in thousands of dollars.

a = inflation factor used to adjust cost to future years. For 1974 costs, a = 1.

b = RDT&E complexity factor. For state of the art system, b = 1.

c = 8.37

d = .0157

FIGURE 58

GUIDANCE RDT&E COST (U)

Reference: Equation 1 Section 2.4.2

$$C_{GRD} = a\left(b\, e^{\left(c + dC_{GFU}{}^{f}\right)} + g\right)$$

Assuming:

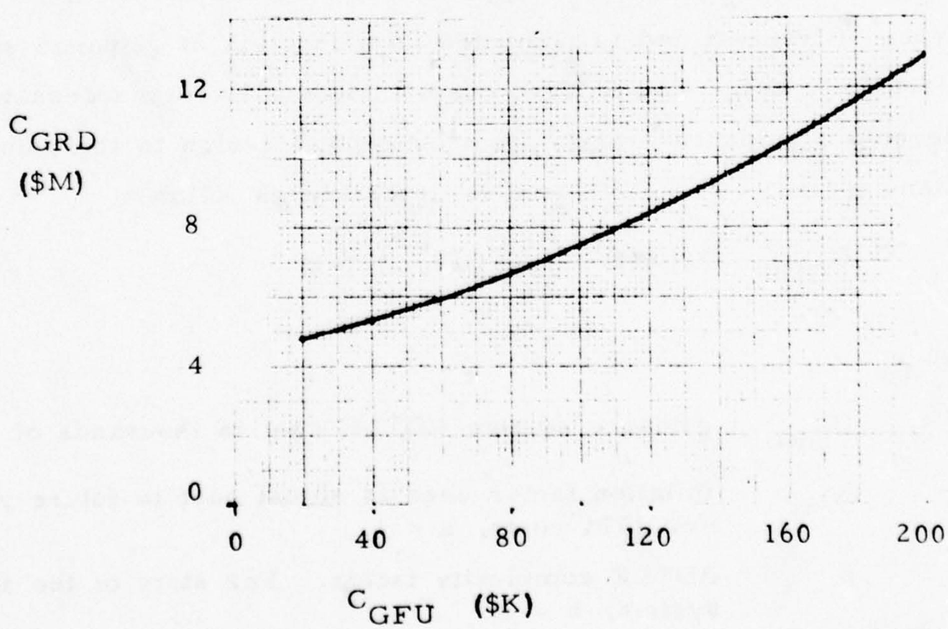
$a = 1$ $d = .0157$

$b = 1$ $f = .35$

$c = 8.37$ $g = 0$

this becomes:

$$C_{GRD} = e^{(8.37 + .0157\, C_{GFU}\,(.35))}$$



f = .35

g = miscellaneous cost term in thousands of dollars. Normally, the value is zero.

C_{GFU} = Guidance system first unit cost in thousands of dollars.

Figure 58 shows the CER results as a function of guidance system first unit cost, assuming values for the other required inputs. The CER is assumed valid over the total range of missile guidance systems used in the SEATIDE process.

2.4.2.2 Controls

The control system RDT&E costing methodology was lifted directly from Reference 2. It covers the type of control systems of interest to the SEATIDE process and is a function of the dynamic pressure encountered, the control surface area, and adaptive gain control ("dither"). The RDT&E costs include all costs necessary to develop a control system to the point of manufacture. The CER used is defined as follows:

$$C_{CRD} = a\ ((b + c\ Q_A + d\ K_{GAIN})\ e + f) \qquad (1)$$

Fig. 59

where:

C_{CRD} = control system RDT&E costs in thousands of dollars.

a = inflation factor to adjust cost for future years. For 1974 costs, a = 1.

b = 4798.

c = 222.7

d = 5796.3

e = RDT&E complexity factor used to adjust cost for exceptional problems or windfall. For state of the art systems, e = 1.

f = miscellaneous cost term in thousands of dollars.

Q_A = product of dynamic pressure encountered times control surface area in thousands of pounds. In SEATIDE, control surface area is defined as tail area. ($Q_A < 170$)

FIGURE 59
CONTROLS RDT&E COST (U)

Reference: Equation 1 Section 2.4.2.2

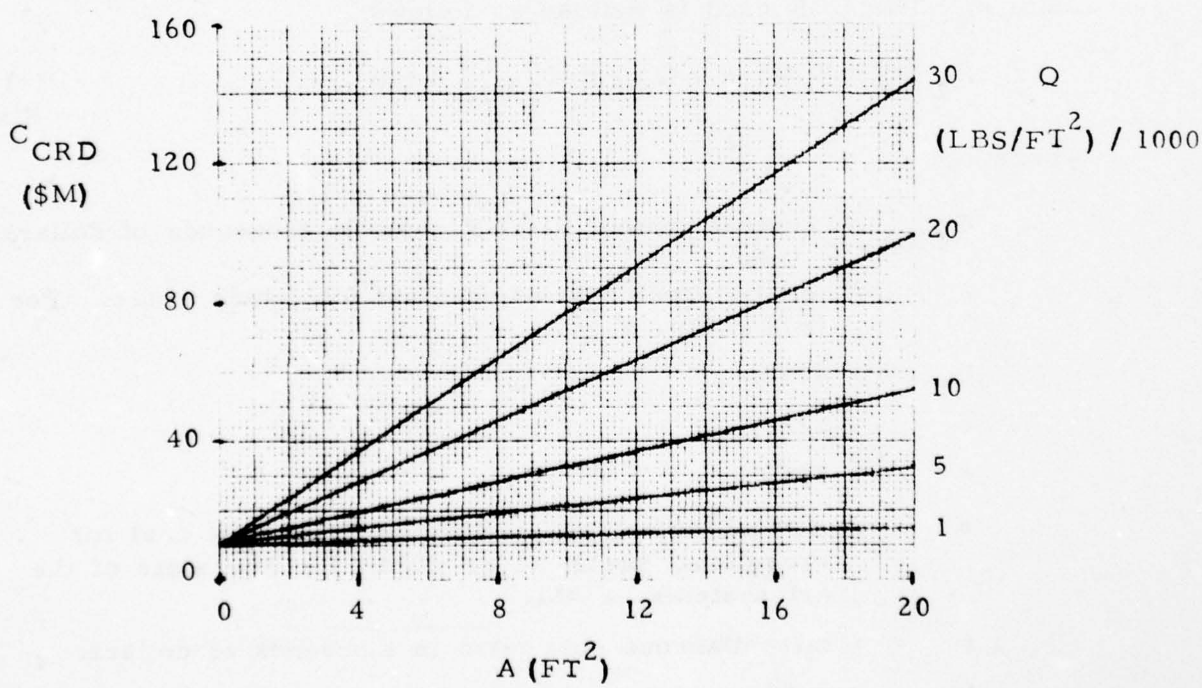
$$C_{CRD} = a\,(\,(\,b + c\,Q_A + d\,K_{GAIN})\,e + f)$$

Assuming:

$a = 1$ $\quad d = 5796.3$
$b = 4798.$ $\quad e = 1$
$c = 222.7$ $\quad f = 0$
$K_{GAIN} = 1$ $\quad Q_A = Q\,(A)$

this becomes:

$$C_{CRD} = 4798 + 222.7\,Q_A + 5796.3$$



K_{GAIN} = an adaptive gain control term. If adaptive gain ("dither") is used, $K_{GAIN} = 1$. If not, $K_{GAIN} = 0$.

Figure 59 shows the CER results as a function of dynamic pressure (Q) and tail area (A), assuming values for the other terms in the equation. The CER is assumed valid over the total ranges of dynamic pressure and tail surface areas used in the SEATIDE cruise missile systems.

2.4.3 Production CERS

2.4.3.1 Passive/Semi-Active Guidance Systems

The first production unit passive/semi-active radar seeker CER includes all hardware associated with the sensor subsystem, including sensor electronics, sensor electromechanical components, inertial components, wiring, radome, and heating protection elements housing the seeker. The CER was lifted directly from Reference 2 and is discussed as follows:

$$C_{GFUP} = a \left[\frac{1.16\, b}{350} \left(c\, K_{LEG}\, F_C^{\,d} + e\, K_{GTG}\, F_c^{\,f} + g\, K_{STAB} + h\, K_{AGATE} + i\, N_{CHAN}\, K_{SGATE} + j\, K_{SGATE} \right) + k \right] \quad (2)$$

Fig. 60

where:

C_{GFUP}	=	guidance system first unit cost in thousands of dollars.
a	=	inflation factor used to adjust cost for future years. For 1974 costs, a = 1.
b	=	production complexity factor used to adjust costs for exceptional problems or windfalls. For state of the art systems, b = 1.
c	=	to be supplied by DE-1
d	=	to be supplied by DE-1
e	=	to be supplied by DE-1
f	=	to be supplied by DE-1
g	=	to be supplied by DE-1
h	=	to be supplied by DE-1

FIGURE 60
GUIDANCE FIRST UNIT COST, PASSIVE/SEMI-ACTIVE RADAR SEEKER (U)

Reference: Equation 2 Section 2.4.3.1

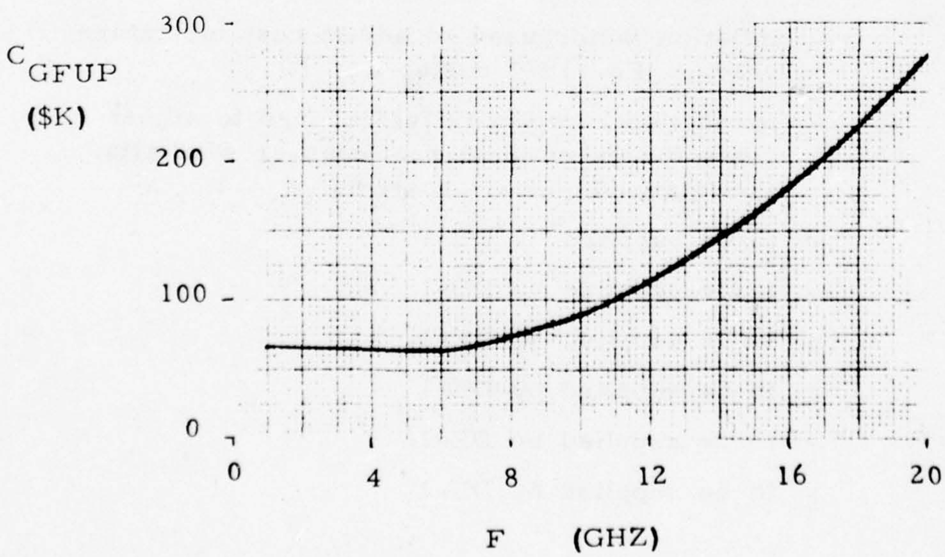
$$C_{GFUP} = a\left[\frac{1.16\,b}{1000\,(.35)}\left(c\,K_{LEG}\,F^{d} + e\,K_{GTG}\,F^{f} + g\,K_{STAB} + h\,K_{AGATE} + i\,N_{CHAN}\,K_{SGATE} + j\,K_{SGATE}\right) + k\right]$$

Assuming:

a = 1	g = 10500	KSTAB = 1.
b = 1	h = 2400	K_{LEG}, K_{GTG} = 0 if F≤6
c = 7129.	i = 143	1 if F>6
d = -.056	j = 2885	K_{AGATE} = 1
e = 62	k = 0	K_{SGATE} = 0
f = 2.35		N_{CHAN} = 0

this becomes:

$$C_{GFUP} = \frac{1.16}{1000\,(.35)}\left(7129\,K_{LEG}\,F^{-0.056} + 62\,K_{GTG}\,F^{2.35} + 10500 + 2400\right)$$



i = to be supplied by DE-1

j = to be supplied by DE-1

k = miscellaneous cost term in thousands of dollars.

F_C = center frequency in GHZ

K_{LEG} = If $F_C \leq 6$, $K_{LEG} = 1$; If $F_C > 6$, $K_{LEG} = 0$.

K_{GTG} = If $F_C \leq 6$, $K_{GTG} = 0$; If $F_C > 6$, $K_{GTG} = 1$.

K_{STAB} = If system stabilized in place, $K_{STAB} = 1$. If not, $K_{STAB} = 0$.

K_{AGATE} = If angle gating used, $K_{AGATE} = 1$. If not, $K_{AGATE} = 0$.

N_{CHAN} = number of doppler channels if $K_{STAB} = 1$. If not, $K_{STAB} = 0$, $N_{CHAN} = 0$.

K_{SGATE} = If speed gating used, $K_{SGATE} = 1$. If not, $K_{SGATE} = 0$.

Figure 60 shows the CER sensitivity as a function of frequency (F_C), assuming value for the other required inputs. The validity of the CER is stated in Reference 2 as between 2.9 and 10 GHZ (F_C) and zero to 30 doppler channels (N_{CHAN}).

2.4.3.2 Active Radar Guidance System (Magnetron)

The first production unit active radar seeker CER include all hardware associated with the sensor subsystem, including sensor electronics, sensor electromechanical components, inertial components, wiring, radome, and heating protection elements housing the seeker. A magnetron transmitter is used. The CER is lifted directly from Reference 2 and is described as follows:

$$C_{GFUA} = a\left[\frac{1.16\ (1.35)\ b}{350}\left(c\ K_{LEG}\ F_C^{\ d} + e\ K_{GTG}\ F_C^{\ d} + g\ K_{STAB} + h\ K_{AGATE} + i\ N_{CHAN}\ K_{SGATE} + j\ K_{SGATE} + k + l\ (P_{PEAK})^m + n\ F_C^{\ P}\ P_{PEAK}\right) + q\right] \quad (3)$$

Fig. 61

FIGURE 61

GUIDANCE FIRST UNIT COST, ACTIVE RADAR (MAGNETRON)

Reference: Equation 3 Section 2.4.3.2

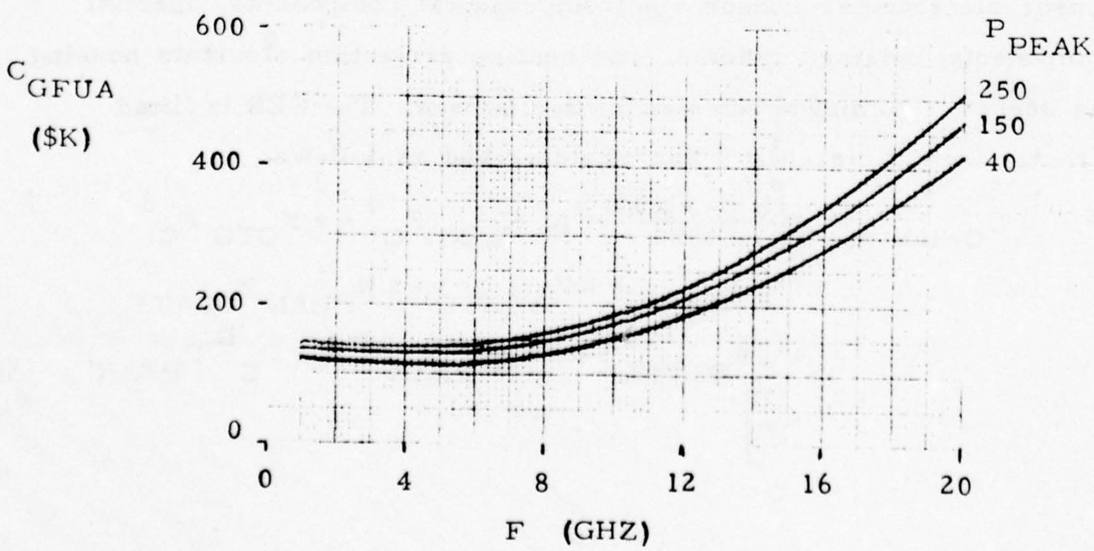
$$C_{GFUA} = a\left[\frac{1.16\,(1.35)\,b}{1000\,(.35)}\left(c\,K_{LEG}\,F^{d} + e\,K_{GTG}\,F^{f} + g\,K_{STAB} + h\,K_{AGATE} + i\,N_{CHAN}\,K_{SGATE} + j\,K_{SGATE} + k + l\,P_{PEAK}^{\;m} + n\,F^{p}\,P_{PEAK}\right) + q\right]$$

Assuming:

a = 1	g = 10500	l = 1620	KSTAB = 1
b = 1	h = 2400	m = .33	K_{GTG}, 0 if F≤6
c = 7129	i = 148	n = .041	KLEG = 1 if F>6
d = -.056	j = 2885	p = 2.5	K_{AGATE} = 1
e = 62	k = 1500	q = 0	K_{SGATE},
f = 2.35			N_{CHAN} = 0

this becomes:

$$C_{GFUA} = \frac{1.16\,(1.35)}{1000\,(.35)}\left(7129\,K_{LEG}\,F^{-.056} + 62\,K_{GTG}\,F^{2.35} + 10500 + 2400 + 1500 + 1620\,P_{PEAK}^{\;.33} + .041\,F^{2.5}\,P_{PEAK}\right)$$



where:

C_{GFUA} = guidance system first unit cost in thousands of dollars

a = inflation factor used to adjust cost for future years. For 1974 costs, a = 1.

b = production complexity factor used to adjust costs for exceptional problems or windfalls. For state of the art systems, b = 1.

c, d, e, f, g, h, i, j, k, l, m, n, p } = to be supplied by DE-1

F_C, K_{LEG}, K_{GTG}, K_{STAB}, K_{AGATE}, N_{CHAN}, K_{SGATE} } = same as defined under 2.4.3.1.

P_{PEAK} = peak generated transmit power in kilowats

q = miscellaneous cost term in thousands of dollars.

Figure 61 shows the CER sensitivity as a function of frequency and peak power, assuming value for the other required inputs. The validity of the CER is stated in Reference 2 as between 2.9 and 10 GHZ frequency and .1 to 50 KW peak power. For the purposes of the SEATIDE process, however, the CER is assumed valid up to 20 GHZ and 250 KW peak power.

2.4.3.3 Infrared Seeker

The first production unit passive infrared seeker CER includes all hardware associated with the sensor subsystem, including sensor electronics, sensor electromechanical components, inertial components, wiring, radome, and heating protection elements housing the seeker. The CER was lifted directly from Reference 2 and is described as follows:

$$C_{GFUI} = a\left[\frac{1.16\,b}{350}\left(c\,F_C^{\,d}\,B_{SP}^{\,e} + f\,(N_{DET} - 1) + g\right) + h\right] \quad (5)$$

Fig. 62

where:

C_{GFUI} = guidance system first production unit cost in thousands of dollars.

a = inflation factor used to adjust cost for future years. For 1974 costs, a = 1.

b = production complexity factor used to adjust costs for exceptional problems or windfalls. For state of the art systems, b = 1.

c, d, e, f, g } = to be supplied by DE-1

h = miscellaneous cost term in thousands of dollars.

F_C = center frequency in μM

B_{SP} = spectral bandwidth in μM

N_{DET} = number of detectors

Figure 62 shows the CER sensitivity as a function of frequency and number of detectors. The validity of the CER is stated in Reference 2 as valid between frequencies of 3-5μM, bandwidth of .5-2μM, and numbers of detectors between 1 and 10. However, for the purposes of SEATIDE, the CER is assumed valid up to frequencies of 14μM and bandwidth up to 6μM.

FIGURE 62

GUIDANCE FIRST UNIT COST, PASSIVE IR SEEKER (U)

Reference: Equation 5 Section 2.4.3.3

$$C_{GFUI} = a\left\{\frac{1.16b}{1000(.35)}\left[c\,F^{d}\,B_{SP}^{\ e} + f\,(N_{DET} - 1) + g\right] + h\right\}$$

Assuming:

a = 1 e = -1.147

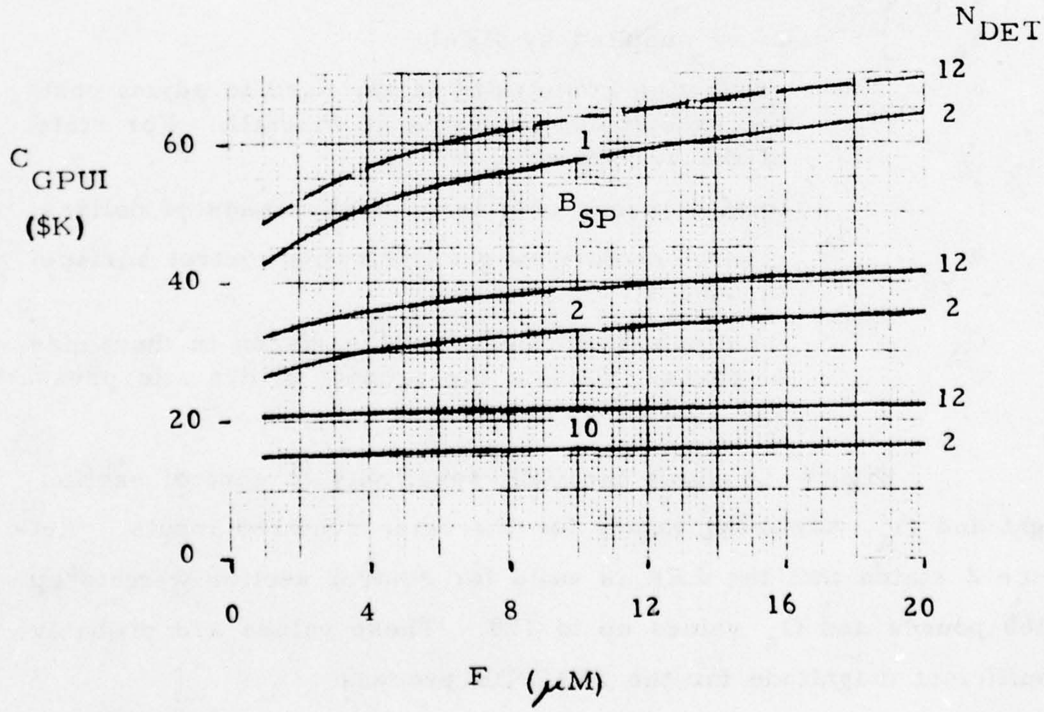
b = 1 f = 175

c = 9018 g = 3700

d = .177 h = 0

this becomes

$$C_{GFUI} = \frac{1.16}{1000(.35)}\left[9018\,F^{.177}\,B_{SP}^{\ -1.147} + 175\,(N_{DET} - 1) + 3700\right]$$



2.4.3.4 Control Systems with Autopilot

The first production unit CER for control systems with autopilot includes the costs of actuators, accumulators, energy system, nozzles, thrusters, tanks, valves, wiring, structural and heat protection elements, pumps, and plumbing of the control system plus the movable and nonmovable control surfaces. It also includes autopilot related gyros, accelerometers, and electronics. The CER was taken directly from Reference 2 and is described as follows:

$$C_{CFU} = a \left[\frac{1.16\,(b\,W_{CS} + c\,Q_A - d)\,e}{198} + f \right] \qquad (2)$$

Fig. 63

where:

C_{CFU} = control systems first unit cost in thousands of dollars.

a = inflation factor to adjust costs to future years. For 1974 costs, $a = 1$.

b, c, d = to be supplied by DE-1

e = production complexity factor used to adjust cost for exceptional problems of windfall. For state of the art systems, $e = 1$.

f = miscellaneous cost term in thousands of dollars.

W_{CS} = control section weight (including control surface) in pounds.

Q_A = maximum force on control surfaces in thousands of pounds. This is the product of dynamic pressure and control surface area.

Figure 63 shows the CER sensitivity to control section weight and Q_A, assuming values for the other required inputs. Reference 2 states that the CER is valid for control section weights up to 360 pounds and Q_A values up to 170. These values are probably of sufficient magnitude for the SEATIDE process.

FIGURE 63
CONTROLS FIRST UNIT COST (WITH AUTOPILOT) (U)

Reference: Equation 2 Section 2.4.3.4

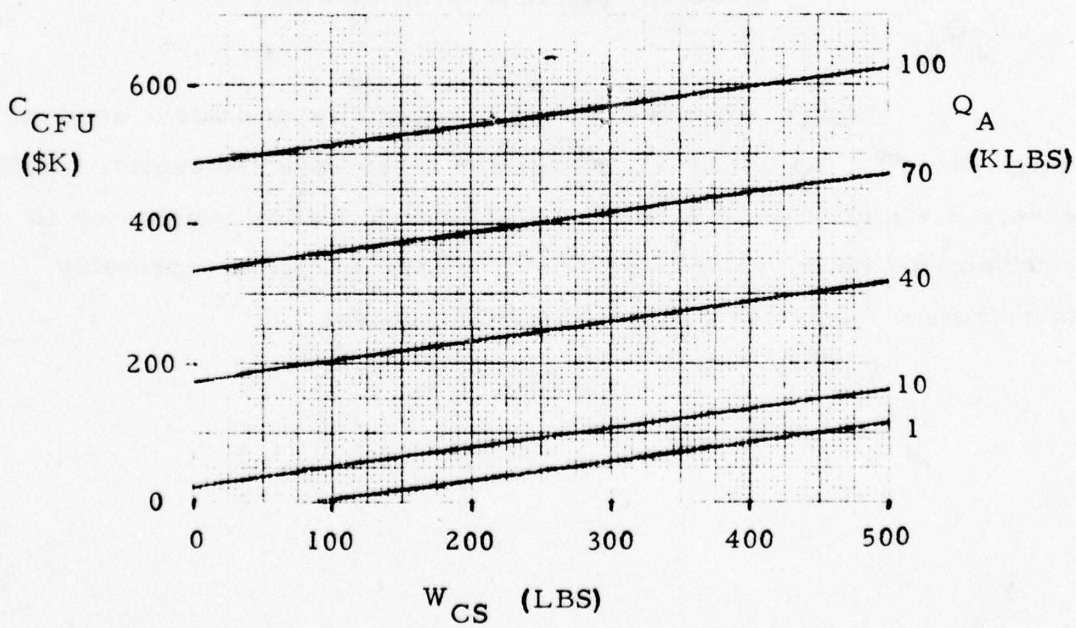
$$C_{CFU} = a\left[\frac{1.16\ (b\ W_{CS} + c\ Q_A - d)\ e}{198} + f\right]$$

Assuming:

a = 1 d = 5116
b = 48 e = 1
c = 881 f = 0

this becomes:

$$C_{CFU} = \frac{1.16\ (48\ W_{CS} + 881\ Q_A - 5116)}{198}$$



2.4.3.5 Control Systems without Autopilot

This CER was lifted directly from Reference 2 and constructed in the same fashion as the CER for control system with autopilots, except that no autopilot related items are included in the costing. The CER is described as follows:

$$C_{CFU} = a \left[\frac{1.16\,(b\,W_{CS} + c\,Q_A + d)\,e}{198} + f \right] \qquad \begin{array}{l}(3)\\ \text{Fig. 64}\end{array}$$

where:

C_{CFU} = control systems first unit cost in thousands of dollars.

a, e, f = same as that defined under 2.4.3.4.

b, c, d = same as that defined under 2.4.3.4 except that the value to be supplied by DE-1 are different than those used in 2.4.3.4.

W_{CS}, Q_A = same as that defined under 2.4.3.4

Figure 64 shows the CER sensitivity to control section weight and Q_A, assuming values for the other required inputs. Reference 2 states that CER is valid for control section weights up to 360 pounds and Q_A values up to 170. These values are probably of sufficient magnitude for the SEATIDE process.

FIGURE 64

CONTROLS FIRST UNIT COST (WITHOUT AUTOPILOT) (U)

Reference: Equation 3 Section 2.4.3.5

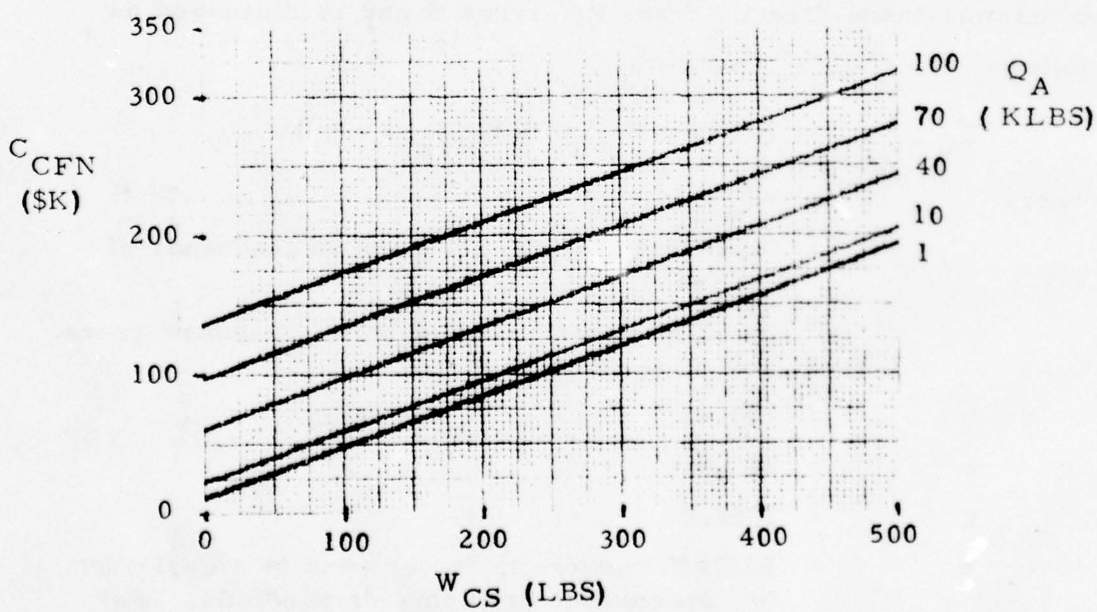
$$C_{CFN} = a \left[\frac{1.16\ (b\ W_{CS} + c\ Q_A + d)\ e}{198} + f \right]$$

Assuming:

a = 1 d = 1880
b = 62 e = 1
c = 213 f = 0

this becomes:

$$C_{CFN} = \frac{1.16\ (62\ W_{CS} + 213\ Q_A + 1880)}{198}$$



2.5 WARHEAD

2.5.1 Sources and Assumptions

Warhead costing methodologies were obtained from two basic sources: (1) Cost Estimating Relationships for Tactical Missile RDT&E (Reference 3), and (2) The ADTC Air Launched Weapon System Cost Model (Reference 2). All warheads are assumed to be high explosive blast, blast frag, or shaped charge with either a contact or proximity fuze. The warhead unit was costed at a system level, and no subsystem details, such as fuzing, charge, and safe/arm device are available.

2.5.2 Warhead RDT&E

Warhead RDT&E costs include the design and engineering associated with the warhead, safe/arm device, warhead firing switch, booster charge, fuzing, and necessary wiring. The cost estimating relationship (CER) used to estimate warhead RDT&E costs was taken directly from Reference 3 and is discussed as follows:

$$C_{WHR} = a\,((b + c\,W_{WH} + d\,K_{FUZE})\,e + f) \qquad (1)$$

Fig. 65

where:

C_{WHR} = total warhead RDT&E costs in thousands of dollars.

a = inflation factor to adjust cost for future years. For 1974 costs, a = 1.

b = 103.43

c = 23.096

d = 1352.0

e = RDT&E complexity factor used to adjust cost for exceptional problems or windfalls. For state of the art warheads, this value equals 1.

FIGURE 65
WARHEAD RDT&E COST (U)

Reference: Equation 1 Section 2.5.2

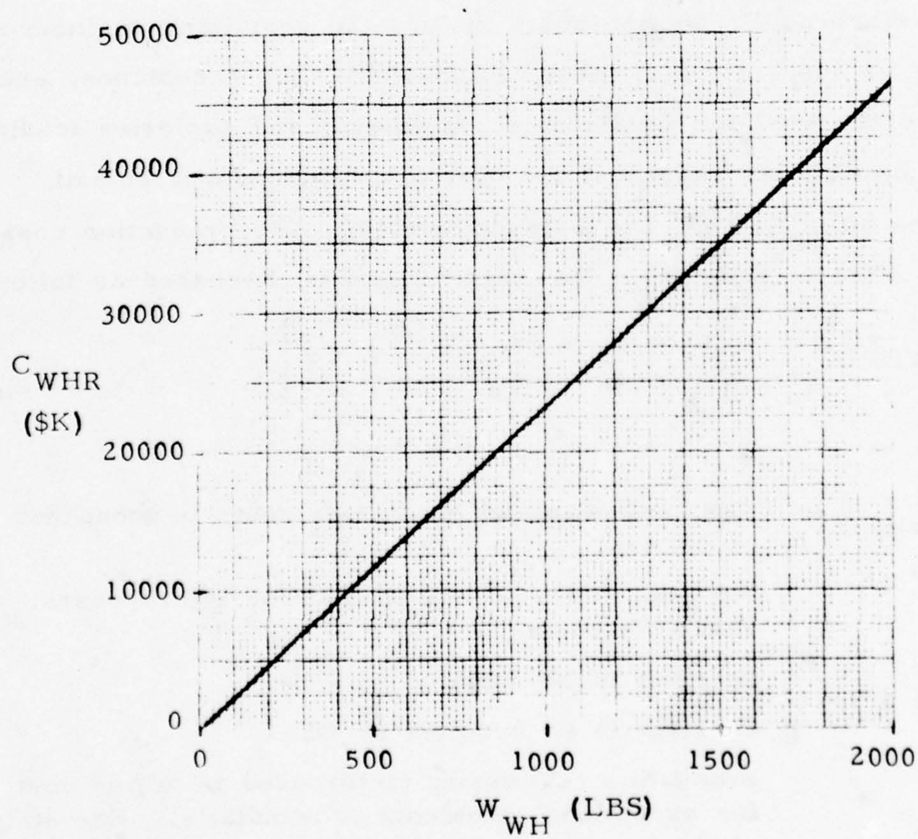
$$C_{WHR} = a\ ((b + c\ W_{WH} + d\ K_{Fuze})\ e + f)$$

Assuming:

$a = 1$ $d = 1352$ $K_{Fuze} = 0$
$b = 103.43$ $e = 1$
$c = 23.096$ $f = 0$

this becomes:

$$C_{WHR} = 103.43 + 23.096 W_{WH}$$



f	=	miscellaneous cost term in thousands of dollars. This value is normally zero.
W_{WH}	=	warhead weight in pounds.
K_{FUZE}	=	factor for fuzing type (0 for contact fuze, 1 for proximity fuze)

Figure 65 shows the CER results as a function of warhead weight, assuming value for the other required inputs. The validity of the CER has been tested in Reference 3 for warhead weights between 86 and 651 pounds. For the purposes of relative costing, it is assumed valid over the total range of non-nuclear warhead weights encountered in the SEATIDE process.

2.5.3 Warhead Production Costs

Warhead Production costs include the sustaining engineering, sustaining tooling, test equipment, ECO/ECP's, lot acceptance, and the cost of the warhead metal parts, explosive, and explosive loading. The production costs represent the cost to produce the first unit off the line after RDT&E has been completed. The production cost CER was lifted directly from Reference 2 and is discussed as follows:

$$C_{WHFU} = a \left[\frac{1.28\,(b + c\,(W_{WH})^{1/2})d}{600} + e \right] \qquad (2)$$

Fig. 66

where:

C_{WHFU}	=	first unit warhead production costs in thousands of dollars.
a	=	inflation factor to adjust cost for future years. For 1974 costs, a = 1.
b	=	constant to be supplied by DE-1
c	=	constant to be supplied by DE-1
d	=	production complexity factor used to adjust cost for exceptional problems or windfalls. For state of the art warheads, this value equals 1.

FIGURE 66

WARHEAD FIRST UNIT COST (U)

Reference: Equation 2 Section 2.5.3

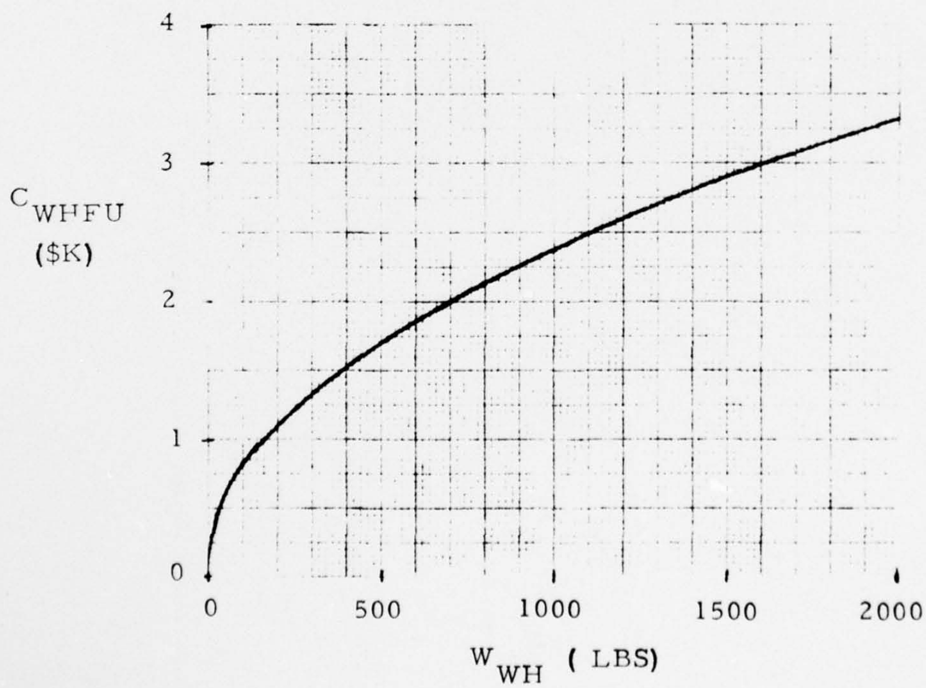
$$C_{WHFU} = a \left[1.28 \frac{(b + c(W_{WH})^{1/2}) d}{600} + e \right]$$

Assuming:

a = 1 d = 1
b = 65 e = 0
c = 43

this becomes:

$$C_{WHFU} = 1.28 \frac{65 + 43 (W_{WH})^{1/2}}{600}$$



e = miscellaneous cost term in thousands of 1974 dollars. Normally the value is zero.

W_{WH} = warhead weight in pounds.

Figure 66 shows the CER results as a function of warhead weight, assuming values for the other required inputs. The validity of the CER is expressed in Reference 2 as between 8 and 250 lbs. W_{WH}. For the purposes of relative costing, however, the CER is assumed valid across the total range of non-nuclear warhead weights used in the SEATIDE process.

3.0 RCM STRUCTURE

The Relative Cost Model (RCM) is an integral part of the Concept Generation and Screening Model (CGSM). The roles of the RCM within the CGSM are shown in the flow diagram on Figure 67. The RCM is primarily designed to provide relative cost data to the CGSM for use in screening missile concepts to dominance levels. Cost in that case is based on the subsystem and system sizing and performance data computed as a routine part of concept generation. The RCM is also designed to provide parametric data to the user independently of concept generation. Cost in that case is based on an input set of sizing and performance parameters. Input to the CGSM required to execute the RCM is discussed in Volume IIIA, Sections III-3.0 and III-4.0. Cost output is described in Volume IIIA, Section IV.

The RCM consists of eleven subroutines and approximately 1300 cards (excluding CGSM executive logic required for input and throughput of data). A listing of those modules is included as Appendix B.

The RCM functional flow is included as Figure 68. Each system (guidance, controls, warhead, airframe and integration, and propulsion) is costed sequentially, and total cost is the sum of all system costs. Both first unit production and RDT&E costs are computed for each system and are totaled. Costing of individual systems can be bypassed in a given JOB if desired, as shown on Figure 68. Bypass control is discussed in Volume IIIA, Section III-4.0.

Figure 67

CGSM TOP LEVEL FLOW

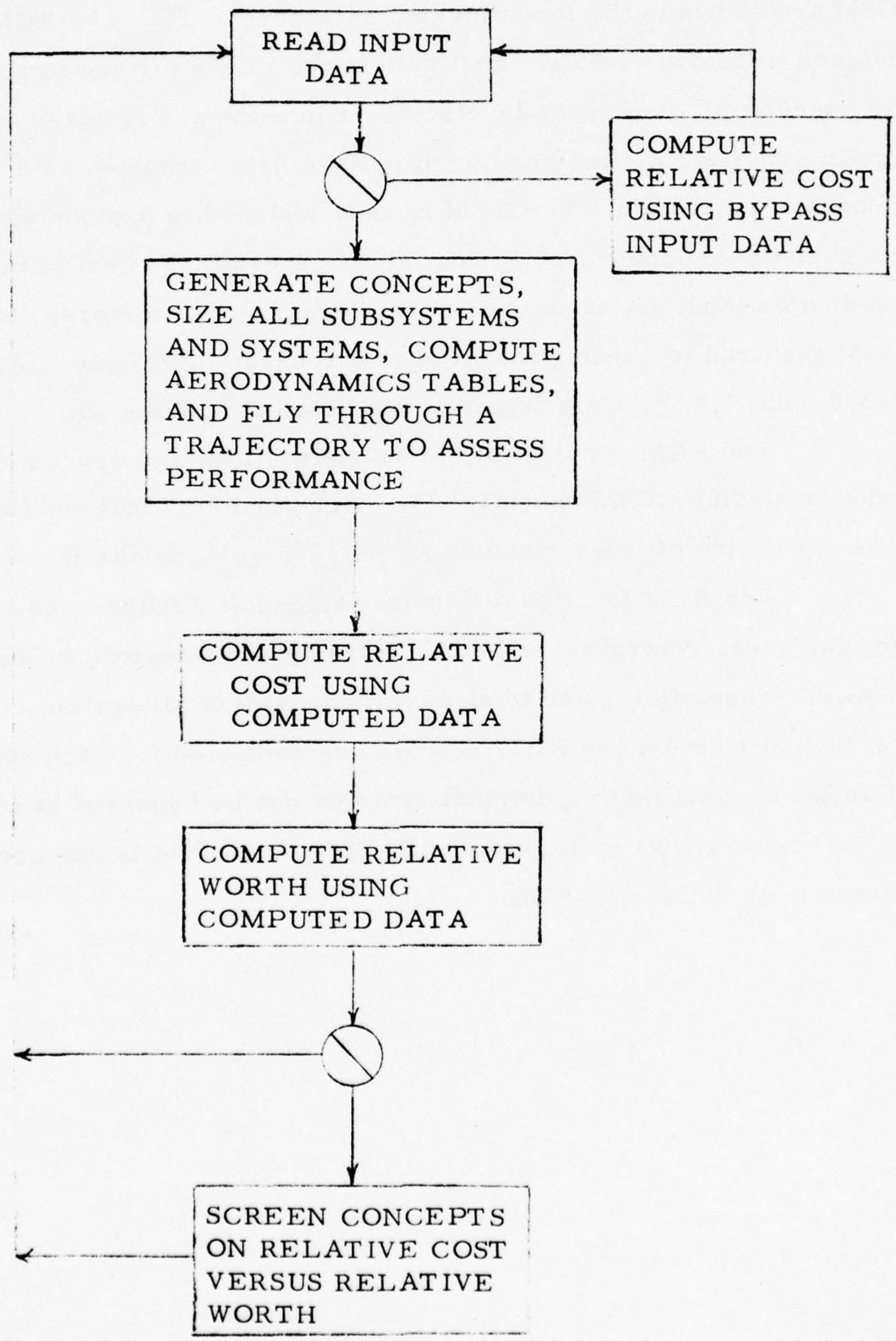


Figure 68

RCM TOP LEVEL FLOW

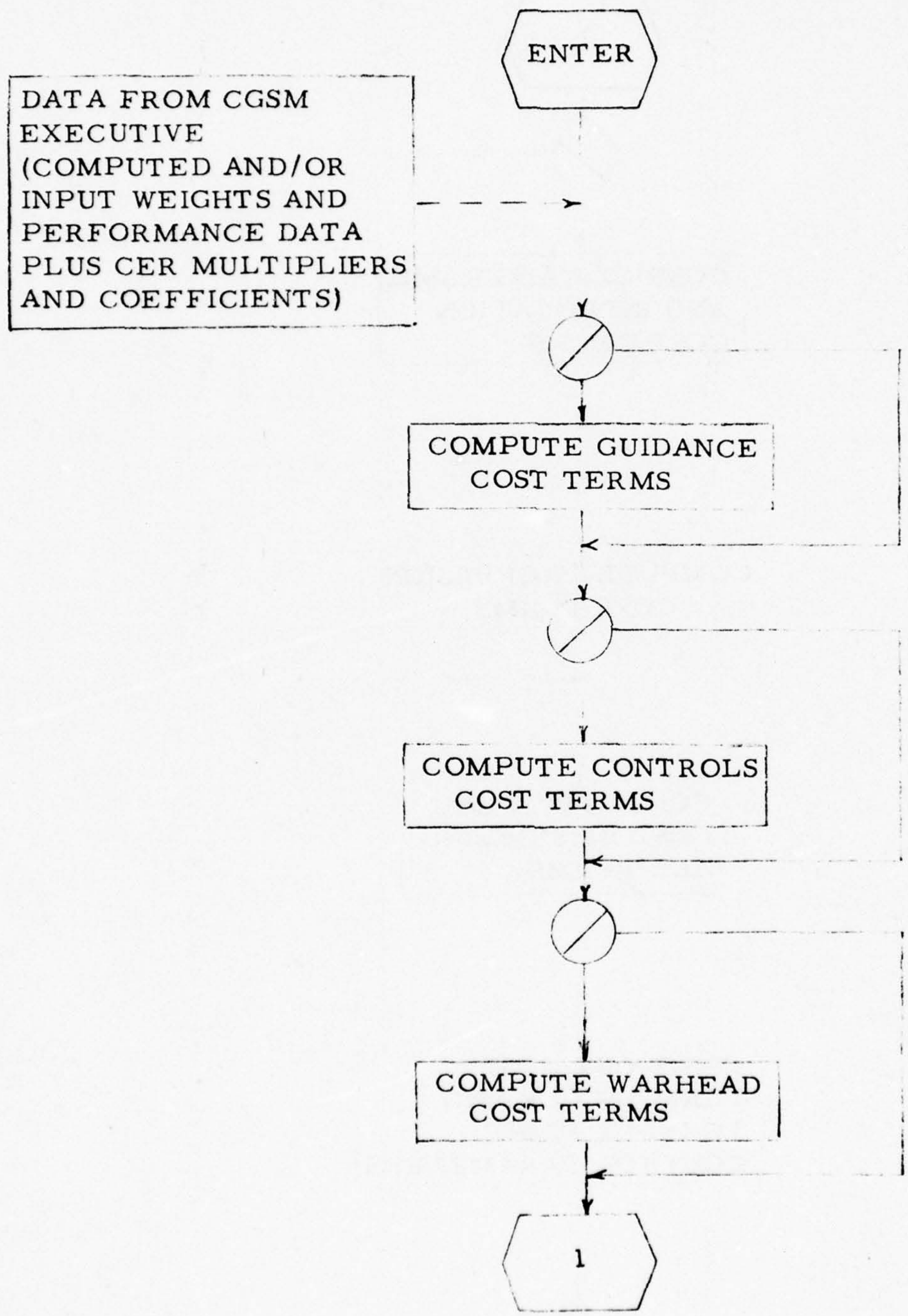
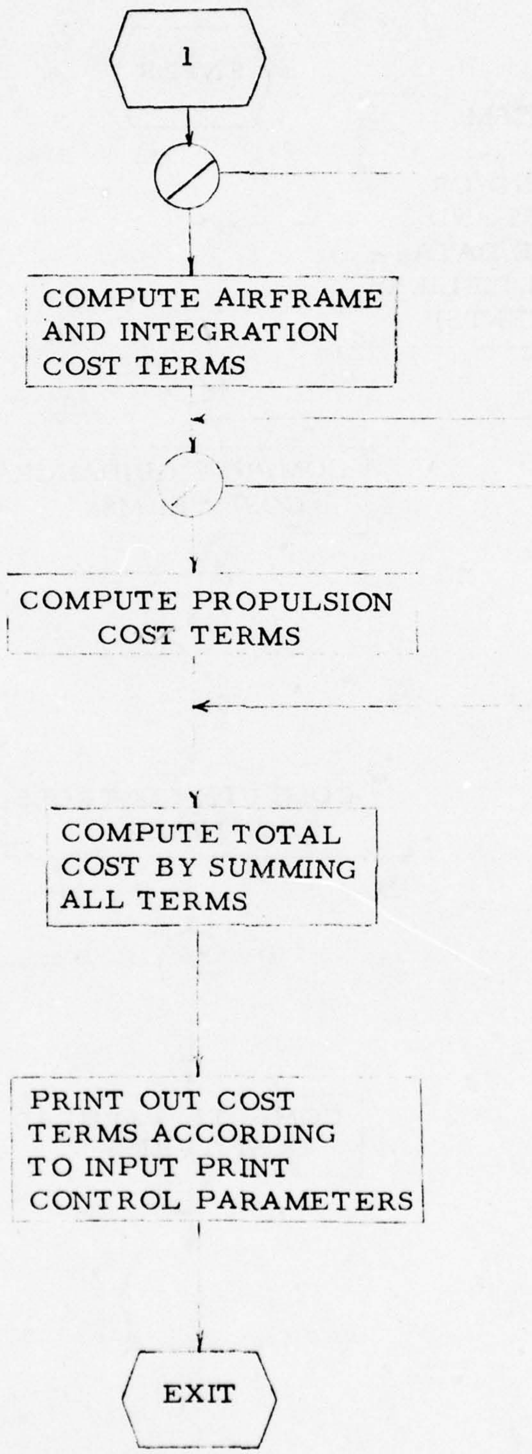


Figure 68 (Continued)



APPENDIX A

TEST CASE DEFINITIONS AND RESULTS

APPENDIX A

SEATIDE RELATIVE COST MODEL TEST CASE DEFINITIONS AND RESULTS

1. TEST CASE DEFINITION

As required in Task 2 of the statement of work, test cases for the demonstration of the relative cost model are defined in this appendix. The test cases involve all three models of the SEATIDE process, but are specially designed for testing the relative cost model. Trade factors are obtained from the Naval Engagement Model (NEM), configurations are generated and screened using the relative cost model in the Cruise Missile Concept Generation and Screening Model (CM-CGSM) and ranked in the Relative Worth Model (RWM). Comparisons are made with and without the relative cost model as a screening parameter. The first test cases utilized involve an air-launched ASM using liquid propulsion. Figure A.1-1 defines the parameters used in this test case, including the missile trajectory. Trade factor variations are made for cruise velocity, total range, and warhead weight. Figure A.1-2 describes the second test case, a solid fueled, ship launched surface-to-surface cruise missile with two external solid rocket boosters. Parameter variations and the missile trajectory are shown. Trade factor calculations are made for warhead weight, cruise velocity, and total range.

Screening and ranking for the two cases are done separately and controlled as follows:

FIGURE A.1-1

CASE 1 - ASM

a. Propulsion: Liquid Rocket

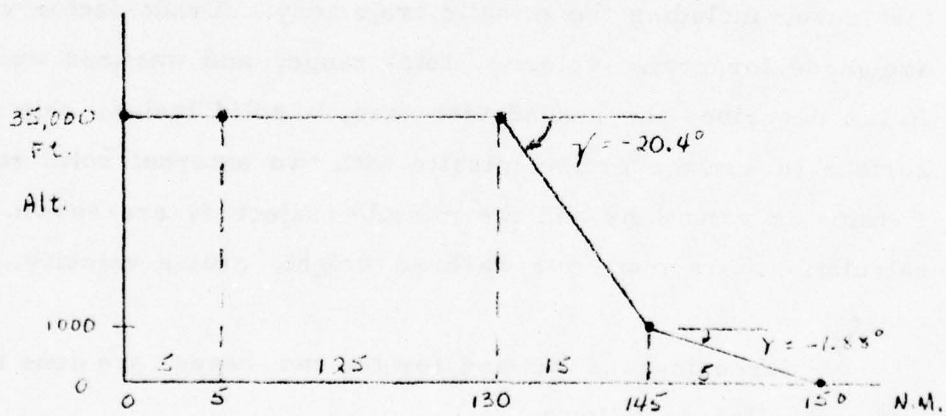
b. Guidance

- Midcourse: Autopilot + Track, Command
- Terminal: Homing Radar

c. Warhead: HE (500, 1000, 2000)* Lbs.

d. Trajectory:

- Launch: Air, 35,000 Ft, 400 Kts
- Cruise: 35,000 Ft, (500, 1000)* Kts.
- Range, Total: (100, 150, 200)* NM
- Run-In: Low Level, 5 NM, V_{max}



*Note: Numbers in parenthesis show variations, baseline values are underlined.

FIGURE A.1-2

CASE 2 - SSM

a. Propulsion: Solid Rocket Sustainer with 2 Solid Rocket Boosters

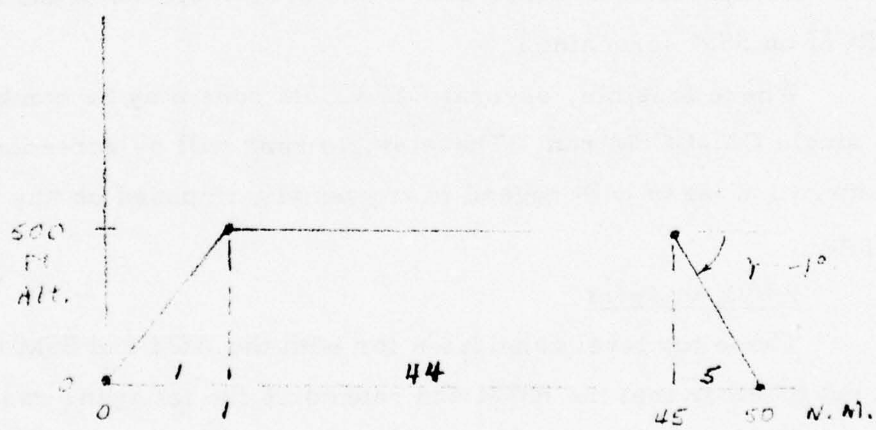
b. Guidance

- Midcourse: Autopilot + Track, Command
- Terminal: Homing Radar

c. Warhead: HE (500, 1000, 2000)* Lbs.

d. Trajectory:

- Launch: Surface
- Cruise: 500 Ft, (800, 1250)* Kts.
- Range, Total: (25, 50, 100)*



*Note: Numbers in parenthesis show variations, baseline values are underlines.

1.1 Case I - ASM Analysis

Within the CM-CGSM, screening is done to obtain top level candidates for each of the following subcases:

Case 1.1.R - ASM, 500 KT Cruise, Screen using RCM

Case 1.1.W - ASM, 500 KT Cruise, Screen using Weight

Case 1.2.R - ASM, 1000 KT Cruise, Screen using RCM

Case 1.2.W - ASM, 1000 KT Cruise, Screen using Weight

Comparison of Cases 1.1.R and 1.1.W will show the influence of the relative cost model on ASM screening.

1.2 Case II - SSM Analysis

Within the CM-CGSM, screening is done to obtain top level candidates for each of the following subcases:

Case 2.1.R - SSM, 800 KT Cruise, Screen using RCM

Case 2.1.W - SSM, 800 KT Cruise, Screen using Weight

Case 2.2.R - SSM, 1250 KT Cruise, Screen using RCM

Case 2.2.W - SSM, 1250 KT Cruise, Screen using Weight

Comparison of Cases 2.2.R and 2.2.W will show the influence of the RCM on SSM screening.

Where feasible, several CM-CGSM runs may be combined and run as a single CM-CGSM run. These single runs will be screened jointly with consideration taken with regard to any penalty imposed on any particular design.

1.3 RWM Analysis

These top level candidates for both the ASM and SSM analysis were then put together into the RWM and ranked as the following cases:

Case 1.R - ASM, with RCM

Case 2.R - SSM, with RCM

2. NAVAL ENGAGEMENT MODEL - TEST CASE RESULTS

Trade Factors, for use in the CM-CGSM, as discussed in Vol. IIA, Section V, were developed for the ASM and SSM test cases previously defined. Two naval engagements were set up similar to that defined in Appendix A, Vol. IIB. While each contains a mix of Naval weapons, one featured ASMs and the other SSMs. The elements common to the two engagements are:

A BLU Task Force is in transit in the open sea. The Task Force has been under observation for several days, and RED plans a coordinated attack at time T=0 hours. RED will attack with surface ships and land-based aircraft, armed with cruise missiles. BLU will defend with carrier-based aircraft, surface-to-air missiles, and guns. Both sides move along pre-planned routes until engagement interactions produce a change. Force composition, planned routes, and engagement outcomes are given below for the test cases. All positions and planned routes are in terms of an arbitrary rectangular X-Y coordinate system, scaled in nautical miles. Positive Y is north.

Value Lost on each side is in terms of the value scheme developed in Appendix J, Vol. IIB, and shown here in Table A.2-1. Worth is computed as:

$$W = \frac{BVL}{BVL + RVL} \times 100$$

where:

BVL = BLU Value Lost

RVL = RED Value Lost

TABLE A.2-1

VALUE ASSIGNED TO UNITS

TYPE	SYMBOL	NAME	VALUE
BLU			
6113	CVA	Aircraft Carrier	400
6132	CG	Guided Missile Cruiser	80
6153	DD	Destroyer	20
6154	DDG	Destroyer, Guided Missile	40
6155	DLG	Destroyer, Guided Missile	40
6212	VF	Fighter Aircraft	2
6221	VA	Attack Aircraft	2
RED			
8137	CLGM	Light Cruiser, Guided Missile	80
8154	DLG	Destroyer, Guided Missile	40
8227	BGGM	Bomber, Guided Missile	4
8242	BED	Bomber, Director	3

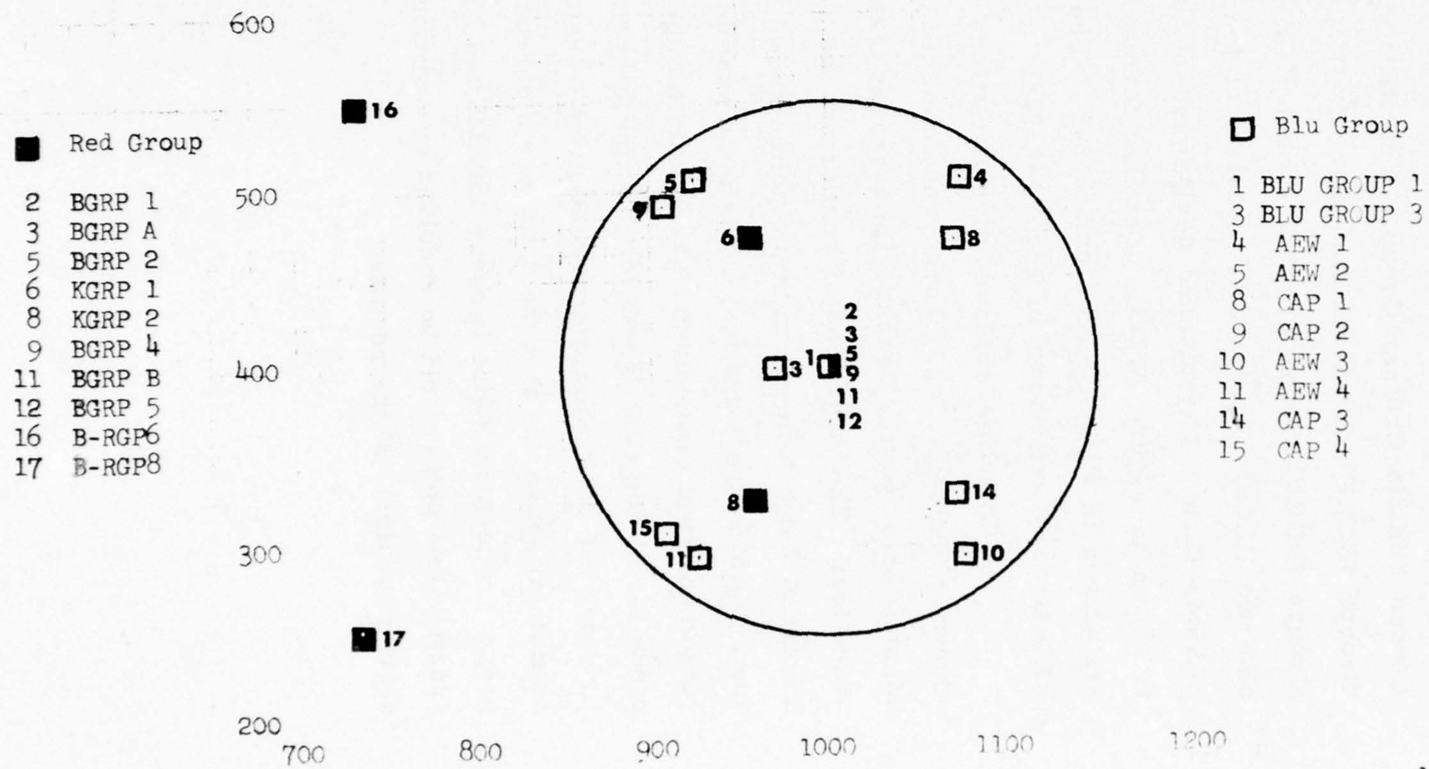
2.1 ASM Trade Factors

The BLU side consists of one Carrier Task Group and one Guided Missile Cruiser Group. The RED side consists of two CLGM Groups (KGRP) and associated aircraft (B-RGPX), and five aircraft Groups (BGRP) carrying ASMs. Each KGRP consists of one CLGM and two DLGs. Each BGRP consists of four BGGM aircraft carrying 2 ASMs each. The planned deployment of the two sides at time T=0 is shown in Figure A.2-1. Detailed formations of the two BLU Groups are shown in Figure A.2-2 and A.2-3. The planned routes for the RED Groups are shown in Figure A.2-4.

A Baseline ASM and five variations were run with results as shown in Table A.2-2. These were obtained as two sets of runs of 4 Monte Carlo "passes" each, with averages taken of BLU value lost and RED value lost. The variations of worth from the baseline worth are plotted in Figure A.2-5. Note the multiple points shown for Delta Worth shown for the 200 NM range variation. This is an example of the use of engineering judgement used to supplant a particular item generated by one of the models. In this case it was felt that the lower point (connected by the dashed line) and the point shown for the baseline were both "outliers" in the statistical sense and that the delta worth versus range did not actually possess a negative slope between 150 NM and 200 NM range. In actual practice this point would be resolved by additional NEM runs and more detailed analysis of the results.

FIGURE A.2-1

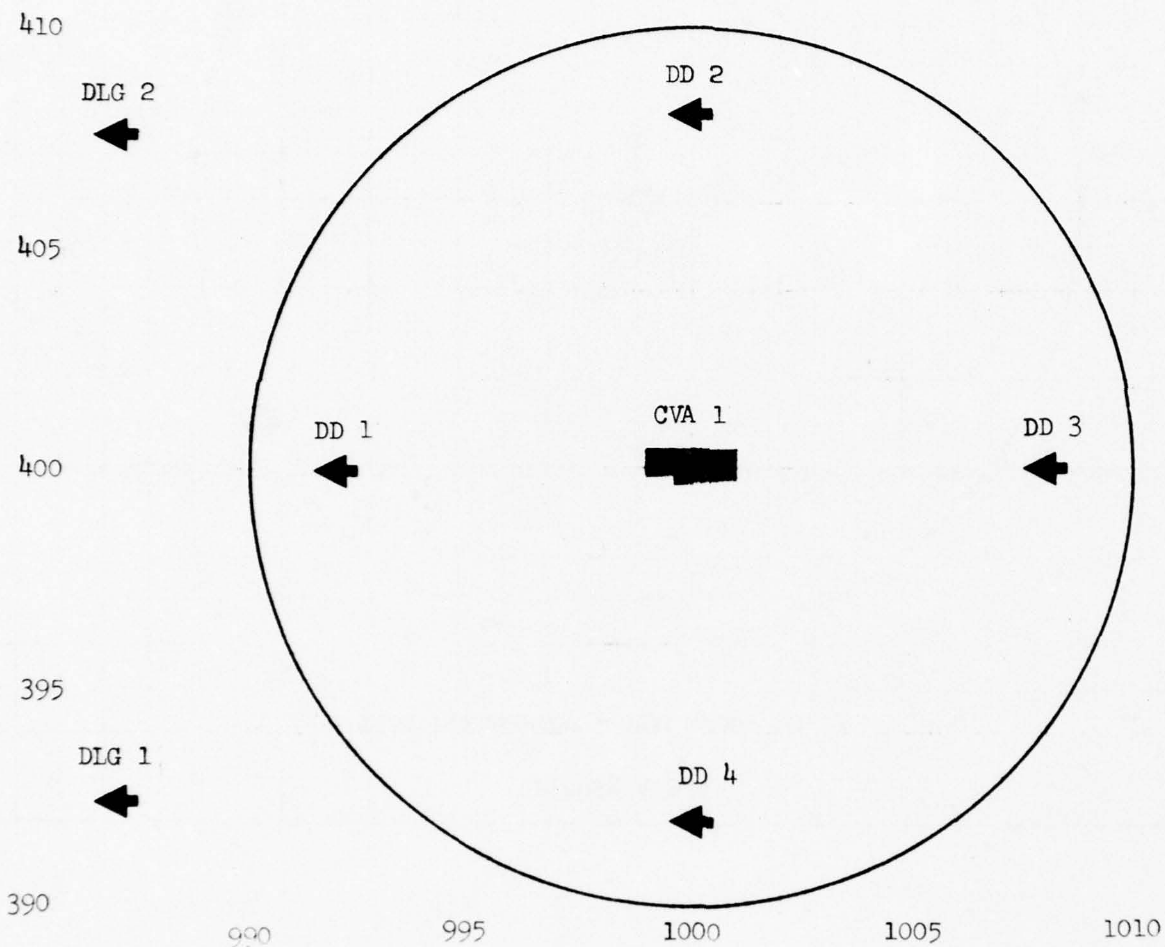
ASM TEST DEPLOYMENT - BLU & RED GROUPS T = 0



1-20-75 data

FIGURE A.2-2

ASM TEST DEPLOYMENT - BLU GROUP NO. 1 T = 0



1-20-75 data

FIGURE A.2-3

ASM TEST DEPLOYMENT - BLU GROUP NO. 3 T = 0

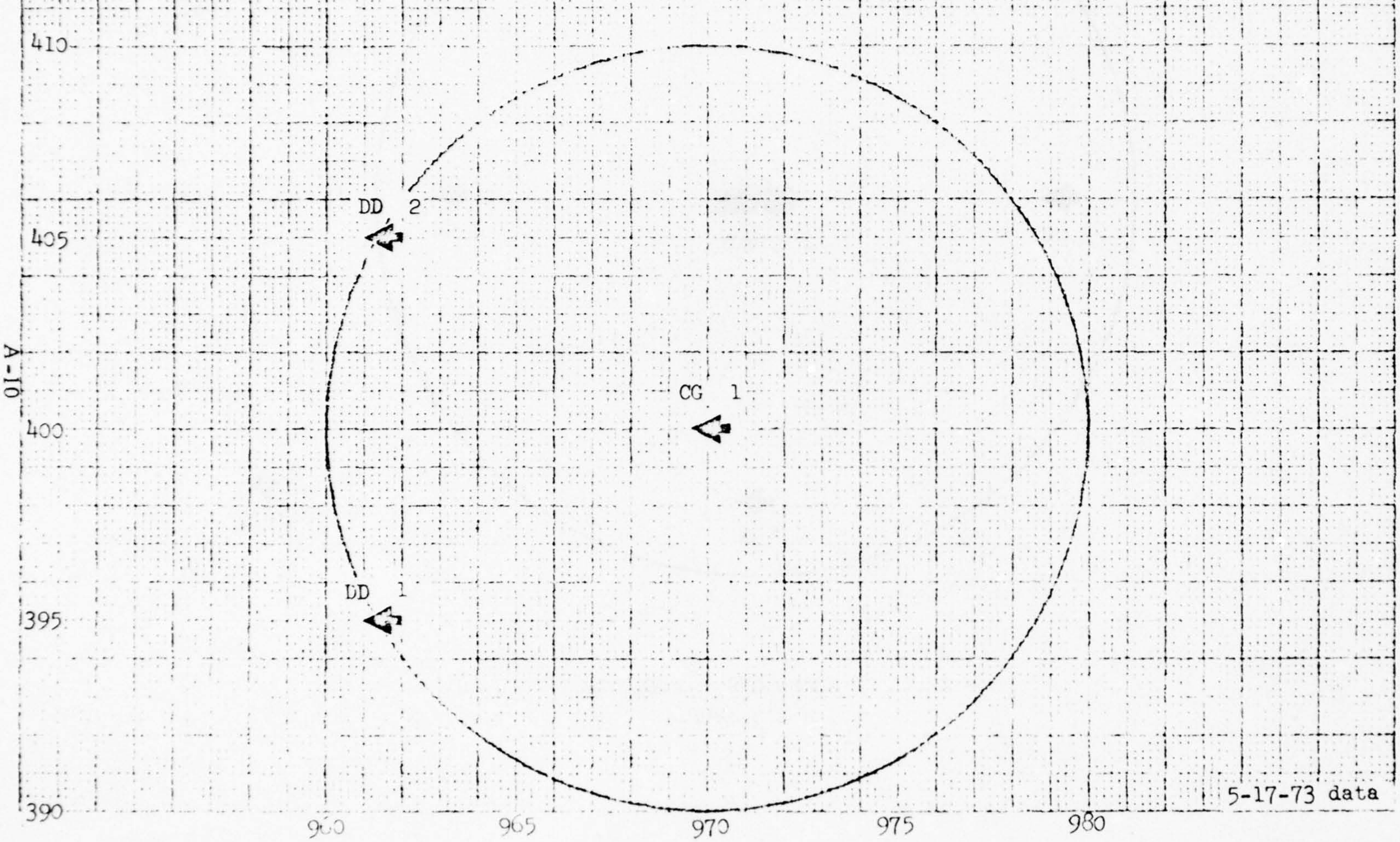


FIGURE A.2-4

ASM TEST DEPLOYMENT - RED GROUPS T = -2 to 0

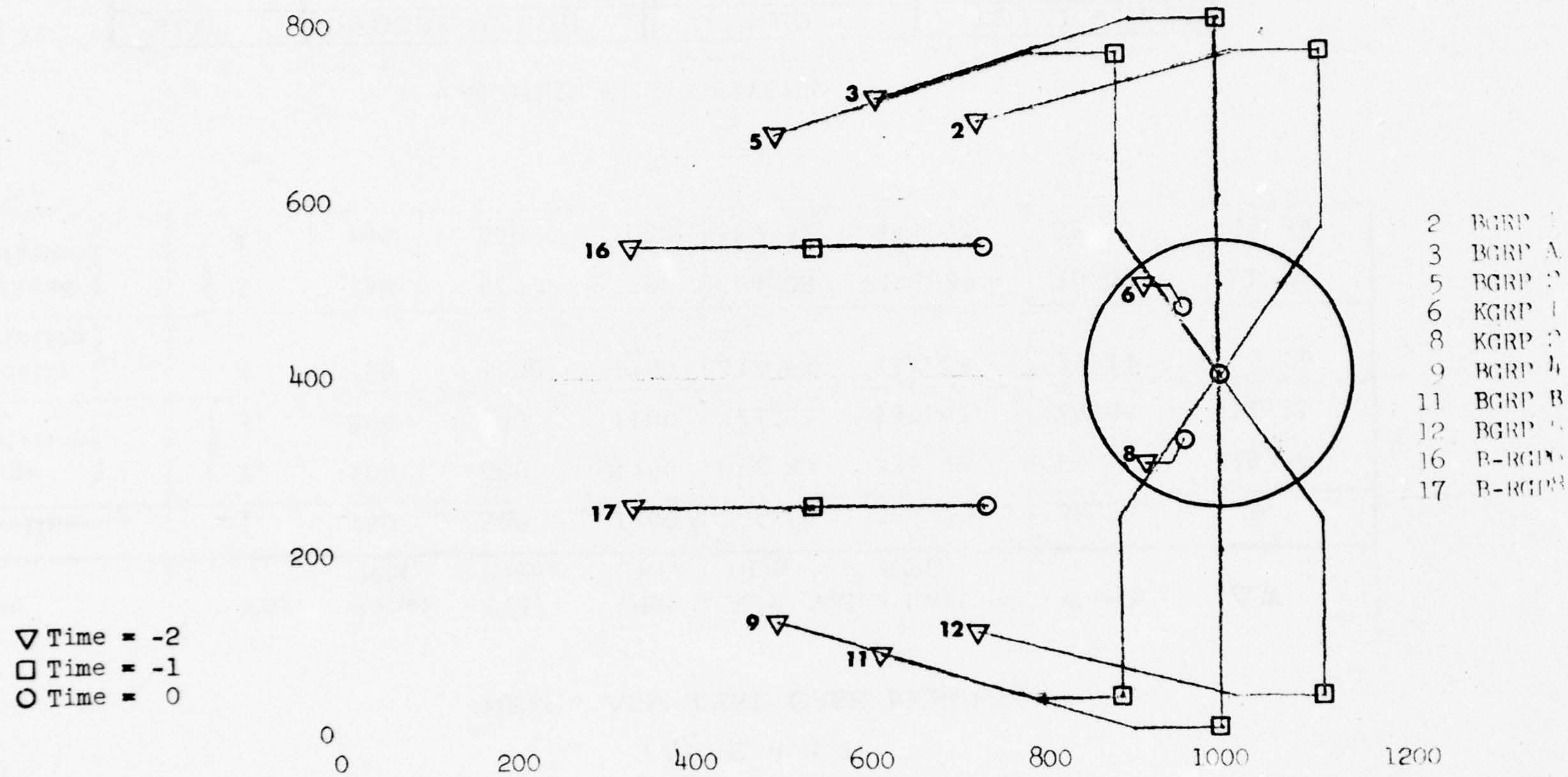


TABLE A.2-2

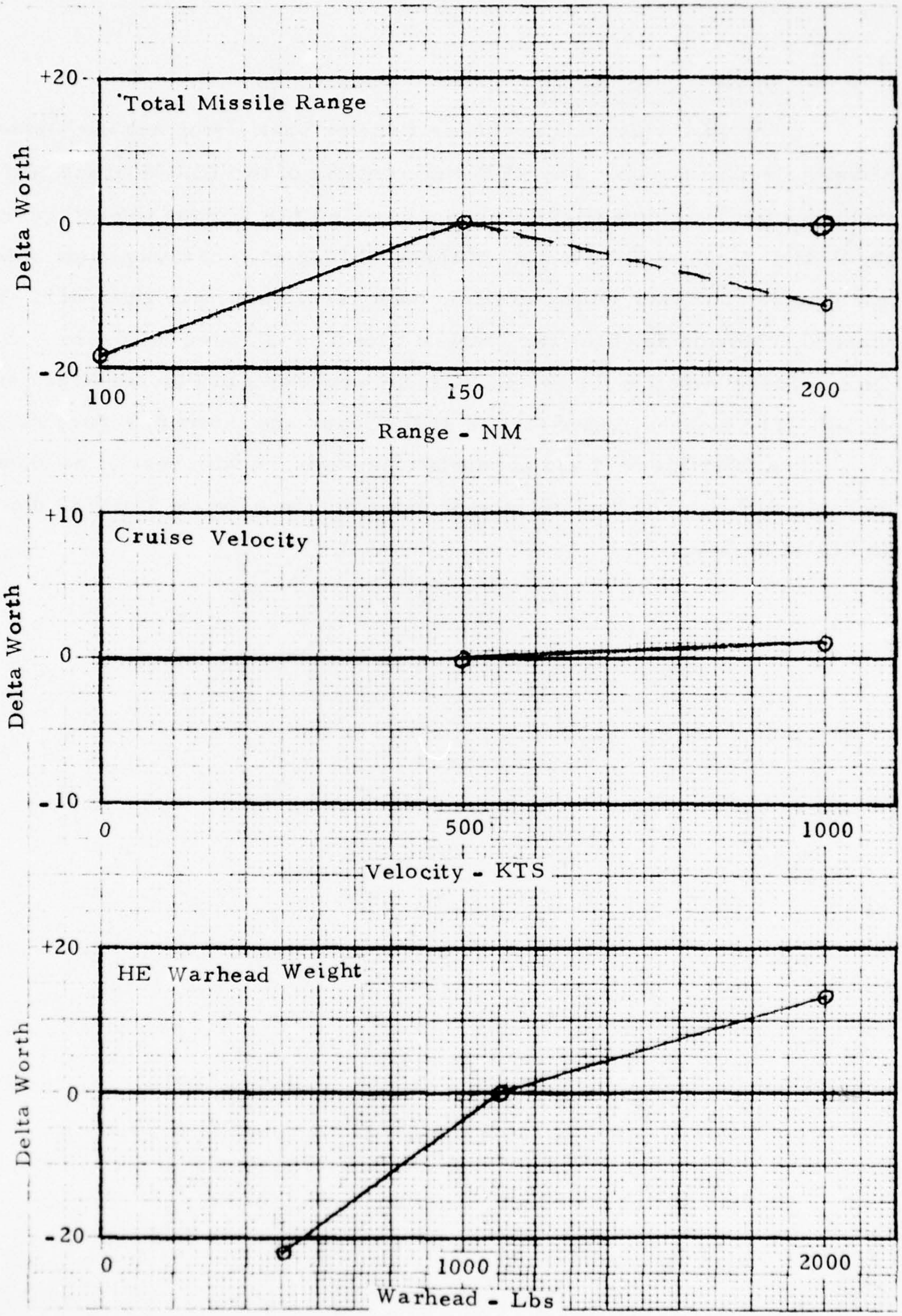
NEM - ASM TEST CASE RESULTS

Case	Var.	Range NM	Vel. Knots	Whd. Lbs.	Avg. Value Lost BLU	Avg. Value Lost RED	Worth	ΔW
Baseline	1.	150	500	1100	206.60	336.29	38.06	0
Range Variation	2.	100	500	1100	82.53	335.42	19.80	-18.26
	3.	200	500	1100	121.52	334.41	26.65	-11.41
Velocity Variation	4.	150	1000	1100	213.54	332.43	39.11	1.06
Warhead Variation	5.	150	500	500	64.28	336.29	16.07	-21.99
	6.	150	500	2000	369.93	341.54	52.00	13.34

VALUE IN ENGAGEMENT

BLU	TOTAL VALUE	RED	TOTAL VALUE
1 CVA	400	2 CLGM	160
2 DLG	80	4 DLG	160
6 DD	120	24 BGGM	96
32 VF	64	4 BED	12
46 VA	92		
1 CG	80		
TOTALS:	836		428

FIGURE A.2-5
ASM TRADE FACTORS



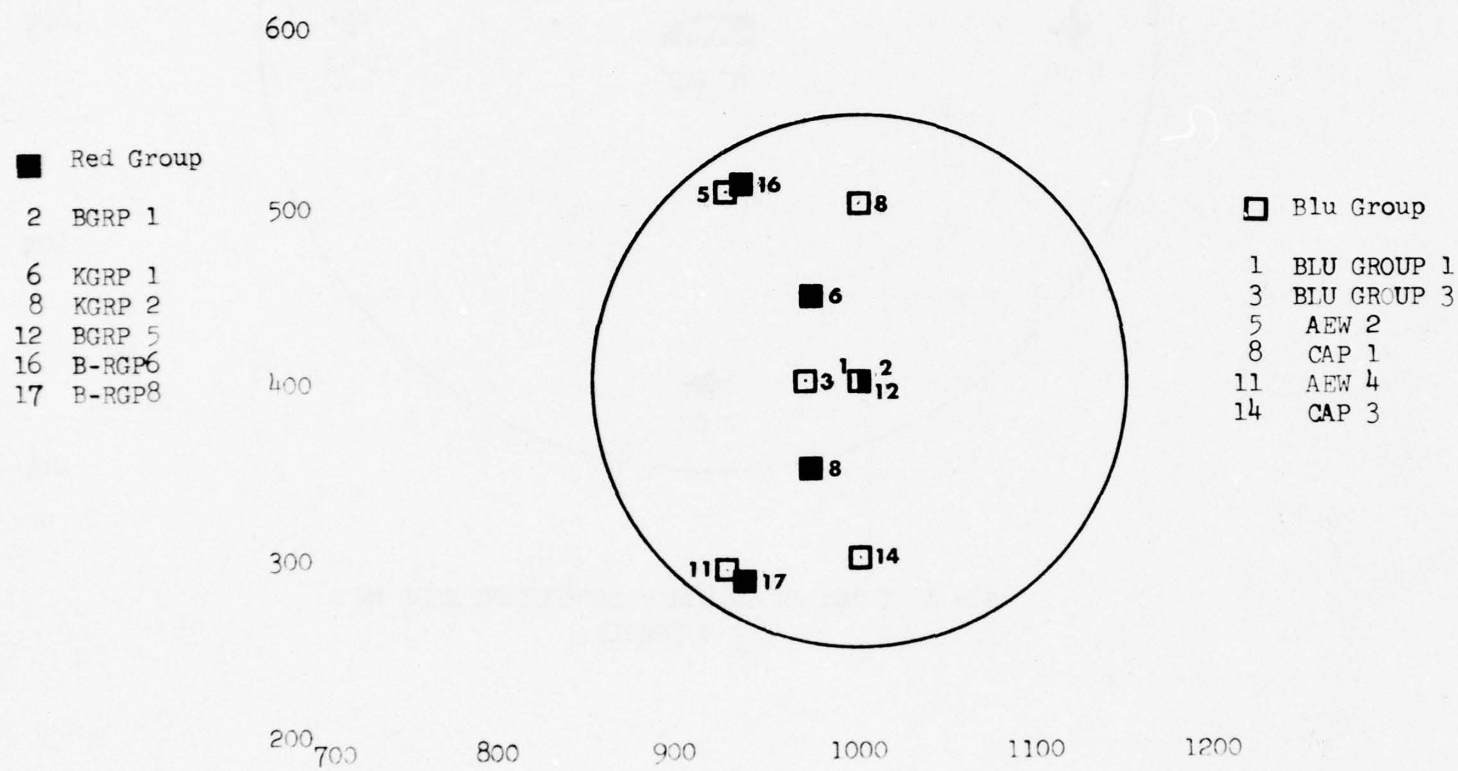
2.2 SSM Trade Factors

The BLU side consists of one Carrier Task Group and one Guided Missile Cruiser Group. The RED side consists of two CLGM Groups (KGRP) and associated aircraft (B-RGPX), and two Aircraft Groups (BGRP) carrying ASMs. Each KGRP consists of three CLGMs each carrying eight SSMs and forty-eight SAMs, plus two DLGs each carrying forty-eight SAMs. The planned deployments of the two sides at time T=0 is shown in Figure A.2-6. Detailed formations of the two BLUGroups are shown in Figures A.2-7 and A.2-8. The planned routes for the RED Groups are shown in Figure A.2-9.

A Baseline SSM and six variations were run with results as shown in Table A.2-3. The variations of Worth from the baseline Worth is plotted in Figure A.2-10.

FIGURE A.2-6

SSM TEST DEPLOYMENT - BLU & RED GROUPS T = 0



1-21-75 data

FIGURE A.2-7

A SM TEST DEPLOYMENT - BLU GROUP NO. 1 T = 0

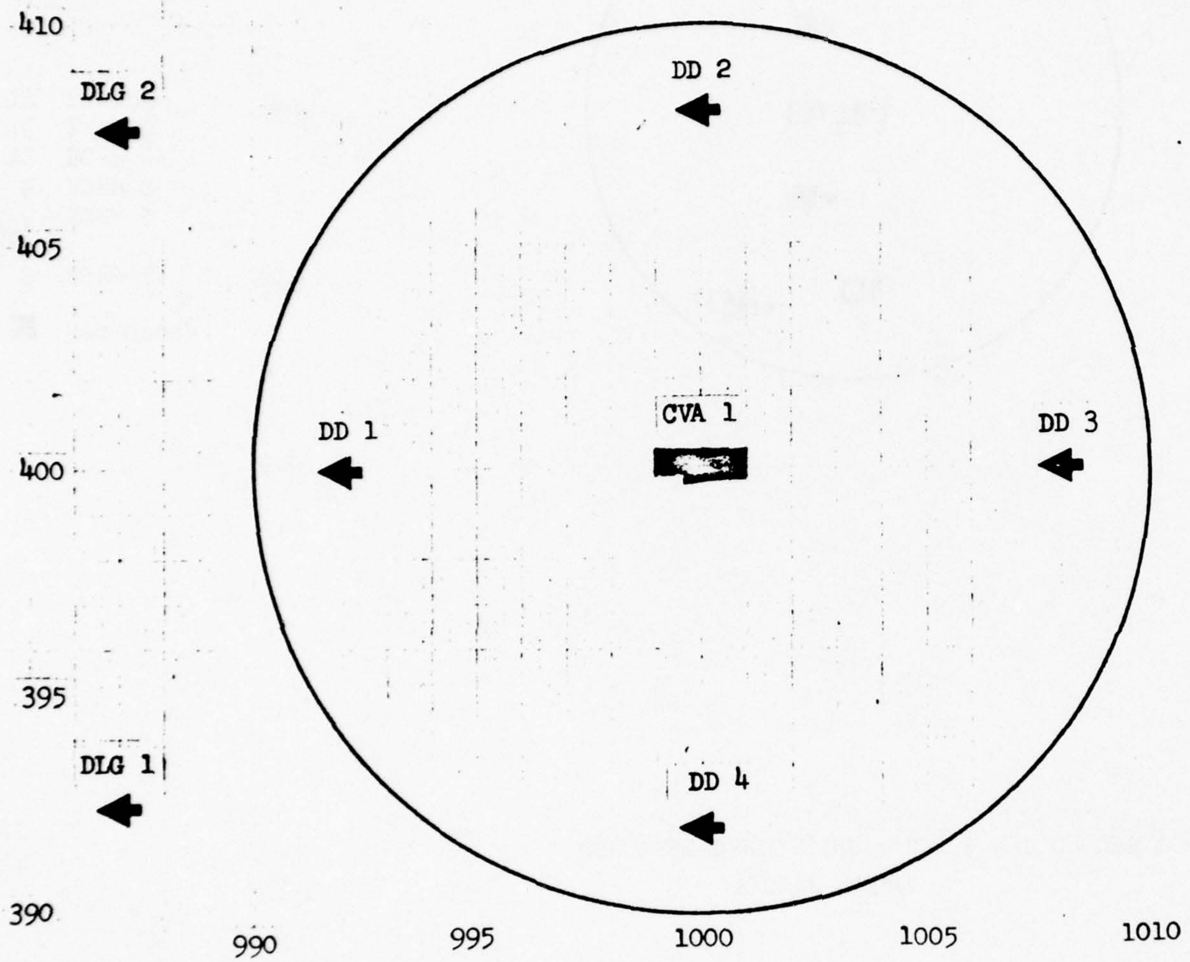


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FIGURE A.2-8

SSM TEST DEPLOYMENT - BLU GROUP NO. 3 T = 0

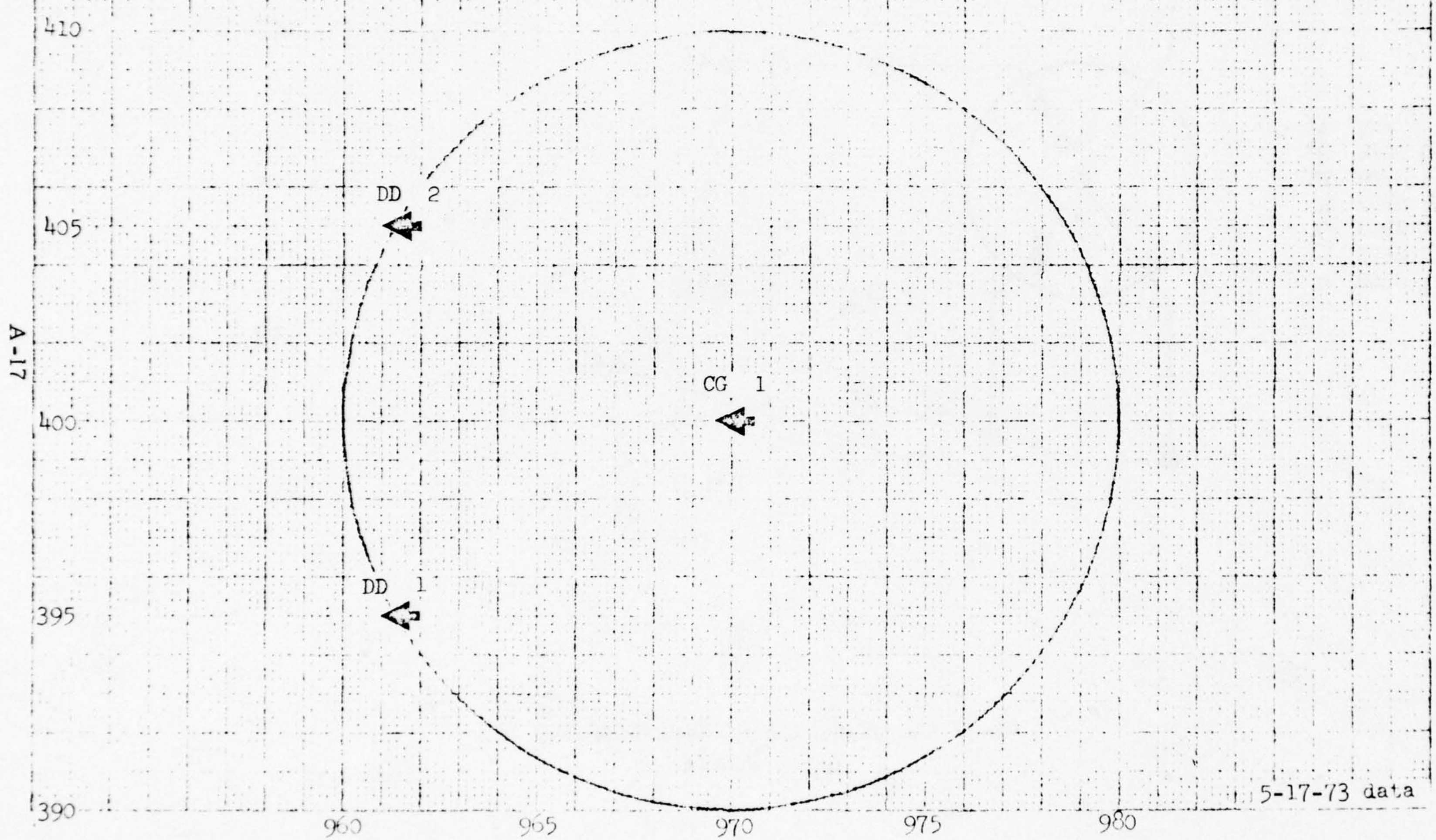
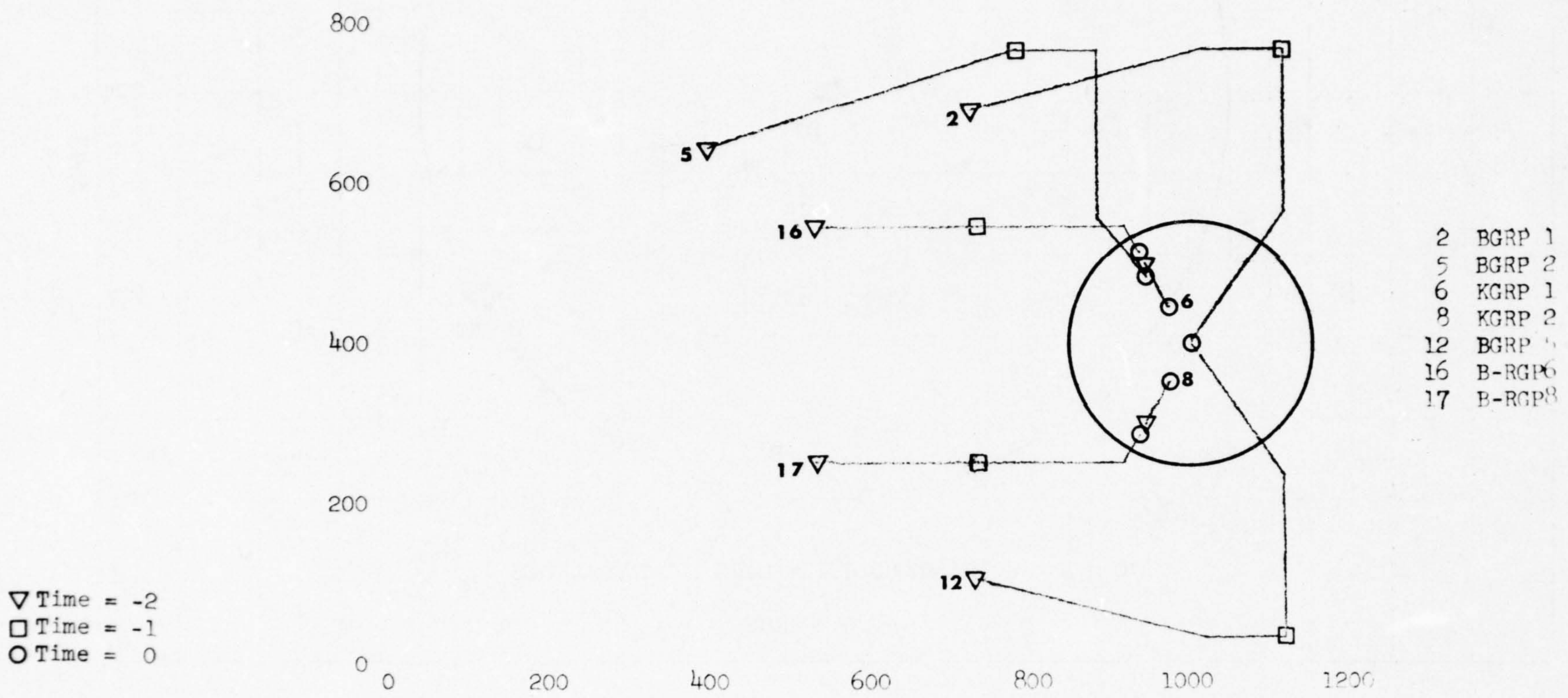


FIGURE A.2-9

SSM TEST DEPLOYMENT - RED GROUPS T = -2 to 0



1-21-75

TABLE A.2-3

NEM - SSM TEST CASE RESULTS

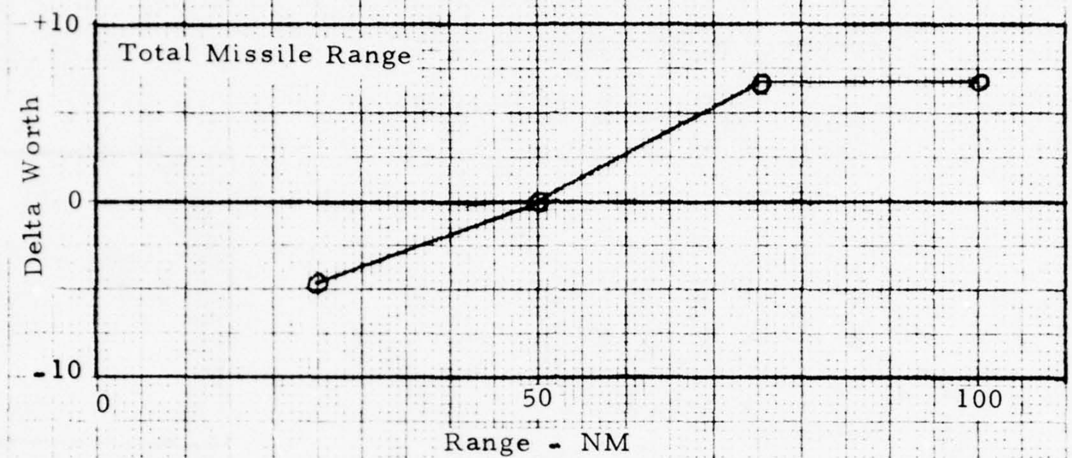
Case	Run	Range NM	Vel. Knots	Whd. Lbs.	Avg. Value Lost BLU	Avg. Value Lost RED	Worth	ΔW
Baseline	1.	50	800	1000	132.81	221.81	37.45	0.
Range Variation	2.	25	800	1000	121.43	248.96	32.78	-4.67
	3.	75	800	1000	137.31	173.76	44.14	6.69
	4.	100	800	1000	137.31	173.76	44.14	6.69
Velocity Variation	5.	50	1600	1000	151.90	204.67	42.60	5.15
Warhead Variation	6.	50	800	500	91.63	201.77	31.23	-6.22
	7.	50	800	2200	207.18	169.36	55.02	17.57

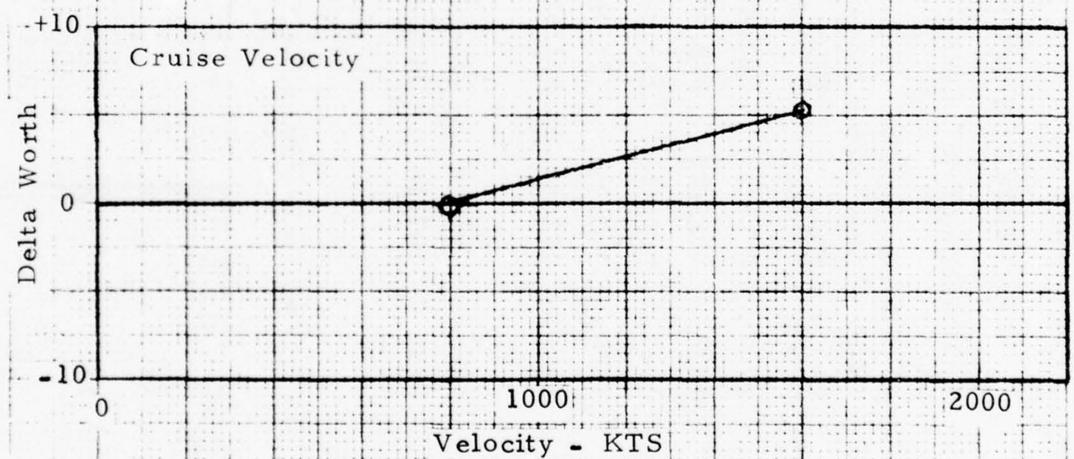
VALUE IN ENGAGEMENT

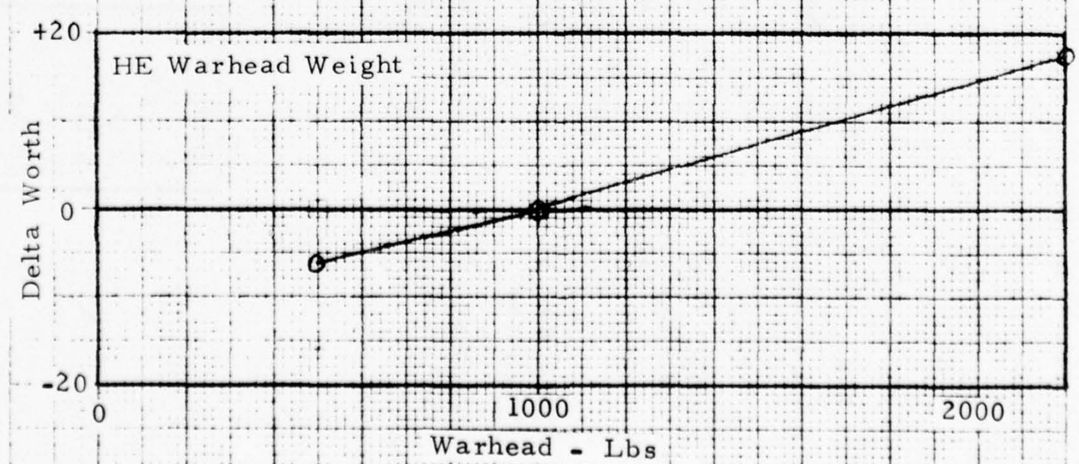
BLU	TOTAL VALUE	RED	TOTAL VALUE
1 CVA	400	6 CLGM	480
2 DLG	80	4 DLG	160
6 DD	120	4 BGGM	16
26 VF	52	2 BGGJ	6
28 VA	56	4 BED	12
1 CG	80		
TOTALS:	788		674

FIGURE A.2-10

SSM TRADE FACTORS







3. CONCEPT GENERATION AND SCREENING MODEL - TEST CASE RESULTS

CGSM test case results are presented in this section. Those results are discussed as three topics, including the following: (1) ASM test cases with screening on RCM cost; (2) SSM test cases with screening on RCM cost; and (3) ASM/SSM test cases with screening on weight. Cases 1.1.R and 1.2.R (see Sections 1.1 and 1.2 above) are discussed as a part of topic (1), while Cases 2.1.R and 2.2.R are discussed under topic (2). The third topic includes Cases 1.1.W, 1.2.W, 2.1.W, and 2.2.W.

3.1 ASM TEST CASE - SCREENING USING RCM

The first test case called for generation and screening of a non-boosted ASM to meet the mission requirements listed on Figure A.1-1. A single CGSM job was constructed and executed to meet those requirements, and the input for that job is listed in card image form on Figure A.3-1. Missile diameters from 26 to 34 inches were required along with total missile weights from 8000 to 9500 pounds. Warhead weights of 500, 1000, and 2000 pounds were postulated for the test case (see Figure A.1-1). Each combination of diameter and warhead weight had to be matched with a unique input payload length using compatibility matrices. Wing area and tail area were computed and input for each diameter (based on cruising at 35,000 ft. at Mach 0.87) and were matched with those diameters using a compatibility matrix.

An integrated missile design was generated for each compatible permutation of total weight, diameter, warhead weight, payload compartment length, tail area, and wing area. A total of 53 designs were successfully integrated. A summary plot of those missiles' airframe dimensions is included as Figure A.3-2 for a warhead weight of 1000 pounds. Missile length is shown to vary between 300 and 500 inches in that plot.

Each of the designed missiles was flown over the three test case trajectories. Several designs were unable to fly all of the trajectories due to performance limitations (incompatibilities between design and performance inputs); however, a total of 138 design/performance combinations were successful. A summary plot of those missiles' range capabilities is included as Figure A.3-3 for two of the cruise speeds. Total missile range is seen to be very sensitive to cruise speed. That is, an increase in speed is achievable only at the expense of a reduction in total range. The dependence of range on speed is itself dependent on such design parameters as cruise altitude, wing and tail areas, and maximum thrust. Those parameters can be controlled by input in a given CGSM job.

Each successful design/trajectory combination was assigned a concept number in the CGSM and each was passed along to the Relative Cost Model (RCM) within the CGSM for costing. First unit production cost was designated as the screening cost parameter during this CGSM job. The worth of each concept is computed based on NEM data (see Section 2) and the set of concepts is screened on cost versus worth. ASM test case screening results are shown on Figures A.3-4 through A.3-7. A copy of the CGSM summary output for top level screened concepts is found in Figure A.3-4. All top level concepts are seen to be low speed missiles (VCR = cruise Mach no. = 0.87). Small warheads tend to dominate at lower cost, while larger warheads dominate at higher cost. The NEM data on worth versus total range (see Figure A.2-5 in Section 2) shows that worth levels off at ranges in excess of about 150 n.mi. That trend in the worth data affects screening to the extent that concepts which differ only in total weight tend to cluster at the point that range passes 150 n.mi. That clustering is seen clearly in Figure A.3-5, which is a plot in cost/worth coordinates of the top four levels of ASM concepts. Concepts whose range is less than 150 n.mi. appear singly and do not cluster.

Data shown in Figure A. 3-4 (CGSM printout) and Figure A. 3-5 (plotted) serve to aid in narrowing down the set of concepts by focusing attention on those with high worth. Crossplots such as those in Figures A. 3-6 and A. 3-7 are useful in explaining and illustrating trends identified in Figures A. 3-4 and A. 3-5. Effects of variations in speed and warhead weight on concept worth and cost are illustrated in Figure A. 3-6. The "vertical" lines correspond to variations in warhead weight with all else constant, and the "horizontal" curves correspond to cruise speed variations. Vertical lines in cost/worth coordinates correspond to extremely favorable trends, while horizontal lines signify unfavorable trends. Applying those criteria to Figure A. 3-6 leads to a selection of low speed and large warheads as favorable ASM characteristics. The crossplot on Figure A. 3-7 illustrates that the value of missile total weight is a function of cruise speed. At the lowest speed, where even the smallest missile generated in the test case can fly 150 miles or more, total weight does not significantly affect cost or worth (with all else constant). At that lowest speed, weight could be fixed by launcher constraints. At the higher speeds, increases in weight become desirable.

3.2 SSM TEST CASE - SCREEN USING RCM

The second test case called for generation and screening of a boosted SSM to meet the mission requirements listed in Figure A. 1-2. A single CGSM job was constructed and executed to meet those requirements, and the input for that job is listed in card image form on Figure A. 3-8. Missile diameters from 26 to 30 inches were required along with total missile weights from 6000 to 16000 pounds. Warhead weights of 500, 1000, and 2000 pounds were postulated for the test case (see Figure A. 1-2). Each combination of diameter and warhead weight had to be matched with a unique input payload length using compatibility matrices. Wing area and tail area were computed and input for each diameter (based on cruising at 500 ft. at Mach 1. 2) and were matched with those diameters using a compatibility matrix.

An integrated missile design was generated for each compatible permutation of total weight, diameter, warhead weight, payload compartment length, tail area, and wing area. A total of 36 designs were successfully integrated. A summary plot of those missiles' airframe dimensions is included as Figure A.3-9, for a warhead weight of 1000 pounds. Missile length is shown to vary between 200 and 400 inches in that plot. A typical SSM launch tube length limit is plotted on Figure A.3-9 for reference.

Each of the designed missiles was flown over the three test case trajectories. Several designs were unable to fly all of the trajectories due to performance limitations (incompatibilities between design and performance inputs); however, a total of 108 design/performance combinations were successful. A summary plot of those missiles' range capabilities is included as Figure A.3-10 for a cruise speed of 1.2.

The effects of cruise speed on total range were found to be minor within the SSM operating regime postulated for this test case. The dependence of range on speed is itself dependent on such design parameters as cruise altitude, wing and tail areas, and maximum thrust. Those parameters can be controlled by input in a given CGSM job.

Each successful design/trajectory combination was assigned a concept number in the CGSM and each was passed along to the Relative Cost Model (RCM) within the CGSM for costing. First unit production cost was designated as the screening cost parameter during this CGSM job. The worth of each concept is computed based on NEM data (see Section 2) and the set of concepts is screened on cost versus worth. SSM test case screening results are shown on Figures A.3-11 through A.3-14. A copy of the CGSM summary output for top level screened concepts is found in Figure A.3-11. Low cost within level 1 corresponds to small, low-speed missiles with small warheads. Cost and worth increase as total weight, warhead weight, and speed increase, so that the highest cost concept in level 1 is the largest and fastest missile with the largest warhead.

Data shown in Figure A.3-11 (CGSM printout) and Figure A.3-12 (plotted) serve to aid in narrowing down the set of concepts by focusing attention on those with high worth. Crossplots such as those in Figures A.3-13 and A.3-14 are useful in explaining and illustrating trends identified in Figures A.3-11 and A.3-12. Effects of variations in speed and warhead weight on concept worth and cost are illustrated in Figure A.3-13. The "vertical" lines correspond to variations in warhead weight with all else constant, and the "horizontal" curves correspond to cruise speed variations. Vertical lines in cost/worth coordinates correspond to extremely favorable trends, while horizontal lines signify unfavorable trends. Applying those criteria to Figure A.3-13 leads to a selection of low speed and large warheads as favorable SSM characteristics.

The crossplot of Figure A.3-14 shows the effects of total weight and warhead weight variations on cost and worth. Increasing total weight is shown to increase both worth and cost with a generally unfavorable trend.

3.3 ASM/SSM TEST CASES - SCREEN USING WEIGHT

The CGSM test cases discussed in Sections 3.1 and 3.2 were executed with total weight specified as the parameter to be used along with relative worth for screening. The results of those screening jobs are shown on Figures A.3-15 through A.3-18. Figure A.3-15 and A.3-17 present the CGSM printed output provided for level 1 concepts for the SSM and ASM, respectively. Figures A.3-16 and A.3-18 include cost/worth plots for the top four levels of SSM and ASM concepts. For both SSM and ASM missile classes, level 1 contains only those concepts with the largest warhead. Level 1 SSMs are all high speed concepts; however, level 1 ASMs are all low-speed concepts. Those results are not compatible with the screening results presented for the two missile classes in Sections 3.1 and 3.2.

A comparison of screen-to-cost results and screen-to-weight results is presented on Figures A.3-19 and A.3-20. Data are presented for the SSM only; however, all conclusions drawn in the screening comparison apply equally to the ASM missile class. The effects of cruise speed variations on cost and worth are shown on Figure A.3-19 for both screen-to-cost and screen-to-weight test cases. An increase in speed is seen to be an "unfavorable" option when cost is the screening parameter, since cost increases much more rapidly than worth. The opposite effect is seen when weight is the screening parameter, there being a net increase in worth with no cost penalty for the higher speed concepts. The trend seen for screen-to-cost is the valid trend. Missile cost (especially airframe and controls system components) does increase as missile speed increases, as can be verified using historical data. Effects of warhead weight on cost and worth are shown on Figure A.3-20 for both screen-to-cost and screen-to-weight test cases. Comparable trends are observed in both cases, although the added cost of the larger warhead is evident for screen-to-cost and is obscured for screen-to-weight.

The CGSM user is provided with the option of screening on RCM cost or on total weight. That choice is a routine part of CGSM input selections. Screening on RCM cost is recommended to the user as the more realistic option.

FIGURE A.3-1

ASM Test Case Input

```
LIQUIC ROCKET ASM TEST CASE - SCREENING ON COST   CM-CGSM    1 FEB 75                   PAGE   2

INPUT CARD IMAGES

 1.                  * * * *    UNCLASSIFIED      * * * *
 2. LIQUID ROCKET ASM TEST CASE - SCREENING ON COST   CM-CGSM    1 FEB 75
 3.ZIP  4 1
 4. &NAM1
 5.   INPRIN=0, NPAGE=6, KFIL12=0, IAIR=0, IPSM=0, IVP=0, ICOST=0,
 6. &END
 7.ZIP  7 4 1                                  READ BASIC VARIABLES
 8.TABLE NO.    2010000             74001    9
 9.KVAR.NAME* * * *NVAL   VALUE 1   VALUE 2   VALUE 3   VALUE 4   VALUE 5   VALUE 6
10.                       VALUE 7   VALUE 8   VALUE 9
11.  1. W.AREA        3   36.9      49.       63.
12.  1.
13.  2. T.AREA        3   16.5      21.9      28.2
14.  2.
15.  3. W.ASP.R.      1   2.136
16.  3.
17.  4. LT.PLC        9   109.      115.      144.      103.      108.      124
18.  4.                   99.       105.      112.
19.  5. W/H WT        3   500.      1000.     2000.
20.  5.
21.  6. CONT.WT       1   140.
22.  6.
23.  7. CIAMETER      3   26.       30.       34.
24.  7.
25.  8. BOO.T/W       1   0.0
26.  8.
27.  9. MAX THR       1   6000.
28.  9.
29. 10. ISP           1   285.
30. 10.
31. 11. PCHAM         1   625.
32. 11.
33. 12. MIX R         1   2.6
34. 12.
35. 13. DUMMY         1   0.
36. 13.
37. 14. DUMMY         1   0.0
38. 14.
39. 15. DUMMY         1   0.
40. 15.
41. 16. DUMMY         1   0.
42. 16.
43. 17. WEIGHT        6   8000.     8250.     8500.     8750.     9000.     9500.
44. 17.
45.-1
46.TABLE TYPE
47.CCNSTANTS
48.ZIP  8 6
49. &NAMCST
50.   WTGUID=250,
```

FIGURE A.3-1 (Cont'd.)

```
LIQUID ROCKET ASM TEST CASE - SCREENING ON COST   CM-CGSM    1 FEB 75                PAGE   3

 INPUT CARD IMAGES

 51.    KCTYPF=21,
 52.  &END
 53.ZIP  9 3
 54.  &NAM3
 55.    WORTHI=38.056,
 56.    NRMAX=4, DWRMAX=-32.5,-18.25,0,0,   PVRMAX=75,100,150,1000,
 57.    NWTWH=5, PVWTWH=500,1000,1100,2000,2200,   DWWTWH=-22,-2.2,0,12.4,14,
 58.    NVCR=3, PVVCR=.87,1.31,1.74,    DWVCR=0,2.7,5.1,
 59.  &END
 60.ZIP  4 8
 61.  &NAMCNF
 62.    NALT=3,  NRM=9,      ALTV(1)=0.0, 10000,   40000.,
 63.    RMV(1)=0.4, 0.8, 0.9, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0,
 64.     IPLANW=4,IWTS=1,RLS=25.1,SLEW=58.5,STEW=39.5,TRAW=.06,
 65.       TRW=.399, WWINGI=393.,
 66.   ARVT=.6786, IPLANT=4,PANWHT=84,PANWVT=75,SLET=60,SLEVT=62.5,
 67.   FACTOR=0.7,    GULT=7.5,
 68.   STET=45,STEVT=35,TRAT=.055,TRAVT=.05,TRT=.568,TRVT=.6222,
 69.     RXINT=.5, RXINVT=.5, RXINW=.5,
 70.   VTALOC=.524, WTI=159,
 71.      ZPOPT=1, WOVAST=2.73,
 72.  &END
 73.ZIP  512
 74.  &NAMLR
 75.   OBT=0,ETACL=.97,ETAISP=.90,EXSI=4.47,ITANK=1,IWTANK=0,METAL=1,
 76.   P1=5511., P2=.00546, P3=176.96,P4=.03649, P5=1.7, P6=.0378, P7=1.468,
 77.    P8=6E-5,
 78.   PBELLL=80,PSTAR=75,PT=1.5,PVOX=17.2,REH=2, RHOF=49.05, RHOOX=89.42,
 79.   TFRAC=1.00,TRATIL=10,WOVAC1=.0581,WOVAC2=.0581,WOVAN1=.02,
 80.         WOVAN2=.006,
 81.   WMISCL=0,XOLMIS=0,
 82.  &END
 83.ZIP  615             I
 84.  &NAMVPM
 85.    ALPMAX(1)=6*20.,              ANZMAX(1)=6*10.,
 86.    ALTF(1)=35000., 35000., 20000., 10000., 1000., 0.0,
 87.  . FVALUE(1)=0.87, 50., -20.4, 5., 0.0, 5.0,
 88.    ICONT(1)=1, 13, 9, 1, 14, 1,    IPTYPE(1)=6*3,  MHGEN(1)=6*0,
 89.    ITERM(1)=8, 4, 1, 7, 1, 4,  MODES(1)=1, 0,-1,-1, 0, 1,
 90.    NAERO(1)=6*2, XMACHF(1)=6*0.87,
 91.     ALTI=35000., GAMMAI=0.0, NCPHAZ=2, NLPHAZ=6,
 92.    XMACHI=0.7,     MOPT=1,
 93.    CONT1(1)=0.0, 100.,
 94.    COND1(1)=0.0, 0.0,
 95.    CONT3(1)=0., 2., 4., 10., 100.,
 96.    COND3(1)=1., -2., -4., -4., -4.,
 97.    CONT4(1)=0.0, 100.,
 98.    COND4(1)=-20.4, -20.4,
 99.    CONT6(1)=0.0, 2.0, 100.,
100.    COND6(1)=0.0, -1.88, -1.88,
```

FIGURE A.3-1 (Cont'd.)

```
LIQUID ROCKET ASM TEST CASE - SCREENING ON COST   CM-CGSM    1 FEB 75                    PAGE   4

INPUT CARD IMAGES

101.    NCPHAZ=0,
102.    ZPRINT=6*0,
103. &END
104.ZIP  615          2
105. &NAMVPM
106.    XMACHF=6*1.31,  FVALUE(1)=1.31,
107. &END
108.ZIP  615          3
109. &NAMVPM
110.    XMACHF=6*1.74,   FVALUE(1)=1.74,
111. &END
112.ZIP 11 1
113.TABLE NO.   201                READ COMPAT MAT
114.COMPATIBILITY FOR LIQUID ASM      NUMBER OF MATRICES  =                5
115.COMPATIBILITY MATRICES KEYS ON NEXT CARD            GROUP =            1
116.   1( 1, 7)  2( 2, 7)  3( 4, 5)  4( 4, 7)  5( 7,17)
117.COMPATIBILITY MATRIX NO.      1                GROUP                   1
118. 11 12 13       1    0    0
119. 21 22 23       0    1    0
120. 31 32 33       0    0    1
121.COMPATIBILITY MATRIX NO.      2                GROUP                   1
122. 11 12 13       1    0    0
123. 21 22 23       0    1    0
124. 31 32 33       0    0    1
125.COMPATIBILITY MATRIX NO.      3                GROUP                   1
126. 11 TO 13       1    0    0
127. 21 TO 23       0    1    0
128. 31 TO 33       0    0    1
129. 41 TO 43       1    0    0
130. 51 TO 53       0    1    0
131. 61 TO 63       0    0    1
132. 71 TO 73       1    0    0
133. 81 TO 83       0    1    0
134. 91 TO 93       0    0    1
135.COMPATIBILITY MATRIX NO.      4                GROUP                   1
136. 11 TO 13       1    0    0
137. 21 TO 23       1    0    0
138. 31 TO 33       1    0    0
139. 41 TO 43       0    1    0
140. 51 TO 53       0    1    0
141. 61 TO 63       0    1    0
142. 71 TO 73       0    0    1
143. 81 TO 83       0    0    1
144. 91 TO 93       0    0    1
145.COMPATIBILITY MATRIX NO.      5                GROUP                   1
146. 11 TO 15       1    1    1    1    1    0
147. 21 TO 25       1    1    1    1    1    1
148. 31 TO 35       0    1    1    1    1    1
149. &SUPER
150.    ART=1.863,
```

FIGURE A.3-1 (Cont'd.)

```
LIQUID ROCKET ASM TEST CASE - SCREENING ON COST   CN-CGSM    1 FEB 75                PAGE    5

INPUT CARD IMAGES

151.     BRAT=0.0,  FINE=2.5,   FRBT=1.,
152.   IART=1, IARW=1, IBTL=1, INWORL=0,
153.    ITN=2, ITSECT=2, IWSECT=2, KPROP=20,
154.    NW=1, WMISC=0, ZXNB=0, NZLLRI=6,
155. &END
156.ZIP 11 3
157. &NAMSCR
158.   LEVELS=99,  NCOUT=1000,  NLOUT=4,
159. &END
160.ZIP 10                                STOP
```

FIGURE A.3-2

ASM CONFIGURATION RESULTS

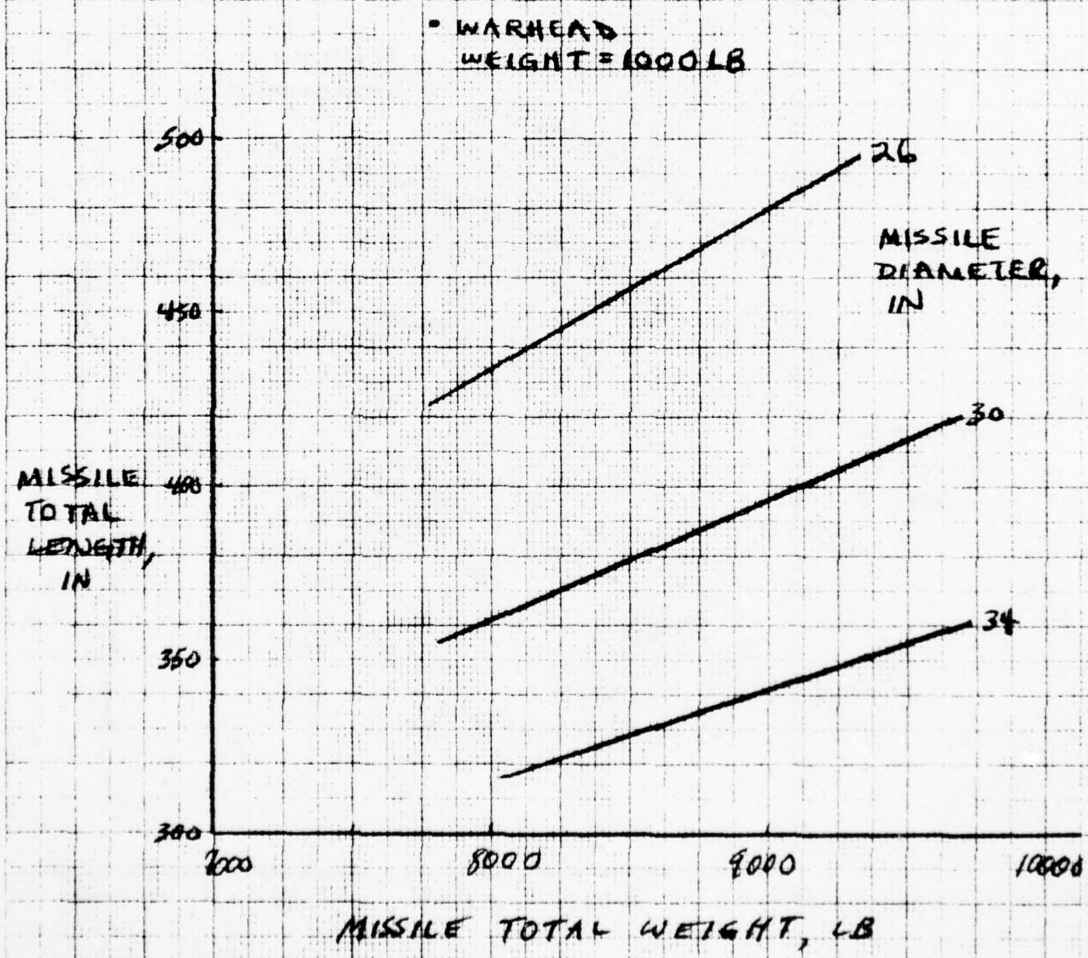


FIGURE A.3-3

ASM CONFIGURATION PERFORMANCE

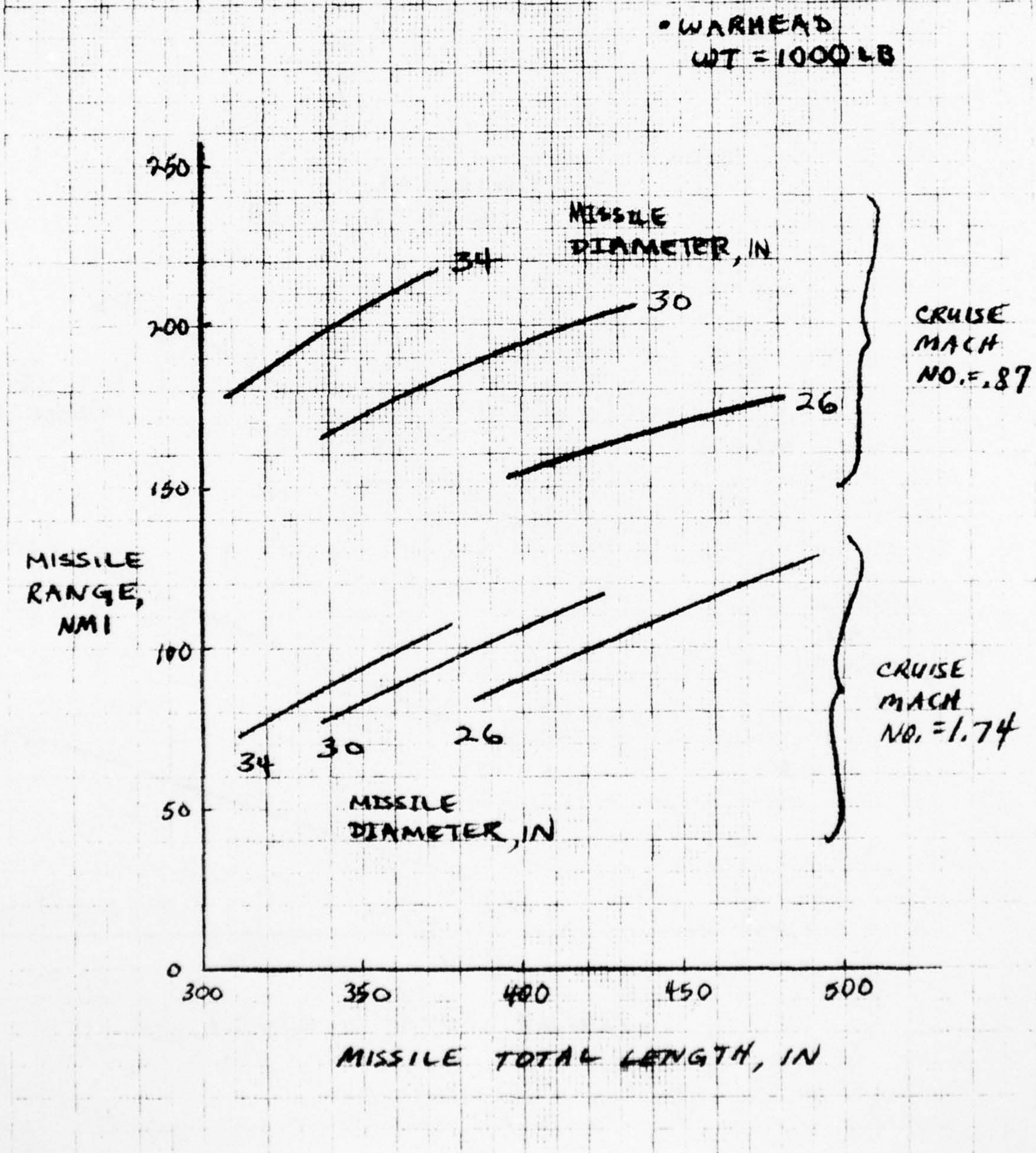


FIGURE A.3-4

CGSM Output For Level 1 - ASM Screened On Cost

LIQUIC ROCKET ASM TEST CASE - SCREENING ON COST CM-CGSM 1 FEB 75

SUMMARY FOR LEVEL 1

CONCEPT	WORTH	COST	LENGTH	RANGE	RCR	RRI	DIAM	WW/H	WEIGHT	VCR
57	16.06	1018.	425.9	222.6	196.3	5.0	30.0	500.	9500.	0.87
54	16.06	1019.	408.5	216.7	190.5	5.0	30.0	500.	9000.	0.87
51	16.06	1019.	399.8	213.4	187.3	5.0	30.0	500.	8750.	0.87
48	16.06	1020.	391.1	209.9	183.9	5.0	30.0	500.	8500.	0.87
45	16.06	1020.	382.4	206.2	180.2	5.0	30.0	500.	8250.	0.87
42	16.06	1021.	373.7	202.3	176.3	5.0	30.0	500.	8000.	0.87
74	35.86	1022.	413.2	198.8	172.5	5.0	30.0	1000.	9500.	0.87
72	35.86	1023.	395.8	192.6	166.4	5.0	30.0	1000.	9000.	0.87
22	35.86	1023.	467.9	174.7	148.4	5.0	26.0	1000.	8750.	0.87
69	35.86	1024.	387.1	189.1	163.1	5.0	30.0	1000.	8750.	0.87
66	35.86	1024.	378.4	185.5	159.5	5.0	30.0	1000.	8500.	0.87
63	35.86	1025.	369.7	181.6	155.7	5.0	30.0	1000.	8250.	0.87
19	35.86	1025.	456.4	171.3	145.2	5.0	26.0	1000.	8500.	0.87
60	35.86	1025.	361.0	177.5	151.6	5.0	30.0	1000.	8000.	0.87
16	35.86	1026.	444.9	168.9	142.8	5.0	26.0	1000.	8250.	0.87
13	35.86	1028.	433.3	165.6	139.6	5.0	26.0	1000.	8000.	0.87
39	44.87	1032.	460.3	134.7	108.4	5.0	26.0	2000.	9000.	0.87
91	50.46	1033.	393.4	155.8	129.5	5.0	30.0	2000.	9500.	0.87
136	50.46	1044.	334.6	165.6	139.4	5.0	34.0	2000.	9500.	0.87
133	50.46	1045.	321.0	157.2	131.1	5.0	34.0	2000.	9000.	0.87
130	50.46	1045.	314.2	152.7	126.6	5.0	34.0	2000.	8750.	0.87

FIGURE A.3-5

ASM SCREENING RESULTS – SCREENED ON COST

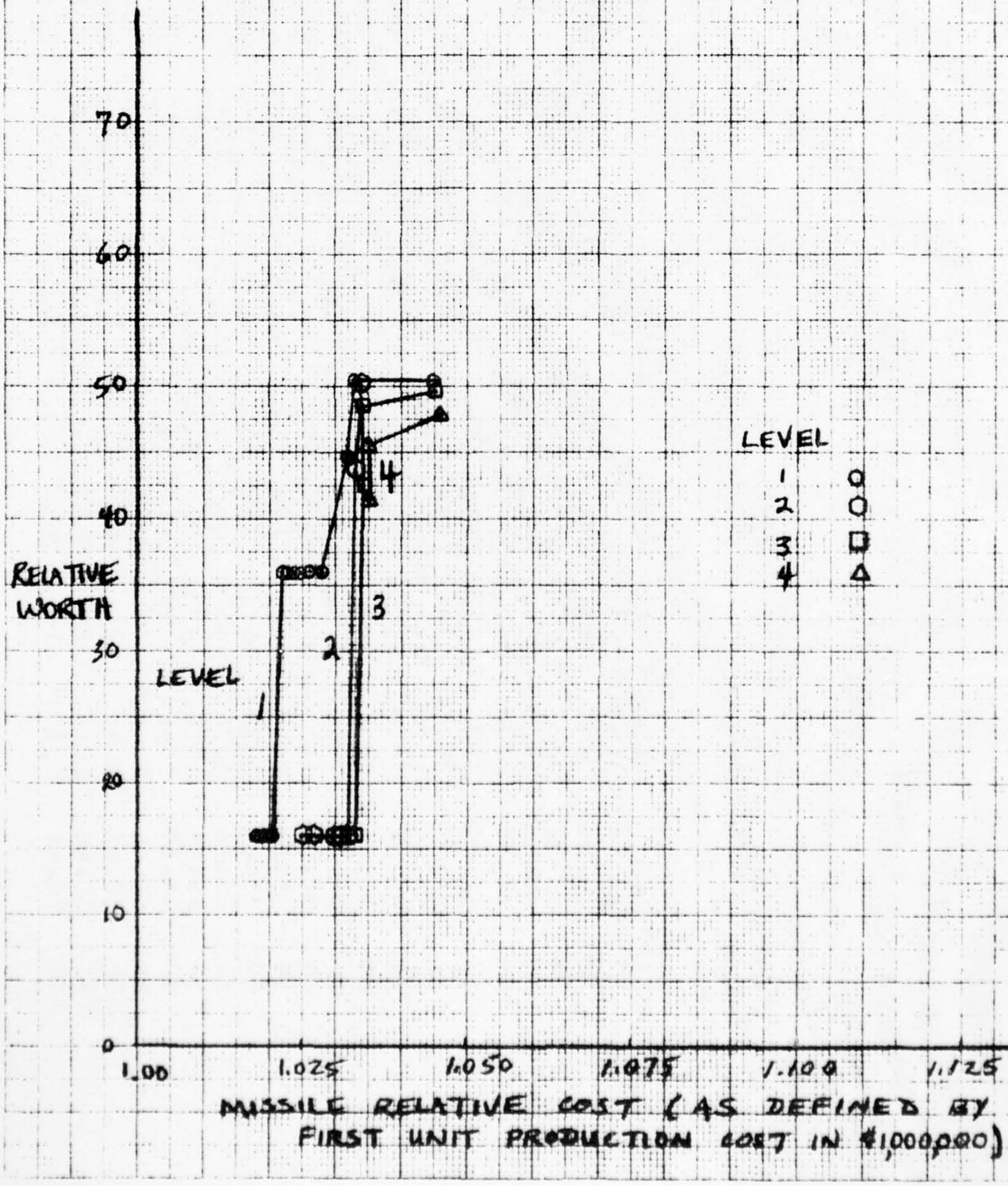
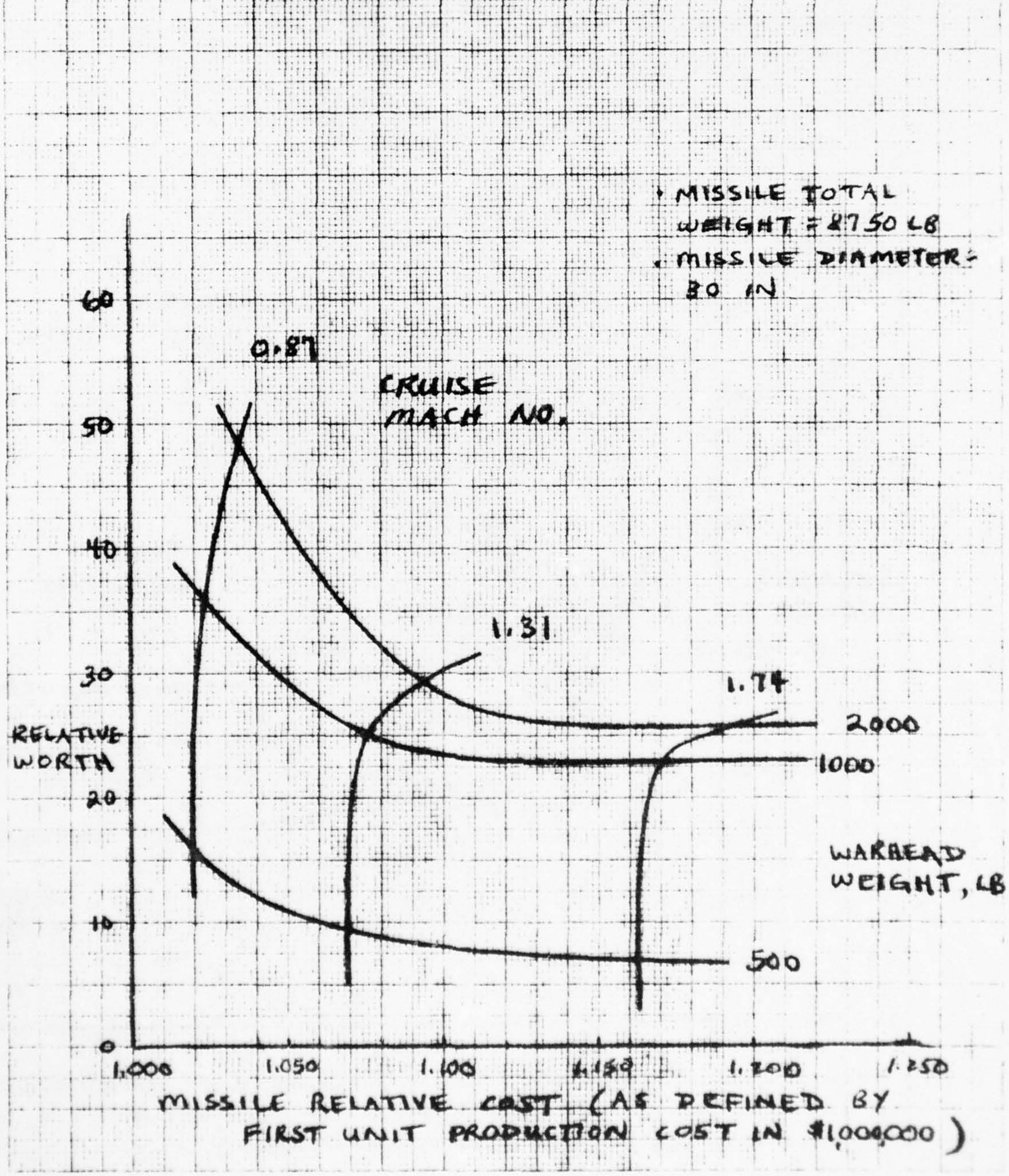


FIGURE A.3-6

ASM SCREENING TRENDS - EFFECTS OF SPEED AND WARHEAD VARIATIONS



AD-A048 368 LTV AEROSPACE CORP DALLAS TEX VOUGHT SYSTEMS DIV F/G 15/7
SEATIDE ANALYSIS PROCESS. VOLUME V. RELATIVE COST MODEL (RCM), (U)
FEB 75 R K MCDONOUGH DAAB09-72-C-0062
UNCLASSIFIED VSD-00.1636-VOL-5 NL

3 of 3
ADA048 368

END
DATE
FILMED
2-78
DDC

FIGURE A.3-9

ASM SCREENING TRENDS - EFFECTS OF SPEED AND TOTAL WEIGHT VARIATIONS

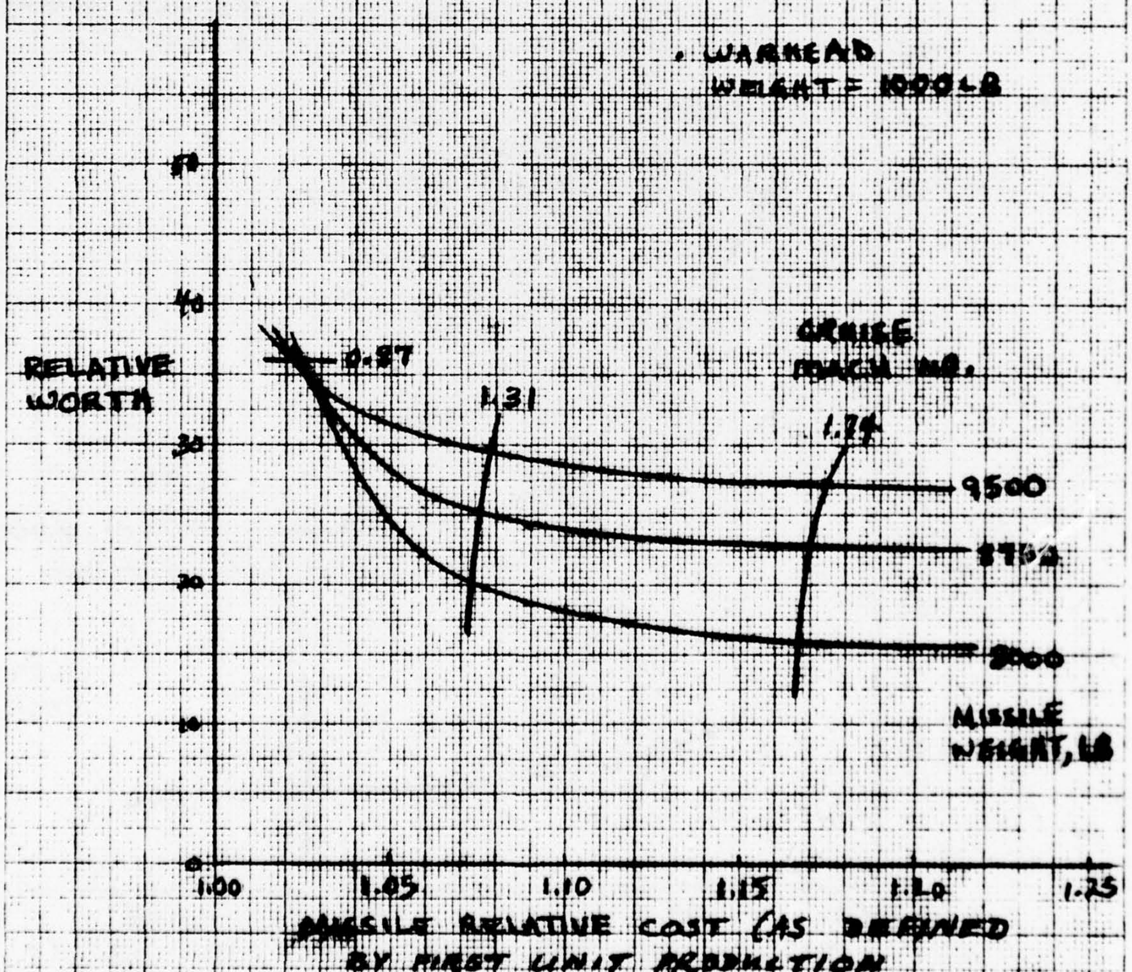


FIGURE A.3-8
SSM Test Case Input

```
SOLID ROCKET SSM TEST CASE - SCREENING ON COST     CM-CGSM  1 FEB 75                    PAGE   2

INPUT CARD IMAGES

 1.    *     *     *     *     *           UNCLASSIFIED          *     *     *     *     *     *
 2. SOLID ROCKET SSM TEST CASE - SCREENING ON COST     CM-CGSM  1 FEB 75
 3.ZIP  4 1                                  OUTPUT CONTROL OPTICNS
 4. CNAM1
 5.    INPRIN=0,
 6.   NPAGE=6, KFIL12=0,
 7.    IAIR=0,   IVP=0,  IPSM=0,
 8.    ICOST=0,
 9. SEND
10.ZIP  7 4 1                                READ BASIC VARIABLES
11.TABLE NO.     2010000          74001     9
12.KVAR.NAME* * * *NVAL   VALUE 1   VALUE 2   VALUE 3   VALUE 4   VALUE 5   VALUE 6
13.                       VALUE 7   VALUE 8   VALUE 9
14.  1. W.AREA        3   13.08     15.24     17.5
15.  1.
16.  2. T.AREA        3   6.2        7.23      8.3
17.  2.
18.  3. W.ASP.R.      1   1.
19.  3.
20.  4. LT.PLC        9   116.      122.      152.      112.      118.      141.
21.  4.                   110.      115.      131.
22.  5. W/H WT        3   500.      1000.     2000.
23.  5.
24.  6. CONT.WT       1   195.
25.  6.
26.  7. DIAMETER      3   26.       28.       30.
27.  7.
28.  8. ROD.T/W       1   10.
29.  8.
30.  9. MAX THR       1   10000.
31.  9.
32. 10. ISP           1   285.
33. 10.
34. 11. PCHAM         1   1500.
35. 11.
36. 12. MIX R         1   1.
37. 12.
38. 13. DUMMY         1   0.
39. 13.
40. 14. DUMMY         1   0.0
41. 14.
42. 15. DUMMY         1   0.
43. 15.
44. 16. DUMMY         1   0.
45. 16.
46. 17. WEIGHT        6   6000.     7500.     8500.     10000.    13000.    16000.
47. 17.
48.-1
49.TABLE TYPE
50.CONSTANTS
```

FIGURE A.3-8 (Cont'd.)


```
INPUT CARC IMAGES

 51.ZIP   8 6
 52. &NAMCST
 53.   WTGUID=350, KGTYPE=22,
 54. &END
 55.ZIP   9 3
 56. &NAM3
 57.   NRMAX=7,
 58.   PVPMAX=1C,25,40,50,64,75,1000,
 59.   OWRMAX=-7.3,-4.7,-2.7,0,5,6.7,6.7,
 60.   NVCR=4,
 61.   PVVCR=1.2,1.5,1.9,2.4,
 62.   CWVCR=0,2.5,4.4,5.4,
 63.   NWTWH=3,
 64.   PVWTWH=5C0,1000,2000,
 65.   CWWTWH=-6.4,0,17.6,
 66.   WCRTH1=37.45,
 67. &END
 68.ZIP   4 8
 69. &NAMCNF
 70.  ALTV(1)=0., 10000.,        ARVT=1., FACTOR=0.6, FSOVCT=0., FSOVCW=0.,
 71.  FSOVVT=0., GULT=10., ILUG=0, IPLANT=1, IPLANW=1, IWTS=3, NALT=2,
 72.  NRM=9, PANWHT=25., PANWT=20., PANWVT=50.,
 73.  RLS=55., RMDES=2.,
 74.  RMV(1)=0.4, 0.8, 0.9, 1.0, 1.2, 1.4, 1.6, 2.0, 3.0,
 75.  RXINT=0.5, RXINW=0.5, SLET=45., SLEVT=60., SLEW=60.,
 76.               STFT=0., STEVT=0., STEW=0., THETAC=0.165, TRAT=0.05,
 77.  TRAVT=0.05, TRAW=0.05, TRT=0.2, TRVT=0.4, TRW=0.4, VTALOC=0.677,
 78.  WOVAHT=6, WOVAST=2.4, WOVAT=6, WOVAVT=6, WOVAW=6, WTI=50, WWINGI=105,
 79.              ZPOPT=1, ZSKINI=0.1, ZWSKIN=280.,
 80. &END
 81.ZIP   5 8
 82. &NAMPOO
 83.             ABM=0.0, AER=2., AFAT=1.5, AIT=0.09,             ASL=2.,
 84.  ASM=1., ASWM=0., CASEM=2, CSTAR=5000., DENI=0.1615, CLFS=0.0,  EAR=2,
 85.  EPI=10., ETAX=C.9, FBM=1.,  FCWM=1.,  FER=2., FIT=0.1,  FJ=0.97,
 86.  FMPAH=0.5, FSL=0., FSULX=1.4, FSWM=0., FSYLX=1.2,  GAM=1.18, GMAX=30.,
 87.  PA=14.7, PBELL=1,  PC=1000., PCM=2000., PHI=21., PSUP=0.,  RBOSS=0.5,
 88.  RHOP=0.0628, RMASW=0.,  RMAW=0.,  RMCW=0.,  RMFSW=0., RMFW=0.,
 89.  RMIW=0.3,  RNBWM=2.42E-6,  RNEC=6.8E-10, RNECC=2.864E-6, RNFC1=0.8,
 90.  RNFC2=1., RNEC3=1.7, RNMW=5., RNRM=0., PNTM=1.216E-4, RNTWM=1.834,
 91.  SAW=0.0,  SEM=1.E7, TCASEF=900., TL=.1,  TMIN=.07,  TTH=45., VRFH=0.,
 92. &END
 93.ZIP   5 8 1
 94. &NAMFXB
 95.  C1=1.1,  C2=1.1,  C3=1.1, C4=2.,  C5=2., C6=2., CLFAR=2.5, EL=2,
 96.  MTLRAM=2, RHOENT=.04, RHOEXT=.04, RHOIN=.065, RHOTHT=.05, RHOX=0.02,
 97.  TEMPC=900., TENT=0.2, TEXIT=0.2, TEXTER=0.0, THETA=45.,  TINAFT=.25,
 98.  TINS=0.25, TMINC=C.06, TMIND=0.06, TTHROT=0.2, WHARNS=25., XSTAP=60.,
 99. &END
100.ZIP   511
```

FIGURE A.3-8 (Cont'd.)

INPUT CARD IMAGES

```
101. &NAMSR
102.   AIAT=0.25,  APAT=1.5,  ETACF=0.97,  EXPBR=0.82,  PBELS=100.,
103.   PHINOZ=17.,  REAH=2,  REFH=2,  RHOISS=0.036,  RHOMTL=0.283,  RHOS=0.062,
104.   SIGMTL=260000.,  TIC=0.1,  TRATIO=10.,  WMSOL=0.0,
105. &END
106.ZIP  615          1
107. &NAMVPM
108.   ALPMAY=7*15,  ALTF=5*500,0,0,   ANZMAX=7*20,
109.   CONI1=0,5,   COND1=20,0,
110.   CONI2=0,100,   COND2=-3,-3,
111.   CONI4=0,100,        COND4=0,0,
112.   CONI6=0,100,   COND6=-2,-2,
113.   CONI7=0,1000,   COND7=-1,-1,
114.   FVALUE=0,-1.5,0,1.2,5,-1,0,
115.   GAMMAF=2*16,4*0,-1,
116.   ICONT=1,6,14,1,13,6,1,  IPTYPE=1,6*3,  ITERM=6,7,1,8,4,1,3,
117.   MFGEN=7*0,  MODES=1,1,0,1,0,-1,-1,  NAERO=1,6*2,
118.   SLOPE=7*0,  TPHASE=0,3*100,0,100,0,  TTOTAL=7*10000,
119.   XMACHF=7*1.2,        ZPRINT=7*0,
120.  ALTI=50.,  DALPH=.009,  DALT=2000.,  DCFN=0.10,  DELMAX=60.,  DHCL=10000.,
121.  DMACH=.05,  DMIN=.001,  DSTART=0.1,  DVCL=100.,  EREF=5E-4,  ERRFAC=5.,
122.  FARMAX=0,  GAMMAI=20.,  GKG=1.0,  GKV=0.001,  GKVCRU=0.1,  GTOPT=1.0,
123.  MCPT=0,  NCPHAZ=5,  NDPHAZ=2,  NLPHAZ=7,  RANGEI=0.0,  RTOL=10.,  TIMEI=0.0,
124.  TPCMGN=0.0,  TT4MAX=3900.,  VELI=50.,  XMACHI=0.0,
125. &END
126.ZIP  615          2
127. &NAMVPM
128.   XMACHF=7*1.5,    FVALUE=0,-1.5,0,1.5,5,-1,0,
129. &END
130.ZIP  615          3
131. &NAMVPM
132.   XMACHF=7*1.9,
133.   FVALUE=0,-1.5,0,1.9,5,-1,0,
134. &END
135.ZIP 11 1
136.TABLE NO.   201                 READ COMPAT MAT
137.COMPATIBILITY FOR SOLID SSM       NUMBER OF MATRICES  =                  5
138.COMPATIBILITY MATRICES KEYS ON NEXT CARD            GROUP =              1
139.  1( 1, 7)  2( 2, 7)  3( 4, 5)  4( 4, 7)  5( 7,17)
140.COMPATIBILITY MATRIX NO.    1                 GROUP                      1
141. 11 12 13      1    0    0
142. 21 22 23      0    1    0
143. 31 32 33      0    0    1
144.COMPATIBILITY MATRIX NO.    2                 GROUP                      1
145. 11 12 13      1    0    0
146. 21 22 23      0    1    0
147. 31 32 33      0    0    1
148.COMPATIBILITY MATRIX NO.    3                 GROUP                      1
149. 11 TO 13      1    0    0
150. 21 TO 23      0    1    0
```

FIGURE A.3-8 (Cont'd.)


```
INPUT CARD IMAGES

151. 31 TO 33     0   0   1
152. 41 TO 43     1   0   0
153. 51 TO 53     0   1   0
154. 61 TO 63     0   0   1
155. 71 TO 73     1   0   0
156. 81 TO 83     0   1   0
157. 91 TO 93     0   0   1
158.COMPATIBILITY MATRIX NO.     4              GROUP           1
159. 11 TO 13     1   0   0
160. 21 TO 23     1   0   0
161. 31 TO 33     1   0   0
162. 41 TO 43     0   1   0
163. 51 TO 53     0   1   0
164. 61 TO 63     0   1   0
165. 71 TO 73     0   0   1
166. 81 TO 83     0   0   1
167. 91 TO 93     0   0   1
168.COMPATIBILITY MATRIX NO.     5              GROUP           1
169. 11 TO 15     1   1   1   1   0   0
170. 21 TO 25     1   1   1   1   1   1
171. 31 TO 35     0   0   1   1   1   1
172. &SUPER
173.   ALTI=50., ART=2.67, BCANTA=0.0, BRAT=0.0, DIAFR=0.5, DVMULT=1.2,
174.   DVTOL=30., FINE=3., FRBT=0.75, IART=1,  IARW=1, IBTL=1, ICNTRL=1,
175.   INWORL=0,          ISURFT=1, ISURFW=1, ITHR=0, ITN=2, ITSECT=2,
176.   IWSECT=2, KINLET=1, KPROP=13, MAXNLT=3, NW=1, NZLLRI=0, NZTEMP=0,
177.   VEOR=700., VL=50., WMISC=  0., XLBDY=0.0, XMACHI=0.0, ZXNB=2,
178. &END
179.ZIP 11 3
180. &NAMSCP
181.    LEVELS=99,  NCOUT=1000,  NLOUT=4,
182. &END
183.ZIP 10
```

BEST AVAILABLE COPY

FIGURE A.3-7
SSM CONFIGURATION RESULTS

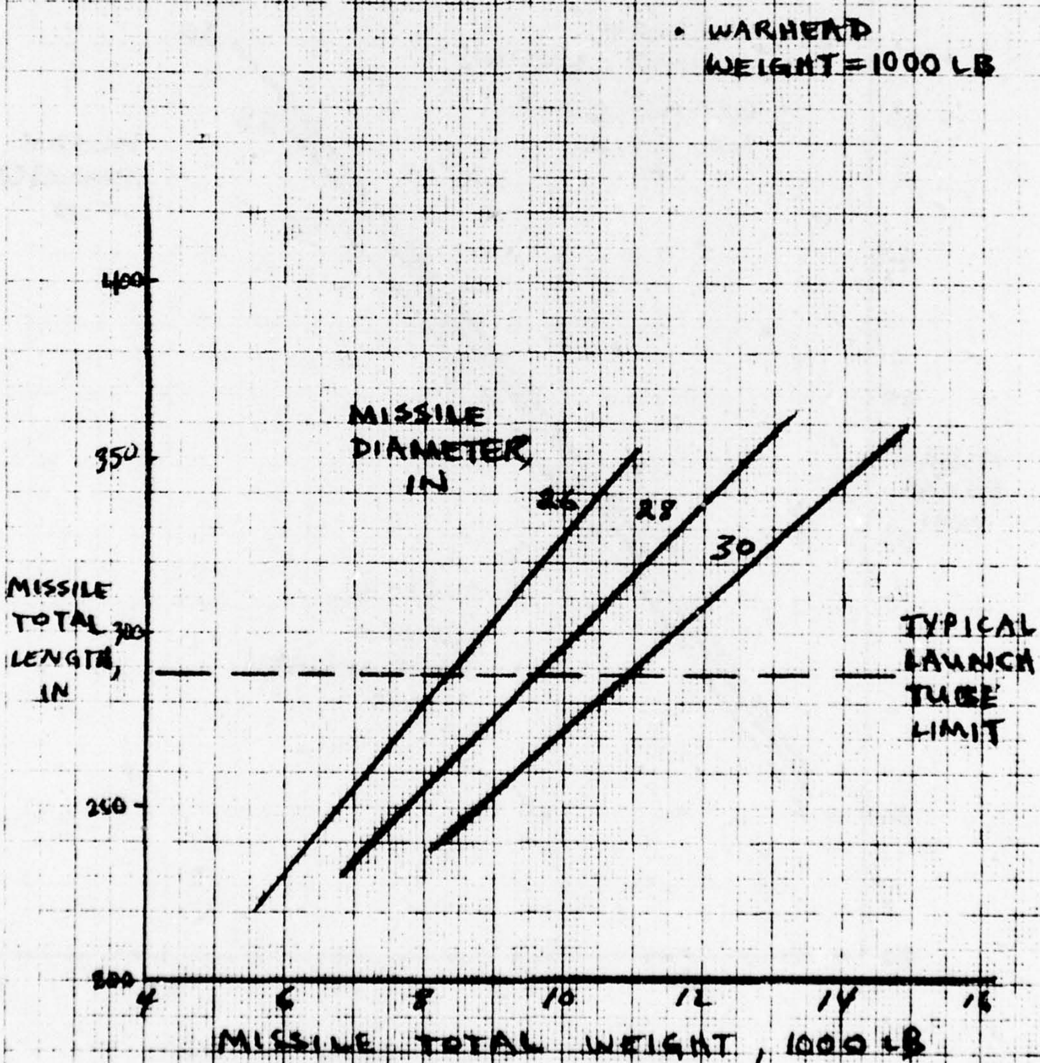


FIGURE A.3.10
SSM CONFIGURATION PERFORMANCE

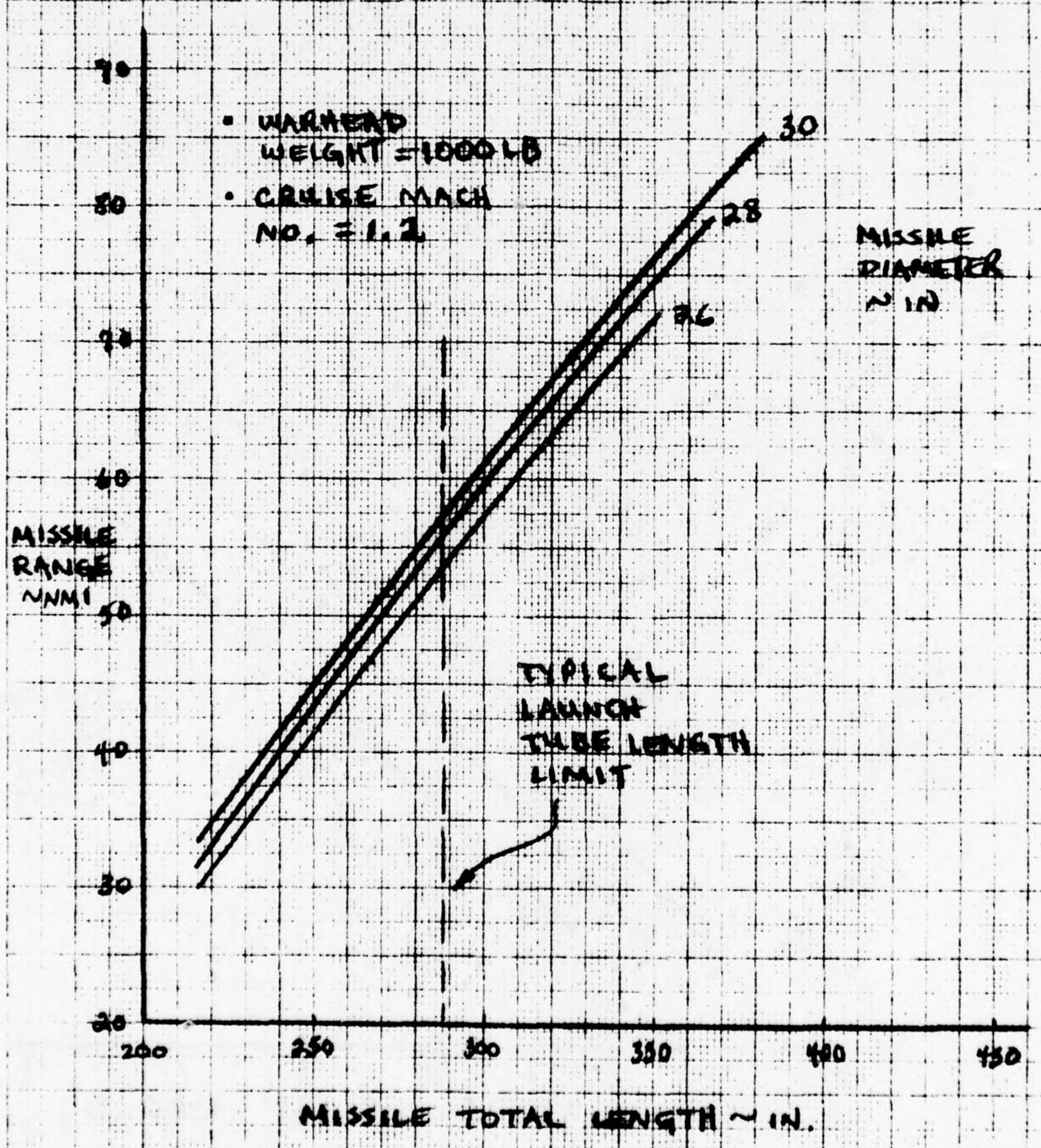


FIGURE A. 3-11

CGSM Output for Level 1 - SSM Screened On Cost

SOLID ROCKET SSM TEST CASE - SCREENING ON COST CM-CGSM 1 FEB 75

SUMMARY FOR LEVEL 1

CONCEPT	WORTH	COST	LENGTH	RANGE	RCR	RRI	DIAM	WW/H	WEIGHT	VCR
1	28.42	708.	238.8	40.2	-33.1	0.0	26.0	500.	6000.	1.20
13	34.05	710.	230.4	34.7	27.6	0.0	26.0	1000.	6000.	1.20
25	50.06	727.	231.0	23.3	16.2	0.0	26.0	2000.	6000.	1.20
28	51.76	750.	267.3	35.6	27.8	0.0	26.0	2000.	7500.	1.20
31	53.26	764.	291.5	43.4	35.1	0.0	26.0	2000.	8500.	1.20
34	56.64	785.	327.4	54.5	45.5	0.0	26.0	2000.	10000.	1.20
76	60.57	849.	355.8	67.4	56.6	0.0	28.0	2000.	13000.	1.20
79	61.75	885.	416.1	83.9	71.0	0.0	28.0	2000.	16000.	1.20
106	61.75	915.	373.4	76.4	63.0	0.0	30.0	2000.	16000.	1.20
77	63.18	968.	355.8	68.1	50.2	0.0	28.0	2000.	13000.	1.50
80	64.25	1007.	416.1	85.4	63.1	0.0	28.0	2000.	16000.	1.50
107	64.25	1048.	373.4	77.6	52.1	0.0	30.0	2000.	16000.	1.50
81	66.15	1185.	416.1	80.0	52.2	0.0	28.0	2000.	16000.	1.90

FIGURE A.3-12
SSM SCREENING RESULTS -
SCREENED ON COST

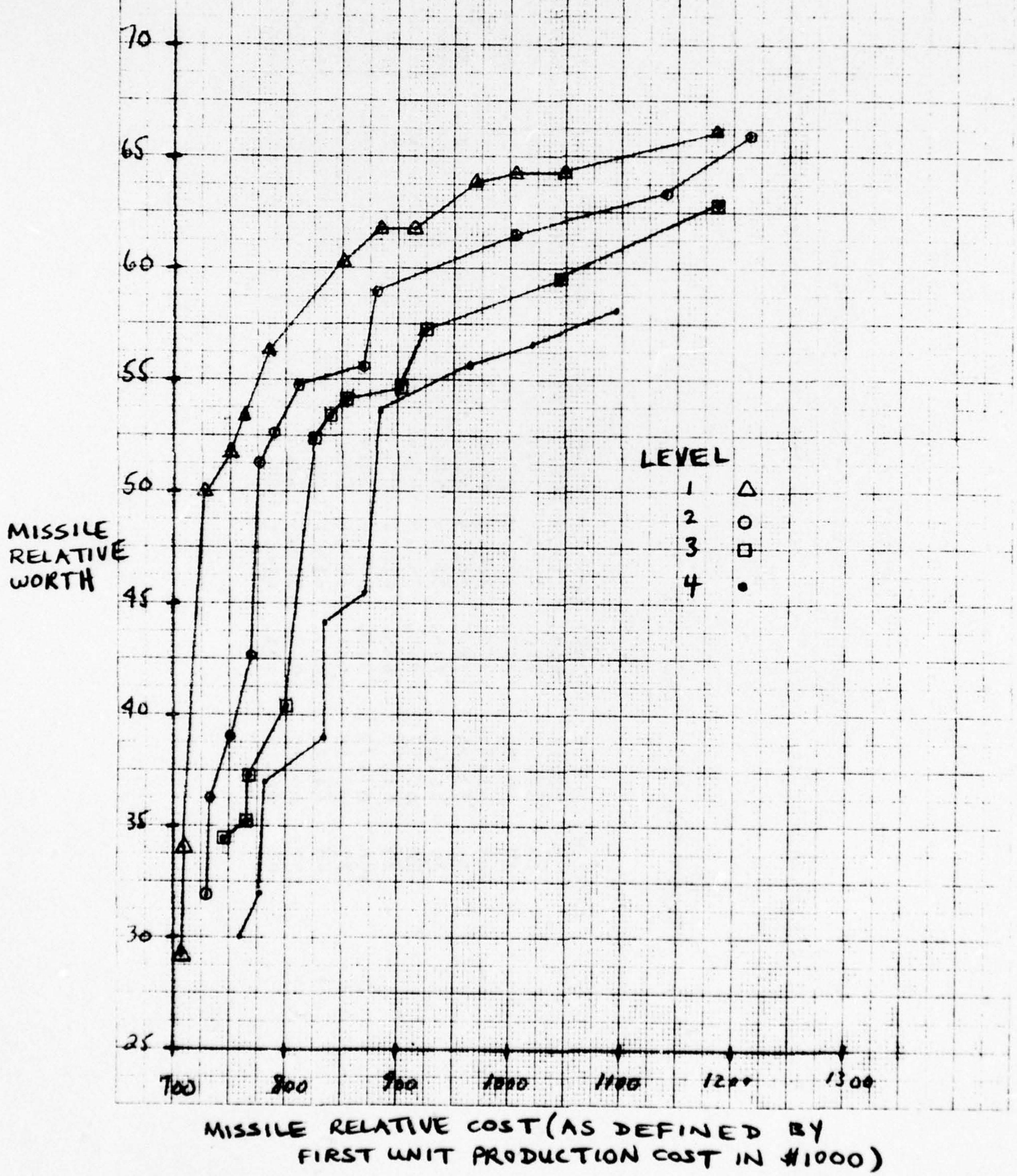


FIGURE A.3-13
SSM SCREENING TRENDS –
EFFECTS OF SPEED
AND WARHEAD VARIATIONS

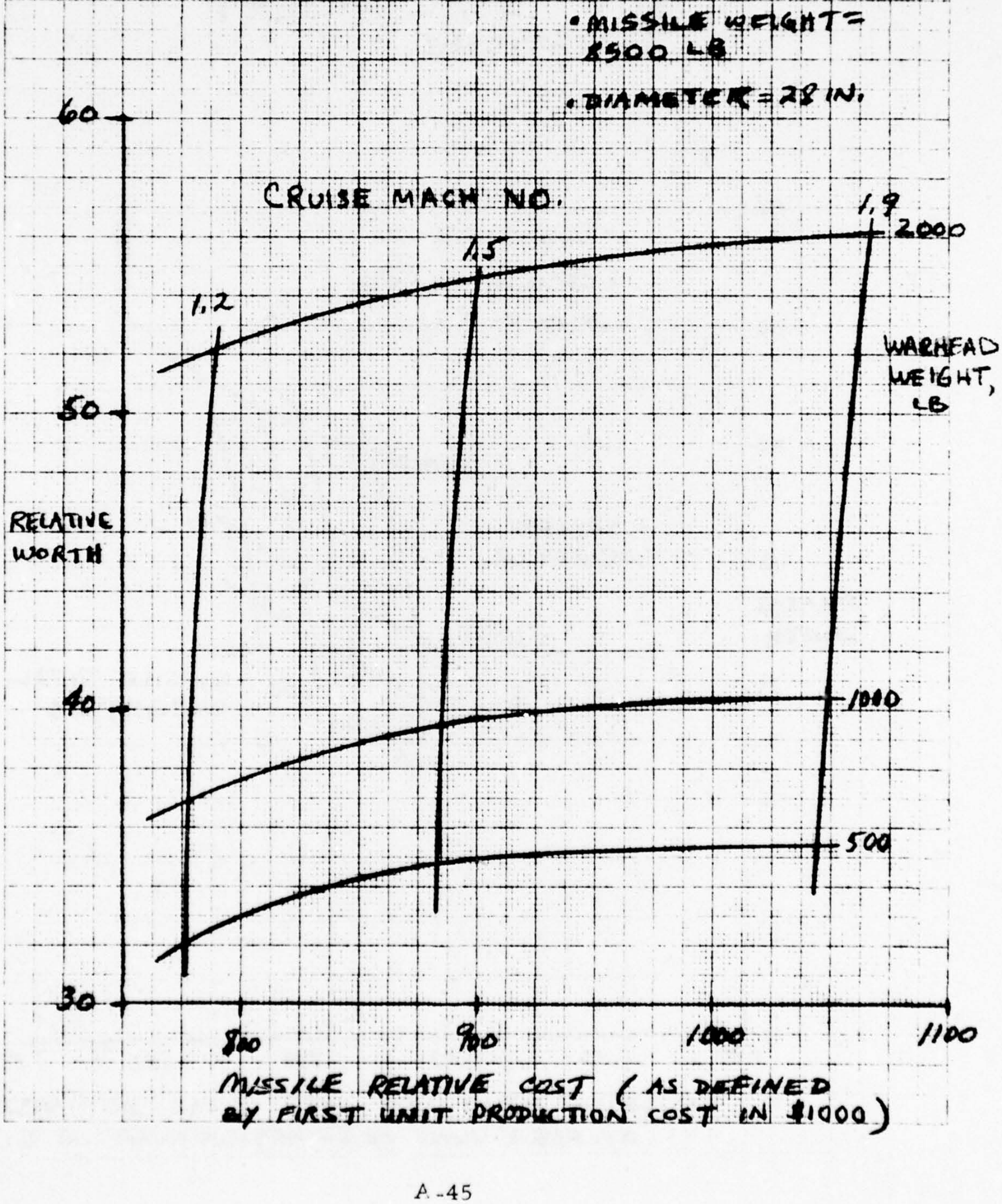


FIGURE A.3-14

SSM SCREENING TRENDS - ~~EFFECTS OF WARHEAD~~ AND TOTAL WEIGHT VARIATIONS

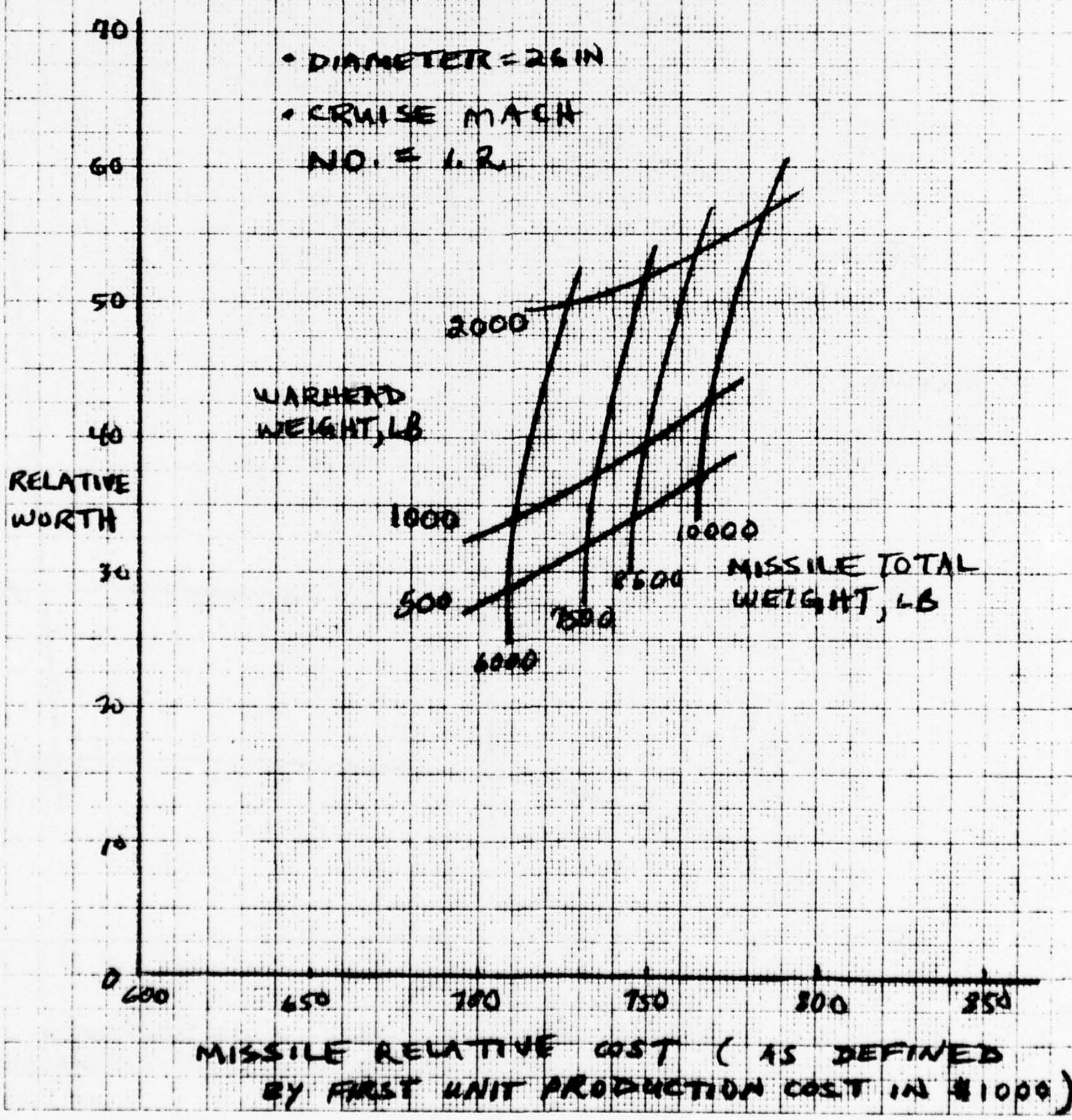


FIGURE A. 3-15

CGSM Output for Level 1 - SSM Screened On Weight

SOLID ROCKET SSM TEST CASE - SCREENING ON WEIGHT CM-CGSM 1 FEB 75

SUMMARY FOR LEVEL 1

CONCEPT	WORTH	COST	LENGTH	RANGE	RCR	RRI	DIAM	WW/H	WEIGHT	VCR
27	53.84	6000.	231.0	19.7	5.3	0.0	26.0	2000.	6000.	1.90
30	55.63	7500.	267.3	31.6	14.4	0.0	26.0	2000.	7500.	1.90
33	56.63	8500.	291.5	39.1	20.0	0.0	26.0	2000.	8500.	1.90
36	59.44	10000.	327.4	50.0	27.7	0.0	26.0	2000.	10000.	1.90
78	64.23	13000.	355.8	63.4	33.2	0.0	28.0	2000.	13000.	1.90
81	66.15	16000.	416.1	80.0	52.2	0.0	28.0	2000.	16000.	1.90

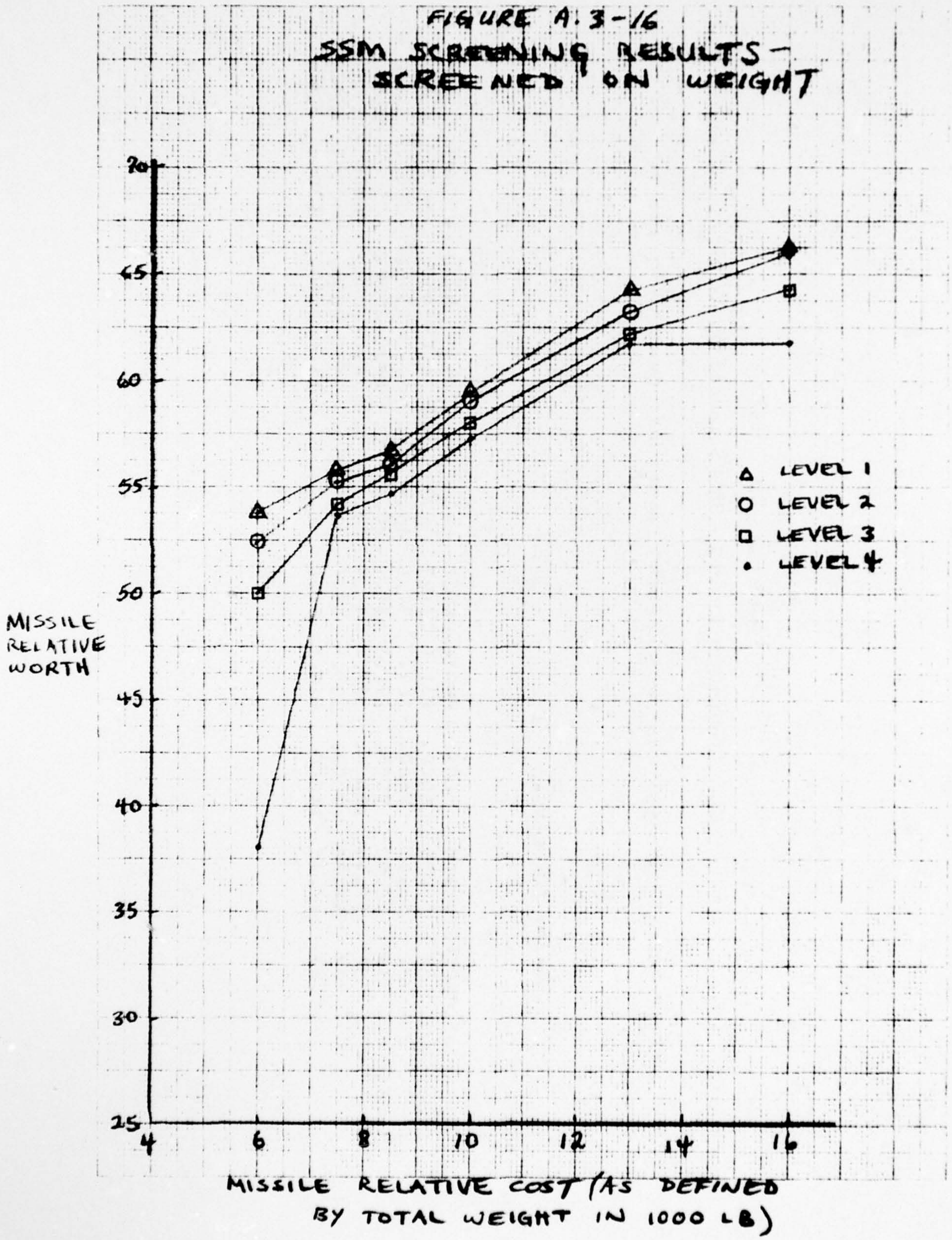


FIGURE A.3-16
SSM SCREENING RESULTS -
SCREENED ON WEIGHT
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
MISSILE RELATIVE WORTH
70
65
60
55
50
45
40
35
30
25
4
6
8
10
12
14
16
MISSILE RELATIVE COST (AS DEFINED BY TOTAL WEIGHT IN 1000 LB)

FIGURE A. 3-17

CGSM Output For Level 1 - ASM Screened On Weight

LIQUID ROCKET ASM TEST CASE - SCREENING ON WEIGHT CM-CGSM   1 FEB 75

SUMMARY FOR LEVEL 1

CONCEPT	WORTH	COST	LENGTH	RANGE	RCR	PRI	DIAM	WW/H	WEIGHT	VCR
72	45.91	8000.	293.6	137.6	111.7	5.0	34.0	2000.	8000.	0.87
75	50.46	8750.	314.2	152.7	126.6	5.0	34.0	2000.	8750.	0.87
78	50.46	9500.	334.6	165.6	139.4	5.0	34.0	2000.	9500.	0.87
51	50.46	9500.	393.4	155.8	129.5	5.0	30.0	2000.	9500.	0.87

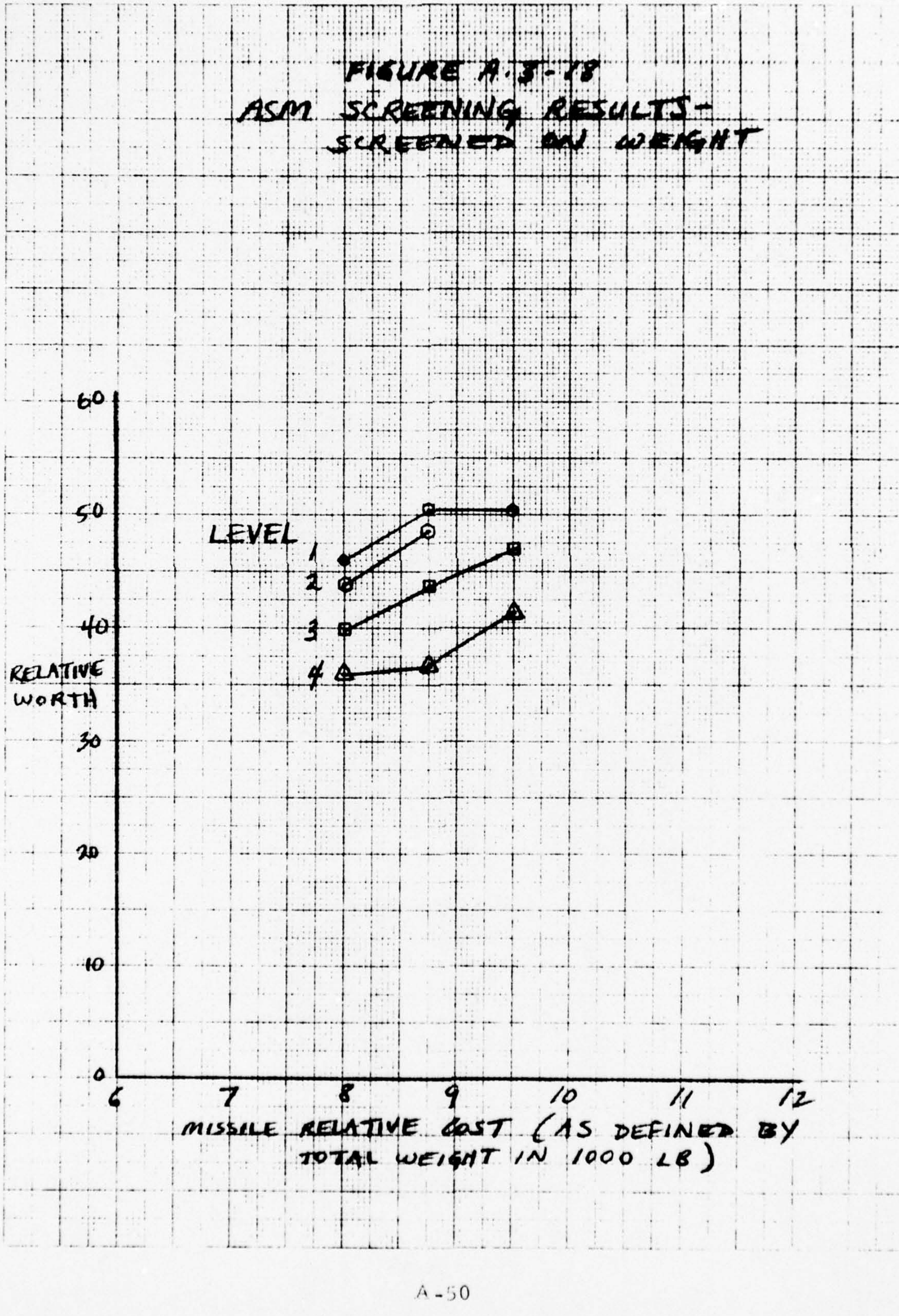


FIGURE A.3-18
ASM SCREENING RESULTS -
SCREENED ON WEIGHT
LEVEL
1
2
3
4
RELATIVE WORTH
0
10
20
30
40
50
60
6
7
8
9
10
11
12
MISSILE RELATIVE COST (AS DEFINED BY TOTAL WEIGHT IN 1000 LB)

FIGURE A.3-19

SSM CRUISE SPEED SCREENING RESULTS - COMPARISON OF SCREEN-TO-COST VS. SCREEN-TO-WEIGHT

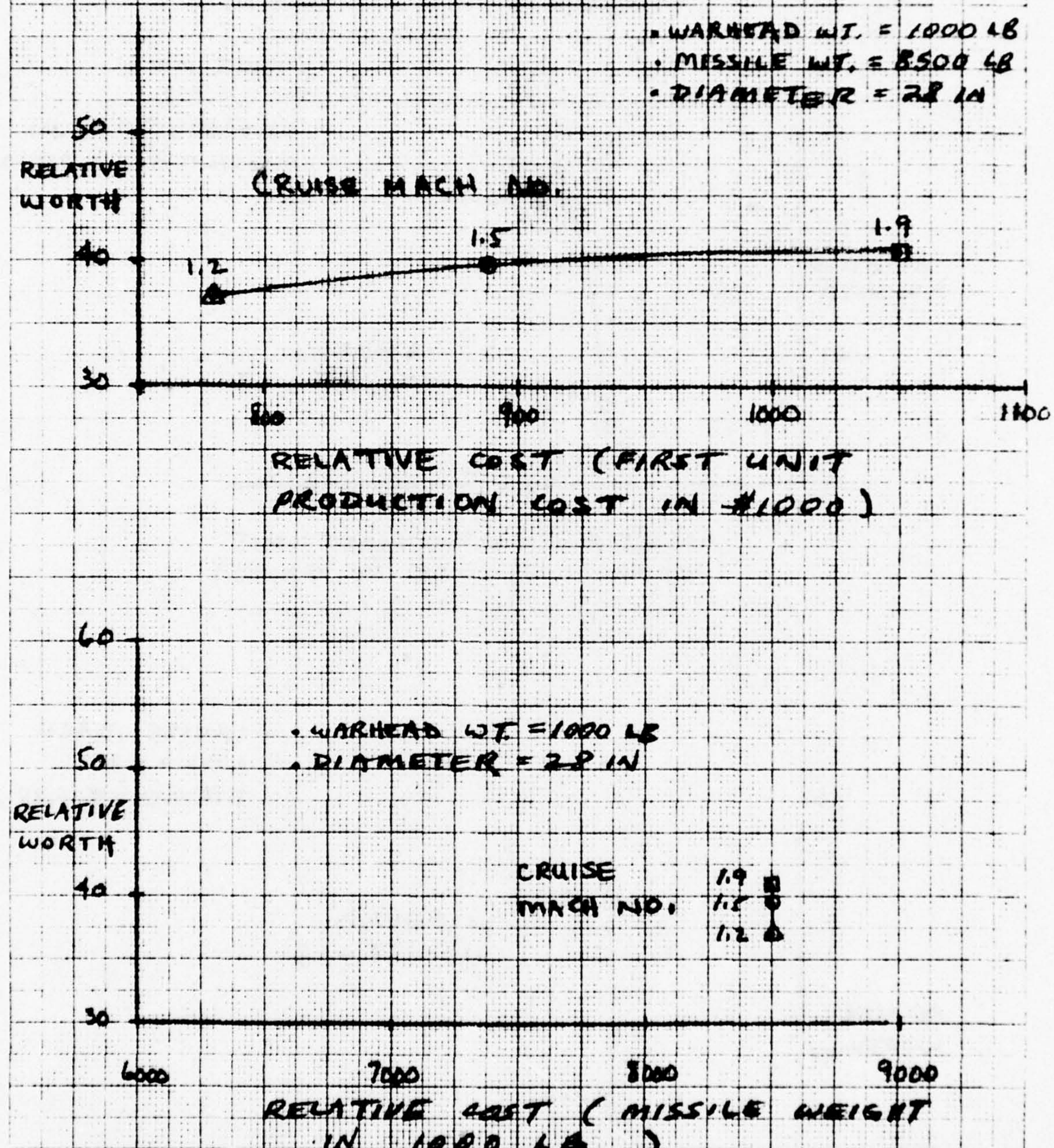
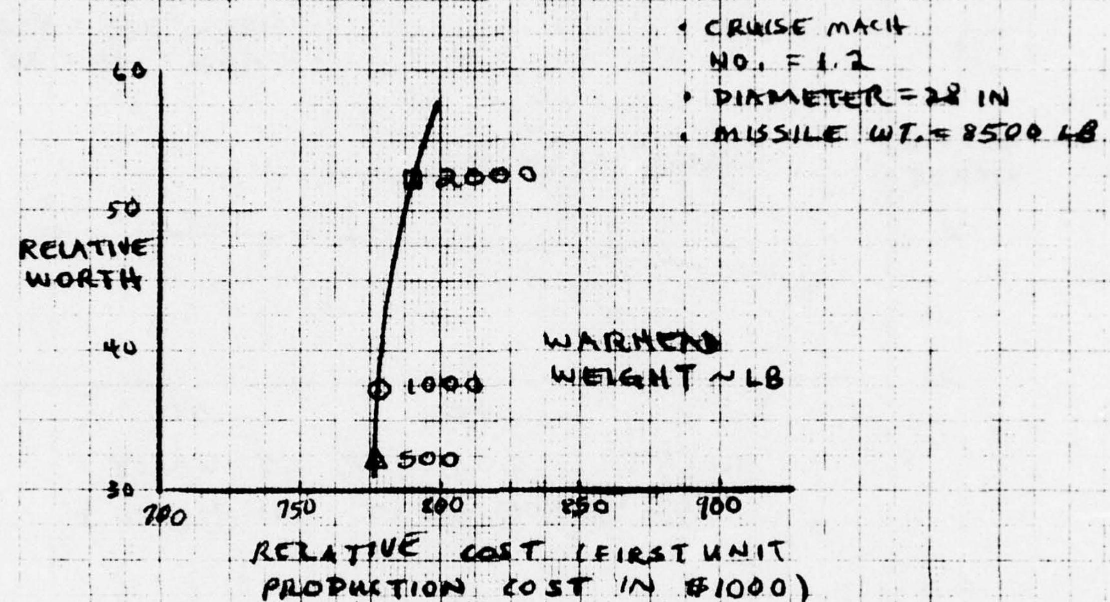
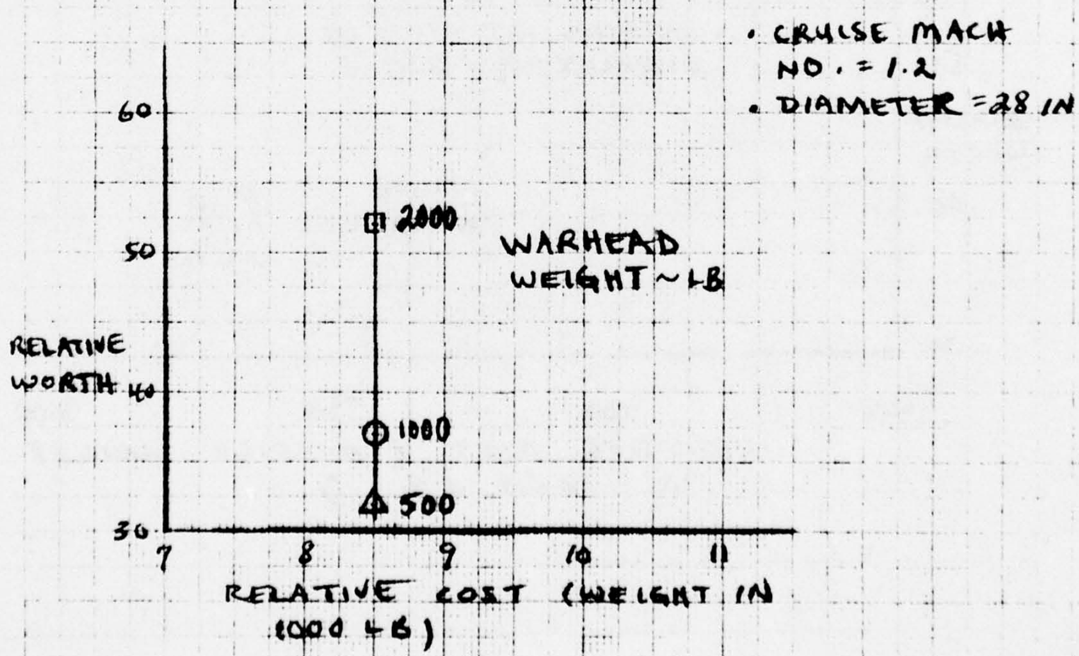


FIGURE A 3-20
SSM WARHEAD SCREENING RESULTS - COMPARISON OF SCREEN-TO-COST VS. SCREEN-TO-WEIGHT





4. RELATIVE WORTH MODEL - TEST CASE RESULTS

Relative Worth Model (RWM) analysis was conducted for the two cases described in Section 1.0 using the level one candidates (after initial screening based on cost) for the ASM and the SSM CM-CGSM test runs. The ASM case had 21 concepts in level one while the SSM case had 13. The trade factors used are shown in Figures A.4-1 and A.4-2 for the ASM and SSM cases, respectively. The ASM and SSM systems data, shown in Figures A.4-3 and A.4-4, were generated within the CM-CGSM except for the years to IOC, which is an analyst input.

4.1 TRADE FACTORS

The theory of trade factor derivation is contained in Appendix B, Volume IV, Relative Worth Model Users Manual, and is not repeated here. The trade factors derived for use in the two test cases are shown in Figures A.4-5 and A.4-6. They cover five areas: cost with respect to cost, total range with respect to cost, cruise velocity with respect to cost, warhead weight with respect to cost, and years to IOC with respect to cost. Note that the sign of the trade factors is chosen by the sign convention that if the variable (e.g., years to IOC) is such that low values are preferred, the trade factor is negative. If high values are preferred, such as warhead weight, the sign is positive.

4.2 RANK AND RANK BOUNDS

Use of the preceding data in the RWM produced the computer outputs shown in Figures A.4-7 and A.4-8, giving system name, rank, and rank bounds (if any). The results show no rank bounds because the inputs were limited to level one concepts only. To illustrate how the ranking should be interpreted, the highest ranking SSM concept is concept SSM-80 (System Number 11), which has a first production unit cost of $1.007 million, a total range of 85.4 nautical miles, a cruise velocity of MACH 1.5, a warhead weight of 2000 pounds HE, and a 4 year time to IOC.

4.3 DISCUSSION

The output of the RWM for both the ASM and SSM test cases supports different conclusions than the CM-CGSM output regarding the preferred systems. In the SSM test case, the CM-CGSM screening for level one concepts suggest that ASM concepts costing around $900K would be near the maximum worth per unit cost point on the level one curve. This area would cover SSM system numbers 7, 8 and 9. The RWM, however, after considering the low cruise velocity of these systems (MACH 1.2) and the trade factors discussed in Figures A.4-5, A.4-6 downgraded these three systems to positions 7, 2, and 5 respectively and elevated system number 11 to position 1. In the ASM test case, concepts costing $1.35 million appear at the maximum worth per unit cost point in the CM-CGSM level one screening. This point would contain system numbers 17 and 18. In the RWM, a higher cost system, system number 19, was preferred due to longer missile range, with all other system characteristics being exactly the same. System numbers 17 and 18 were lowered to position 5 and 3 respectively.

FIGURE A.4-1

RWM. LIQUID ASM. RUN= PAGE 6 2-15-75

PARAMETER TRADE FACTOR DATA PAGE 1

NO.	NAME		MINIMUM	AVERAGE	MAXIMUM
1	COST		-1.000E 00	-1.000E 00	-1.000E 00
2	RANGE	TOTAL	2.440E 02	1.516E 02	5.930E 01
3	VELOCITY	CRUISE	2.480E 00	1.480E 00	4.800E-01
4	WHD	WT	5.555E 03	3.703E 03	1.851E 03
5	YEARS	IOC	-1.850E 00	-3.705E 00	-5.560E 00

FIGURE A.4-2

RWM. SOLID SSM. RUN= PAGE 6 2-15-75

PARAMETER TRADE FACTOR DATA PAGE 1

NO.	NAME		MINIMUM	AVERAGE	MAXIMUM
1	COST		-1.000E 00	-1.000E 00	-1.000E 00
2	RANGE	TOTAL	4.800E 00	9.300E 00	1.380E 01
3	VELOCITY	CRUISE	4.000E-02	6.000E-02	8.000E-02
4	WHD	WT	1.000E 02	1.500E 02	2.000E 02
5	YEARS	IOC	-4.000E-02	-1.700E-01	-3.000E-01

FIGURE A.4-3

RWM. LIQUID ASM. RUN= PAGE 7 2-15-75

SYSTEM DATA PAGE 1

SYS NO.	COST	RANGE TOTAL	VELOCITY CRUISE	WHD WT	YEARS IOC
1	1.018E 01	2.226E 02	8.700E-01	5.000E 02	3.000E 00
2	1.019E 01	2.167E 02	8.700E-01	5.000E 02	3.000E 00
3	1.019E 01	2.134E 02	8.700E-01	5.000E 02	3.000E 00
4	1.020E 01	2.099E 02	8.700E-01	5.000E 02	3.000E 00
5	1.020E 01	2.062E 02	8.700E-01	5.000E 02	3.000E 00
6	1.021E 01	2.023E 02	8.700E-01	5.000E 02	3.000E 00
7	1.022E 01	1.988E 02	8.700E-01	1.000E 03	4.000E 00
8	1.023E 01	1.926E 02	8.700E-01	1.000E 03	4.000E 00
9	1.023E 01	1.747E 02	8.700E-01	1.000E 03	4.000E 00
10	1.024E 01	1.891E 02	8.700E-01	1.000E 03	4.000E 00
11	1.024E 01	1.855E 02	8.700E-01	1.000E 03	4.000E 00
12	1.025E 01	1.816E 02	8.700E-01	1.000E 03	4.000E 00
13	1.025E 01	1.713E 02	8.700E-01	1.000E 03	4.000E 00
14	1.025E 01	1.775E 02	8.700E-01	1.000E 03	4.000E 00
15	1.026E 01	1.689E 02	8.700E-01	1.000E 03	4.000E 00
16	1.028E 01	1.656E 02	8.700E-01	1.000E 03	4.000E 00
17	1.032E 01	1.347E 02	8.700E-01	2.000E 03	5.000E 00
18	1.033E 01	1.558E 02	8.700E-01	2.000E 03	5.000E 00
19	1.044E 01	1.656E 02	8.700E-01	2.000E 03	5.000E 00
20	1.045E 01	1.572E 02	8.700E-01	2.000E 03	5.000E 00
21	1.045E 01	1.527E 02	8.700E-01	2.000E 03	5.000E 00

FIGURE A.4-4

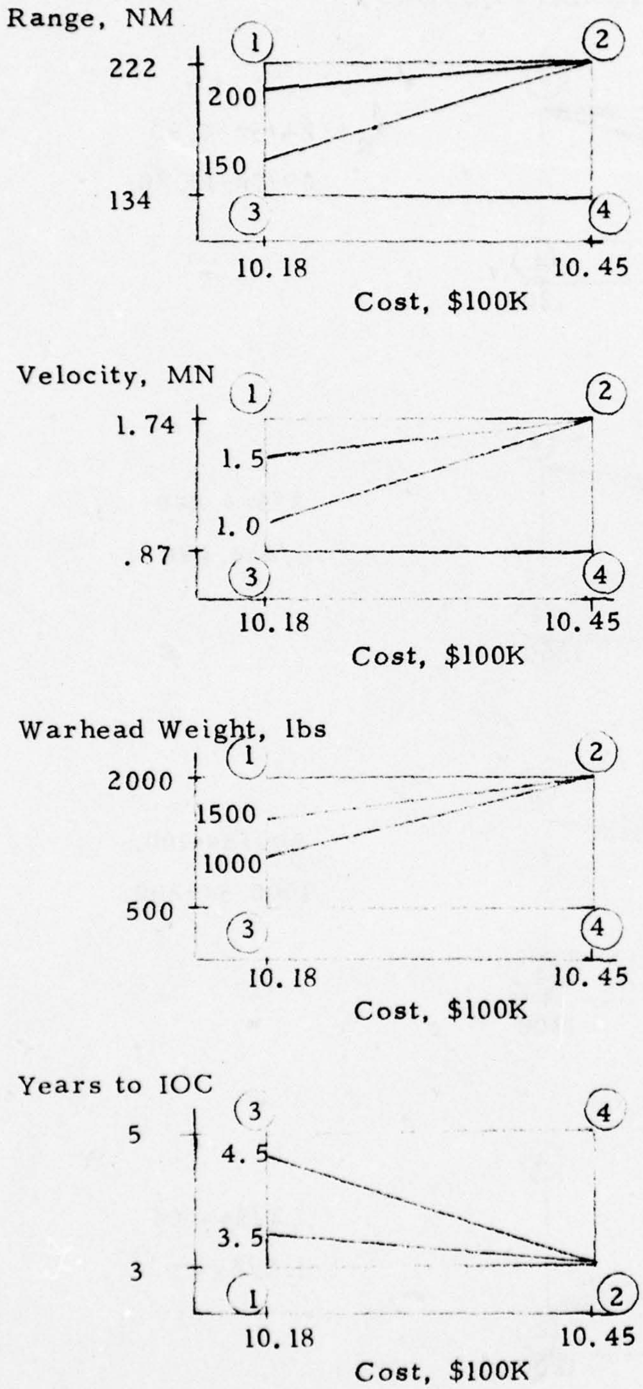
RWM. SOLID SSM. RUN= PAGE 7 2-15-75

SYSTEM DATA PAGE 1

SYS NO.	COST	RANGE TOTAL	VELOCITY CRUISE	WHD WT	YEARS IOC
1	7.080E 00	4.020E 01	1.200E 00	5.000E 02	3.000E 00
2	7.100E 00	3.470E 01	1.200E 00	1.000E 03	3.000E 00
3	7.270E 00	2.330E 01	1.200E 00	2.000E 03	3.000E 00
4	7.500E 00	3.560E 01	1.200E 00	2.000E 03	3.000E 00
5	7.640E 00	4.340E 01	1.200E 00	2.000E 03	3.000E 00
6	7.850E 00	5.450E 01	1.200E 00	2.000E 03	3.000E 00
7	8.490E 00	6.740E 01	1.200E 00	2.000E 03	3.000E 00
8	8.850E 00	8.390E 01	1.200E 00	2.000E 03	3.000E 00
9	9.150E 00	7.640E 01	1.200E 00	2.000E 03	3.000E 00
10	9.680E 00	6.810E 01	1.500E 00	2.000E 03	4.000E 00
11	1.007E 01	8.540E 01	1.500E 00	2.000E 03	4.000E 00
12	1.048E 01	7.760E 01	1.500E 00	2.000E 03	4.000E 00
13	1.185E 01	8.000E 01	1.900E 00	2.000E 03	5.000E 00

FIGURE A.4-5

ASM TRADE FACTORS



$t_R =$ 66/.27=+244.

16/.27=+59.3

.67/.27=+2.48

.13/.27=+.48

1500/.27=+5555.

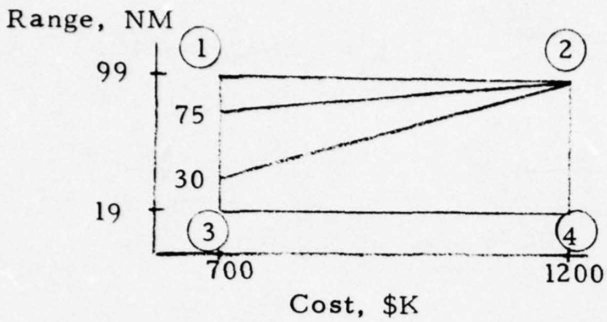
500 /.27=+1851.

.5/.27=−1.85

1.5/.27=−5.56

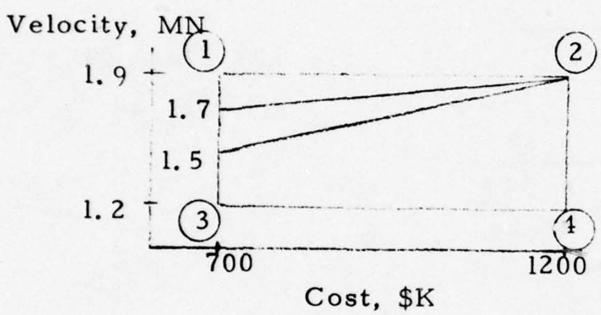
FIGURE A.4-6

SSM TRADE FACTORS



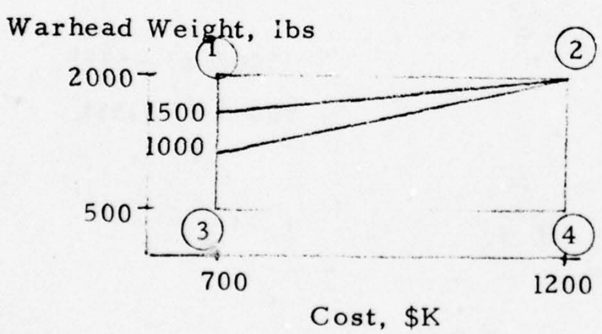
t_R = 24/5=+4.80

69/5=+13.80



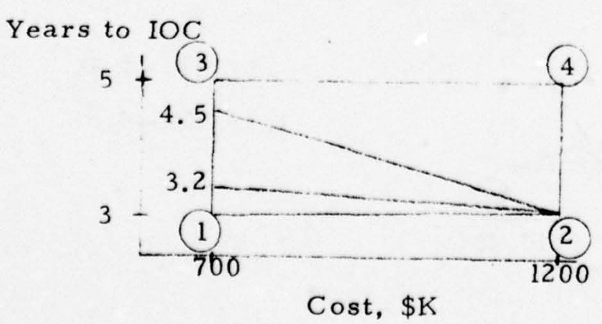
.2/5=+.040

.4/5=+.080



500/5=+100.

1000/5=+200



.2/5=-.04

1.5/5=-.3

FIGURE A.4-7

RWM. LIQUID ASM. RUN= PAGE 5 2-15-75

SYSTEM RANKING SENSITIVITY - RANK BOUND PAGE 1

(BASED ON SYSTEMS RANKED 1 THROUGH 21)

NO.	SYSTEM DESCRIPTION	UPPER BOUND	AVERAGE RANK	LOWER BOUND
1	SSM-57	16	16	16
2	SSM-54	17	17	17
3	SSM-51	18	18	18
4	SSM-48	19	19	19
5	SSM-45	20	20	20
6	SSM-42	21	21	21
7	SSM-74	6	6	6
8	SSM-72	7	7	7
9	SSM-22	12	12	12
10	SSM-69	8	8	8
11	SSM-66	9	9	9
12	SSM-63	10	10	10
13	SSM-19	13	13	13
14	SSM-60	11	11	11
15	SSM-16	14	14	14
16	SSM-13	15	15	15
17	SSM-39	5	5	5
18	SSM-91	3	3	3
19	SSM-136	1	1	1
20	SSM-133	2	2	2
21	SSM-130	4	4	4

FIGURE A.4-8

RWM. SOLID SSM. RUN= PAGE 5 2-15-75

SYSTEM RANKING SENSITIVITY - RANK BOUND PAGE 1

(BASED ON SYSTEMS RANKED 1 THROUGH 13)

NO.	SYSTEM DESCRIPTION	UPPER BOUND	AVERAGE RANK	LOWER BOUND
1	SSM-1	13	13	13
2	SSM-13	12	12	12
3	SSM-25	11	11	11
4	SSM-28	10	10	10
5	SSM-31	9	9	9
6	SSM-34	8	8	8
7	SSM-76	7	7	7
8	SSM-79	2	2	2
9	SSM-106	5	5	5
10	SSM-77	6	6	6
11	SSM-80	1	1	1
12	SSM-107	4	4	4
13	SSM-81	3	3	3

5. GENERAL CONCLUSIONS

The test cases shown here in Appendix A were chosen to demonstrate the uses of a Relative Cost Model in the SEATIDE Process, involving all three models (NEM, CM-CGSM, and RWM). Baseline missions and missile types were chosen to provide as much variety as possible with the budget and time available (one Liquid Rocket ASM, and one Solid Rocket SSM). It is felt that the usefulness of the Relative Cost Model was shown in the results and discussion in Section 3.3.

A reminder is in order about the conclusions to be drawn concerning the "top ranked" concepts which emerge in these test cases. The test cases are not studies of the relative merits of the general properties of a set of parameters (missile range, speed, etc.). Instead, they are a study of these parameters on specified missions, in specified Naval scenarios. Further study (and additional variations) might well reveal that the answers are sensitive to parameters which were not varied but which could be (e.g., the missile cruise altitudes, the terminal dive angle, the wing areas used, etc.).

Note should also be taken of the "top level" screening results in the CGSM. These are a function of the trade factors derived from the NEM and a good practice should be to analyze the sensitivity of the screening results to variations in the trade factors. At the present time this can only be done by systematically varying the trade factors input to the CGSM and making multiple runs. Additionally, it should be remembered that the CGSM screening does not rank concepts, but chooses the "best" for each cost. The analysis of the cost that should be expended versus worth to be gained is to be studied with the aid of the Relative Worth Model (RWM).

APPENDIX B

RELATIVE COST MODEL - SOURCE PROGRAM LISTING

VOUGHT SYSTEMS DIVISION
LTV AEROSPACE CORPORATION

TITLE	
RELATIVE COST MODEL - SOURCE PROGRAM LISTING	Appendix B NO. DATE February 1975

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PREPARED BY R.K. McDonough

APPROVED BY L.L. Gregory

APPENDIX B

RCM SOURCE PROGRAM LISTING

1. INTRODUCTION

This appendix presents the complete source program listing of the RCM. Data and Job Control Language cards required for compilation and use of this program within the CGSM have been discussed in the CGSM Users Manual (Vol. IIIA).

The source program is coded in the FORTRAN IV Computer language. Each subprogram is labeled in card columns 73 through 76, and each card in the subprogram is assigned a sequence number in columns 77 through 80. The RCM includes 11 modules, and consists of approximately 1400 source cards. An index of those modules is contained in Table 1.

2. RCM SOURCE LISTING

```
      SUBROUTINE COST(ICNO)
      COMMON /COSTSC/ CTOT,CPTCT,CRTOT,COMPC(17)
      COMMON /CONLY/ KIND,DIAFRT,SOMMOR(8)
      COMMON /SCRNNL/ SCR351(351), IDU4M4(4)
      EQUIVALENCE ( IDU4M4(3), ICOST )
      COMMON /QACOST/ QMAXQ, VMAXQ, DUMQA(8)
      COMMON /BASVAR/ DBAS8(8), TAREA, DBAS11(11)
      REAL NOZWT,MP
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,ACET,QA,WCS,
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG
      COMMON /COSTIN/   PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,
     3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
     7PRNA12,PRNB12,PRNF12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
     BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
      COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
     4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
     5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
     6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
     7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
     8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
     9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
     APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
     BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
     CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
     DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
     E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
     FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
      COMMON /COSTIN/    PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
     1AFC2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
     2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
     3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
     4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
     5WA2,WB2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
     6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
     7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
      COMMON /COSTIN/    AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
```

```
     1AFD3,AFE3,AFF3,AFF4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
     2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
     3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
     4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
     5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
     6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
     7GF5,GG5,CFTTAB(11),PFTTAB(11)
      COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCCMI,CCCML,CCOMM,
     1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
     2 CGT,CGTOT,CIGN,CIRJFU,       CIRJRD,        CLF,CLFL,CLGG,CLI,CLM,
     3              CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
     4 CMV,CNOZ,CNRJFU,         CNRJRD,        CP,CPAFI,CPENG,CPL,CPLC,
     5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
     6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
     8 CTJLF,CTJLFL,CTJRD,CTJT,              CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
     9 CPOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLTB,CNCZB,
     A CPRB,CPLB,CIGNB,CSAB,PROFEX
      DIMENSION DUMMY(1)
      EQUIVALENCE (CBLC,DUMMY(1))
      DIMENSION COMV(51), ICOMV(51)
      EQUIVALENCE ( COMV(1), WTANK), ( ICOMV(1), WTANK )
      NAMELIST /NCOUT/ COMV,ICOMV,KSTAB,KAGATE,NCHAN,KSGATE,
     1  KG,KC,KW,KA,KP,IGTYPE,ICTYPE
     2   ,KIND,DIAFRT,SOMMOR
     3   ,QMAXQ,VMAXQ,DUMQA,TAREA,QASAV,SSAV
      QASAV = QA
      SSAV = S
      IF ( QMAXQ .GT. 0.0 ) QA = QMAXQ * TAREA / 144./ 1000.
      IF ( VMAXQ .GT. 0.0 ) S = VMAXQ * 3600. / 6076.1155
      IF ( ICOST.NE.0) CALL PAGE
      IF(ICOST.GT.1) WRITE(6,NCOUT)
      DO 80 I=1,104
   80 DUMMY(I)=0.0
      WTANX=0.0
      IF ((KIND .GE. 20) .AND. (KIND .LT. 30)) WTANX=WT
      IF ((KIND .GE. 40) .AND. (KIND .LT. 50)) WTANX=WTANK
      IF (KIND .GE. 50) WTANX=WT
      AZ=A+WTANX
      IF (KG .EQ. 0) CALL GUCOST
      IF (KC .EQ. 0) CALL CTCOST
      IF (KW .EQ. 0) CALL WHCOST
      IF (KA .EQ. 0) CALL AAICST(AZ,DUMMY,1)
      IF (KP .NE. 0) GO TO 50
      IF (KIND .NE. 10 .AND. KIND .NE. 13) GO TO 10
      CALL PSRCST
      IF (KIND .EQ. 13) CALL PEBCST
      GO TO 50
   10 IF (KIND .NE. 20 .AND. KIND .NE. 23) GO TO 20
      CALL PLRCST
      IF (KIND .EQ. 23) CALL PEBCST
      GO TO 50
   20 IF (KIND .NE. 41) GO TO 30
      CALL PIRCST
      GO TO 50
```

```
30    IF (KIND .NE. 43 .AND. KIND .NE. 44) GO TO 40                       COST1110
      CALL PNRCST                                                         COST1120
      IF (KIND .EQ. 43) CALL PEBCST                                       COST1130
      GO TO 50                                                            COST1140
40    IF (KIND .NE. 50 .AND. KIND .NE. 53) GO TO 50                       COST1150
      CALL PTJCST                                                         COST1160
      IF (KIND .EQ. 53) CALL PEBCST                                       COST1170
   50 CONTINUE                                                            COST1180
      CPSINT = ( CPFU - PROFPR ) * 0.15 / 1.15                            COST1190
      CPFU = CPFU + CEBFU                                                 COST1200
      CRPS = CRPS + CEBRD                                                 COST1210
      CPTOT = CPAFI + CPFU + CGFU + CCFU + CWHFU                           COST1220
      CRTOT = CRAFI + CRPS + CGRD + CCRD + CWHR                            COST1230
      CTOT  = CPTOT + CRTOT                                               COST1240
      COMPC( 1)=CPAFI                                                     COST1250
      COMPC( 2)=CPFU                                                      COST1260
      COMPC( 3)=CGFU                                                      COST1270
      COMPC( 4)=CCFU                                                      COST1280
      COMPC( 5)=CWHFU                                                     COST1290
      COMPC( 6)=CRAFI                                                     COST1300
      COMPC( 7)=CRPS                                                      COST1310
      COMPC( 8)=CGRD                                                      COST1320
      COMPC( 9)=CCRD                                                      COST1330
      COMPC(10)=CWHR                                                      COST1340
      NTEN = 10                                                           COST1350
      NKIND = MOD(KIND,NTEN)                                              COST1360
      IF (ICOST .EQ. 0 ) GO TO 9876                                       COST1370
      WRITE(6,5111) NCONFG                                                COST1380
5111  FORMAT( // 8X, 13HCONFIGURATION,   I5  )                            COST1390
      WRITE(6,4210) IYEAR                                                 COST1400
4210  FORMAT(///23X23HRELATIVE COST SUMMARY   /                           COST1410
    1    16X22H(COSTS IN THOUSANDS OF  , I5, 1X8HDOLLARS) / )             COST1420
      WRITE(6,4212) CRTOT,CRAFI,CRPS,CGRD,CCRD,CWHR                       COST1430
4212  FORMAT(  / 8X25HMISSILE DEVELOPMENT COSTS, F35.2 /                  COST1440
    1    19X22HAIRFRAME + INTEGRATION , F14.2 / 19X17HPROPULSION SYSTEMCOST1450
    2   ,F19.2 / 19X15HGUIDANCE SYSTEM,F21.2/ 19X15HCONTROLS SYSTEM,     COST1460
    3    F21.2 / 19X7HWARHEAD,F29.2 )                                     COST1470
      WRITE(6,4214) CPTOT,CPAFI,CPFU,CGFU,CCFU,CWHFU                      COST1480
4214  FORMAT(     8X35HMISSILE FIRST UNIT PRODUCTION COSTS , F25.2 /      COST1490
    1   19X22HAIRFRAME + INTEGRATION,F14.2/ 19X17HPROPULSION SYSTEM ,     COST1500
    2   F19.2 / 19X15HGUIDANCE SYSTEM,F21.2/ 19X15HCONTROLS SYSTEM ,      COST1510
    3   F21.2 / 19X7HWARHEAD,F29.2 )                                      COST1520
      WRITE(6,4216) CTOT                                                  COST1530
4216  FORMAT(     8X40HTOTAL COST THROUGH FIRST UNIT PRODUCTION , F20.2)  COST1540
      IF (ICOST .LE. 0 ) GO TO 9876                                       COST1550
      CALL PAGE                                                           COST1560
      WRITE (6,5111) NCONFG                                               COST1570
      WRITE(6,5210) IYEAR                                                 COST1580
5210  FORMAT(     15X37HRELATIVE COST BREAKDOWN - DEVELOPMENT       /     COST1590
    1     16X22H(COSTS IN THOUSANDS OF ,I5, 1X8HDOLLARS)    )             COST1600
      WRITE(6,5212) CRAFI,CRENG,CRDEV,CRFTO,CRTOOL,CRMFGL,CRMFGM,CRQA,    COST1610
    1      PRRAF                                                          COST1620
5212  FORMAT(      8X22HAIRFRAME + INTEGRATION ,F37.2 /                   COST1630
    1   19X11HENGINEERING,F25.2 / 19X11HDEVELOPMENT, F25.2 /              COST1640
    2   19X16HFLIGHT TEST OPS. ,F20.2 / 19X7HTOOLING, F29.2  /            COST1650
```

```
     3  19X10HMFG. LABOR, F26.2 / 19X14HMFG. MATERIALS,F22.2 /               COST1660
     4  19X17HQUALITY ASSURANCE, F19.2 / 19X6HPROFIT, F30.2    )             COST1670
      WRITE(6,5214) CRPS,CGRD,CCRD,CWHR,CRTOT                                COST1680
 5214 FORMAT(    8X17HPROPULSION SYSTEM,F42.2 /                              COST1690
     1    8X15HGUIDANCE SYSTEM ,F44.2 / 8X15HCONTROLS SYSTEM,F44.2 /         COST1700
     2    8X7HWARHEAD,F52.2 / 8X5HTOTAL,F54.2   )                            COST1710
      WRITE(6,3110)IYEAR,CPAFI                                               COST1720
 3110 FORMAT(/    14X,47HRELATIVE COST BREAKDOWN - FIRST UNIT PRODUCTION COST1730
     1   /   19X,22H(COSTS IN THOUSANDS OF   ,I5, 1X, 8HDOLLARS)  /          COST1740
     2    8X24HAIRFRAME AND INTEGRATION     , F35.2    )                     COST1750
      WRITE(6,3111) CPENG,CPTOOL,CPMFGL,CPMFGM,CPQA,PRFUAF                   COST1760
 3111 FORMAT(   19X11HENGINEERING,F25.2 / 19X7HTOOLING,F29.2 /               COST1770
     1     19X10HMFG. LABOR , F26.2 / 19X14HMFG. MATERIALS , F22.2 /         COST1780
     2     19X17HQUALITY ASSURANCE , F19.2 / 19X6HPROFIT , F30.2  )          COST1790
      WRITE(6,3120) CGFU,CCFU,CWHFU,CPFU                                     COST1800
 3120 FORMAT(    8X15HGUIDANCE SYSTEM , F45.2 /   8X15HCONTROLS SYSTEM ,     COST1810
     1     F45.2 /   8X7HWARHEAD , F53.2 /   8X17HPROPULSION SYSTEM ,F43.2)COST1820
      IF( NKIND .EQ. 3 ) WRITE(6,3130) CEBFU                                 COST1830
 3130 FORMAT(   13X16HEXTERNAL BOOSTER , F31.2 )                             COST1840
      IF (NKIND.EQ. 3) WRITE (6,3140) CTCB,CLIB,CNOZB,CPRB,CPLB,CIGNB,       COST1850
     1 CSAB,PROFEX                                                           COST1860
 3140 FORMAT(19X4HCASE,F32.2 / 19X10HINSULATION,F26.2 /                      COST1870
     1      19X6HNOZZLE,F30.2 / 19X10HPROPELLANT, F26.2 /                    COST1880
     2    19X13HPROP. LOADING ,F23.2 / 19X7HIGNITER, F29.2 /                 COST1890
     3    19X10HSAFE + ARM, F26.2  / 19X6HPROFIT, F30.2    )                 COST1900
      IF ( KIND .LT. 20 ) WRITE(6,3150)  CSRFU                               COST1910
 3150 FORMAT(      13X22HSOLID ROCKET SUSTAINER , F25.2     )                COST1920
      IF ( KIND .LT. 20 ) WRITE(6,3140)CCASE,CLI,CNOZ,CPRC,                  COST1930
     1    CPLC,CIGN,CSA,PROFPR                                               COST1940
      IF( (KIND.LT.30).AND.(KIND.GE.20) ) WRITE(6,3160) CLRFU,CTC,CTP,       COST1950
     1    CM,CPS,CT,CP,CPL,CSA,PROFPR                                        COST1960
 3160 FORMAT(      13X23HLIQUID ROCKET SUSTAINER ,F24.2 /                    COST1970
     1   19X14HTHRUST CHAMBER ,F22.2   / 19X9HTURBOPUMP , F27.2 /            COST1980
     2   19X15HMISC. EQUIPMENT , F21.2 / 19X21HPRESSURIZATION SYSTEM   ,     COST1990
     3   F15.2 / 19X7HTANKAGE , F29.2 / 19X7HFUEL/OX , F29.2 /               COST2000
     4   19X13HPROP. LOADING , F23.2  /  19X10HSAFE + ARM , F26.2 /          COST2010
     5   19X6HPROFIT , F30.2     )                                           COST2020
      IF( KIND .GE. 50 ) WRITE(6,3170) CTJFU,CETJ,CT,CTJLF,CTJLFL,PROFPRCOST2030
 3170 FORMAT(     13X18HTURBOJET SUSTAINER , F29.2 / 19X6HENGINE, F30.2/    COST2040
     1    19X7HTANKAGE ,F29.2 / 19X4HFUEL, F32.2 / 19X13HFUEL LOADING ,      COST2050
     2   F23.2 /    19X6HPROFIT, F30.2  )                                    COST2060
      IPOUT=0                                                                COST2070
      IF( (KIND.GE.40) .AND. (KIND.LT.50) ) IPOUT=1                          COST2080
      IF(KIND.EQ.41) IPOUT=IPOUT + 1                                         COST2090
      IF(IPOUT.EQ.1) WRITE(6,3210) CNRJFU                                    COST2100
 3210 FORMAT(      13X25HNON-INT. RAMJET SUSTAINER    , F22.2 )              COST2110
      IF(IPOUT.EQ.2) WRITE(6,3230) CIRJFU                                    COST2120
 3230 FORMAT(      13X25HINTEGRAL RAMJET SUSTAINER, F22.2 )                  COST2130
      IF(  IPOUT.GT.0)WRITE(6,3211) CT,CEXIN,CPS,CLF,CLFL                    COST2140
 3211 FORMAT(19X7HTANKAGE ,F29.2 / 19X15HEXT. INSULATION, F21.2 /            COST2150
     1      19X21HPRESSURIZATION SYSTEM   ,F15.2 / 19X4HFUEL, F32.2 /        COST2160
     2      19X12HFUEL LOADING  , F24.2  )                                   COST2170
      IF(IPOUT.EQ.1)WRITE(6,3220) CRJC,CCOML,CCOMM,CCOMI,CNOZ,PROFPR         COST2180
 3220 FORMAT( 19X9HCOMBUSTOR,F27.2 / 22X5HLABOR,F16.2 /                      COST2190
     1      22X8HMATERIAL,F13.2/ 22X10HINSULATION,F11.2 /                    COST2200
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2     22X6HNOZZLE,F15.2  / 19X6HPROFIT,F30.2  )                          COST2210
      IF(IPOUT.EQ.2) WRITE(6,3240) CBOOC,CBLC,CBMC,CLI,CNCZ,CPRC,         COST2220
1          CPLC,CIGN,CSA,PROFPR                                            COST2230
3240 FORMAT( 19X17HBOOSTER/COMBUSTOR,F19.2 / 22X10HCASE LABOR,F11.2 /      COST2240
1     22X10HCASE MATL.,F11.2 / 22X10HCASE INSUL,F11.2 /                    COST2250
2     22X6HNOZZLE,F15.2 / 22X9HBOO. PROP,F12.2/ 22X11HB. P. LOAD. ,        COST2260
3     F10.2 / 22X7HIGNITER,F14.2 / 22X10HSAFE + ARM, F11.2 /               COST2270
4     19X6HPROFIT, F30.2  )                                                COST2280
      WRITE(6,3366) CPSINT                                                 COST2290
3366 FORMAT(19X11HINTEGRATION    , F25.2     )                             COST2300
9876 CONTINUE                                                              COST2310
      QA = QASAV                                                           COST2320
      S = SSAV                                                             COST2330
      RETURN                                                               COST2340
      END                                                                  COST2350


      SUBROUTINE AAICST(ASUPLD,TEMP8,INDI)                                 AAIC0010
C                                                                          AAIC0020
C         AIRFRAME AND INTEGRATION COST                                    AAIC0030
C                                                                          AAIC0040
      REAL NOZWT,MP                                                        AAIC0050
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,      AAIC0060
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NCZWT,MP,CASEM,    AAIC0070
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,     AAIC0080
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG               AAIC0090
      COMMON /COSTIN/    PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,  AAIC0100
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,    AAIC0110
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,     AAIC0120
     3PRIF16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,     AAIC0130
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,     AAIC0140
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,    AAIC0150
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,     AAIC0160
     7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,     AAIC0170
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,     AAIC0180
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,     AAIC0190
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,    AAIC0200
     BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,AAIC0210
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,    AAIC0220
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,     AAIC0230
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,   AAIC0240
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,AAIC0250
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,     AAIC0260
     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR       AAIC0270
      COMMON /COSTIN/    PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIP5,AAIC0280
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,    AAIC0290
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,     AAIC0300
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,     AAIC0310
     4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2AAIC0320
     5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9AAIC0330
     6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,    AAIC0340
     7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,     AAIC0350
     8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4AAIC0360
     9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,    AAIC0370
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     APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLE19,PLC19,PTB1,
     BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
     CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
     DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
     E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
     FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRIC26
      COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
     1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
     2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
     3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
     4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
     5WA2,WC2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
     6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
     7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
      COMMON /COSTIN/   AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
     1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
     2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
     3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
     4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
     5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
     6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
     7GF5,GG5,CFTTAB(11),PFTTAB(11)
      COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCCML,CCCMM,
     1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
     2 CGT,CGTOT,CIGN,CIRJFU,       CIRJRD,        CLF,CLFL,CLGG,CLI,CLM,
     3            CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
     4 CMV,CNOZ,CNRJFU,       CNRJRD,        CP,CPAFI,CPENG,CPL,CPLC,
     5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
     6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
     8 CTJLF,CTJLFL,CTJRD,CTJT,          CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
     9 CBODC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
     A CPRB,CPLB,CIGNB,CSAB,PROFEX
      NAMELIST /ERRPRT/ CRENG,CRDEV,CRFTO,CRTOOL,CRMFGL,CRMFGM,CRQA,
     1 CRAFI,CPENG,CPTOOL,CPMFGL,CPMFGM,CPQA,CPAFI,CTAFI
1     TEMP1=AFA1*AFB1*AFC1*AFD1*(AFE1*ASUPLD**AFF1*S**AFG1*QD**AFH1
     1 /1000.)+AFI1*AFD1
2     TEMP2=AFA2*AFB2*1.163*(AFC2*ASUPLD**AFD2*S**AFE2*QD**AFF2/1000.)
     1 +AFB2*AFG2
3     TEMP3=AFA3*AFB3*1.163*(AFC3*ASUPLD**AFD3*S**AFE3*QD**AFF3/1000.)
     1 +AFB3*AFG3
4     TEMP4=AFA4*AFB4*AFC4*AFD4*(AFE4*ASUPLD**AFF4*S**AFG4*QD**AFH4*R
     1 **AFI4/1000.)+AFJ4*AFC4
5     TEMP5=AFA5*AFB5*AFC5*(AFD5*ASUPLD**AFE5*S**AFF5*QD**AFG5/1000.)
     1 +AFC5*AFH5
6     TEMP6=AFA6*AFB6*1.163*(AFC6*ASUPLD**AFD6*S**AFE6*QD**AFF6/1000.)
     1 +AFB6*AFG6
7     TEMP7=AFA7*AFB7*TEMP5+AFC7*AFD7
14    TEMP8=AFA14*(1.+PROFIT)*(TEMP1+TEMP4+TEMP5+TEMP6+TEMP7+TEMP2
     1 +TEMP3)+AFB14*AFC14
      IF (INDI .EQ. 0) RETURN
      CRFNG=TEMP1
      CRDEV=TEMP2
      CRFTO=TEMP3
      CRTOOL=TEMP4
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      CRMFGL=TEMP5                                                      AAIC0930
      CRMFGM=TEMP6                                                      AAIC0940
      CRQA=TEMP7                                                        AAIC0950
      CRAFI=TEMP8                                                       AAIC0960
      PRRAF=(CRAFI-AFB14*AFC14)*PROFIT/(1.+PROFIT)                      AAIC0970
8     CPENG=AFA8*AFB8*AFC8*AFD8*(AFE8*A**AFF8*S**AFG8*((QD+1.)**AFH8    AAIC0980
     1 -QD**AFH8)/1000.)+AFI8*AFD8                                      AAIC0990
9     CPTOOL=AFA9*AFB9*AFC9*AFD9*(AFE9*A**AFF9*S**AFG9*((QD+1.)**AFH9   AAIC1000
     1 -QD**AFH9)*R**AFI9/1000.)+AFJ9*AFC9                              AAIC1010
10    CPMFGL=AFA10*AFB10*AFC10*(AFD10*A**AFE10*S**AFF10*((QD+1.)**AFG10 AAIC1020
     1 -QD**AFG10)/1000.)+AFC10*AFH10                                   AAIC1030
11    CPMFGM=AFA11*AFB11*1.163*(AFC11*A**AFD11*S**AFE11*((QD+1.)**AFF11 AAIC1040
     1 -QD**AFF11)/1000.)+AFB11*AFG11                                   AAIC1050
12    CPQA=AFA12*AFB12*CPMFGL+AFC12*AFD12                               AAIC1060
13    CPAFI=AFA13*(1.+PROFIT)*(CPENG+CPTOOL+CPMFGL+CPMFGM+CPQA)         AAIC1070
     1 +AFB13*AFC13                                                     AAIC1080
      PRFUAF=(CPAFI-AFB13*AFC13)*PROFIT/(1.+PROFIT)                     AAIC1090
15    CTAFI=CPAFI+CRAFI                                                 AAIC1100
      IF (IPRCST .NE. 0) WRITE (6,ERRPRT)                               AAIC1110
      RETURN                                                            AAIC1120
      END                                                               AAIC1130


      SUBROUTINE GUCOST                                                 GUC00010
C                                                                       GUC00020
C          GUIDANCE SYSTEM COST                                         GUC00030
C                                                                       GUC00040
      REAL NOZWT,MP                                                     GUC00050
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,   GUC00060
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,  GUC00070
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,   GUC00080
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG             GUC00090
      COMMON /COSTIN/   PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5, GUC00100
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,  GUC00110
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,   GUC00120
     3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,   GUC00130
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,   GUC00140
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,  GUC00150
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,   GUC00160
     7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,   GUC00170
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,   GUC00180
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,   GUC00190
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,  GUC00200
     BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,GUC00210
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,  GUC00220
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,   GUC00230
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEE5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9, GUC00240
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,GUC00250
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,   GUC00260
     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR     GUC00270
      COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,GUC00280
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIF11,  GUC00290
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,   GUC00300
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,   GUC00310
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      4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
      5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
      6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
      7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
      8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
      9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
      APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
      BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
      CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEF5,PEC6,
      DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
      E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
      FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRIC26
       COMMON /COSTIN/    PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
      1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
      2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
      3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
      4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
      5WA2,WC2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
      6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
      7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
       COMMON /COSTIN/    AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
      1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
      2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
      3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
      4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
      5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
      6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
      7GF5,GG5,CFTTAB(11),PFTTAB(11)
       COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCOML,CCOMM,
      1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
      2 CGT,CGTOT,CIGN,CIRJFU,       CIRJRD,       CLF,CLFL,CLGG,CLI,CLM,
      3              CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
      4 CMV,CNOZ,CNRJFU,       CNRJRD,       CP,CPAFI,CPENG,CPL,CPLC,
      5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
      6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
      7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
      8 CTJLF,CTJLFL,CTJRD,CTJT,         CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
      9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
      A CPRB,CPLB,CIGNB,CSAB,PROFEX
       NAMELIST /ERRPRT/ CGFUP,CGFUA,CGFUX,CGFUI,CGRD,CGTCT
       XDET=NDET
       XSTAB=KSTAB
       XAGATE=KAGATE
       XCHAN=NCHAN
       XSGATE=KSGATE
       XKLE6=1.
       XKGT6=0.
C        FC IS ASSUMED IN GHZ
       IF (FC .LE. 6.) GO TO 1000
       XKLE6=0.
       XKGT6=1.
 1000 IF ( ICTYPE .EQ. 3 ) GO TO 1
       GO TO (2,3,4,5), IGTYPE
C        PASSIVE/SEMI-ACTIVE RADAR SEEKER
 2     CX=GC2*XKLE6*FC**GD2+GE2*XKGT6*FC**GF2+GG2*XSTAB+GH2*XAGATE+GI2
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     1 *XCHAN*XSGATE+GJ2*XSGATE                                            GUC00870
       CGFUP=GA2*(1.16*GB2*CX/350.+GK2)                                    GUC00880
       GO TO 1                                                             GUC00890
C         ACTIVE RADAR (MAGNETRON)                                         GUC00900
 3     CX=GC3*XKLE6*FC**GD3+GE3*XKGT6*FC**GF3+GG3*XSTAB+GH3*XAGATE+GI3     GUC00910
     1 *XCHAN*XSGATE+GJ3*XSGATE                                            GUC00920
       CGFUA=GA3*(1.566*GB3/350.*(CX+GK3+GL3*PPEAK**GM3+GN3*FC**GP3        GUC00930
     1 *PPEAK)+GQ3)                                                        GUC00940
       GO TO 1                                                             GUC00950
C         X BAND                                                           GUC00960
 4     CX=GC4*XKLE6*FC**GD4+GE4*XKGT6*FC**GF4+GG4*XSTAB+GH4*XAGATE+GI4     GUC00970
     1 *XCHAN*XSGATE+GJ4*XSGATE                                            GUC00980
       CGFUX=GA4*(1.566*GB4/156.*(CX+GK4+GL4*PPEAK)+GM4)                   GUC00990
       GO TO 1                                                             GUC01000
C         PASSIVE IR SEEKER                                                GUC01010
 5     CGFUI=GA5*(1.16*GB5/350.*(GC5*FC**GD5*BSP**GE5+GF5*(XDET-1.)        GUC01020
     1 +GG5)+GH5)                                                          GUC01030
 1      IF (IGTYPE .EQ. 1) CGFU=CGFUP                                      GUC01040
        IF (IGTYPE .EQ. 2) CGFU=CGFUA                                      GUC01050
        IF (IGTYPE .EQ. 3) CGFU=CGFUX                                      GUC01060
        IF (IGTYPE .EQ. 4) CGFU=CGFUI                                      GUC01070
       CGRD=GA1*(GB1*(EXP(GC1+GD1*CGFU*GE1))+GF1)                          GUC01080
 6     CGTOT=CGRD+CGFU                                                     GUC01090
       IF (IPRCST .NE. 0) WRITE (6,ERRPRT)                                 GUC01100
       RETURN                                                              GUC01110
       END                                                                 GUC01120

       SUBROUTINE CTCOST                                                   CTC00010
C                                                                          CTC00020
C         CONTROLS COST                                                    CTC00030
C                                                                          CTC00040
       REAL NOZWT,MP                                                       CTC00050
       COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,     CTC00060
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,     CTC00070
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,      CTC00080
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG                CTC00090
       COMMON /COSTIN/    PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,  CTC00100
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,     CTC00110
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,      CTC00120
     3PRIE16,PRIA17,PRIE17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,      CTC00130
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,      CTC00140
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,     CTC00150
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,      CTC00160
     7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,      CTC00170
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,      CTC00180
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,      CTC00190
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,     CTC00200
     BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,   CTC00210
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,     CTC00220
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,      CTC00230
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEE5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,    CTC00240
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,   CTC00250
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,      CTC00260
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     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
      COMMON /COSTIN/    PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
     4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
     5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
     6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
     7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
     8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
     9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
     APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
     BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
     CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
     DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
     E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
     FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
      COMMON /COSTIN/    PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
     1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
     2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
     3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
     4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
     5WA2,WD2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
     6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
     7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
      COMMON /COSTIN/    AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
     1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
     2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
     3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
     4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
     5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
     6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
     7GF5,GG5,CFTTAB(11),PFTTAB(11)
      COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCOML,CCOMM,
     1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
     2 CGT,CGTOT,CIGN,CIRJFU,         CIRJRD,          CLF,CLFL,CLGG,CLI,CLM,
     3            CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
     4 CMV,CNOZ,CNRJFU,          CNRJRD,          CP,CPAFI,CPENG,CPL,CPLC,
     5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
     6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
     8 CTJLF,CTJLFL,CTJRD,CTJT,          CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
     9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
     A CPRB,CPLB,CIGNB,CSAB,PROFEX
      NAMELIST /ERRPRT/ CCFU,CCRD,CCONT
      XGAIN=KGAIN
      GO TO (2,3),ICTYPE
C         WITH AUTOPILOT
  2   CCFU=CA2*(1.16*(CB2*WCS+CC2*QA-CD2)*CE2/198.+CF2)
      GO TO 1
C         WITHOUT AUTOPILOT
  3   CCFU=CA3*(1.16*(CB3*WCS+CC3*QA+CD3)*CE3/198.+CF3)
  1   CCRD=CA1*((CB1+CC1*QA+CD1*XGAIN)*CE1+CF1)
  4   CCONT=CCRD+CCFU
      IF (IPRCST .NE. 0) WRITE (6,ERRPRT)
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      RETURN
      END

      SUBROUTINE WHCOST
C
C        WARHEAD COST
C
      REAL NOZWT,MP
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCCMI,
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,CA,WCS,
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG
      COMMON /COSTIN/  PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,
     3PRIE16,PRIA17,PRIE17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
     7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
     BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
      COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
     4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
     5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
     6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
     7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
     8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
     9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
     APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
     BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
     CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
     DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
     E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
     FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
      COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
     1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
     2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
     3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
     4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
     5WA2,WC2,WF2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
     6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
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      7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
       COMMON /COSTIN/    AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
      1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
      2AFD6,AFF6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
      3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
      4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
      5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
      6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
      7GF5,GG5,CFTTAB(11),PFTTAB(11)
       COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCCML,CCCMM,
      1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
      2 CGT,CGTOT,CIGN,CIRJFU,          CIRJRD,          CLF,CLFL,CLGG,CLI,CLM,
      3            CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
      4 CMV,CNOZ,CNRJFU,          CNRJRD,          CP,CPAFI,CPENG,CPL,CPLC,
      5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
      6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
      7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
      8 CTJLF,CTJLFL,CTJRD,CTJT,          CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
      9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
      A CPRB,CPLB,CIGNB,CSAB,PROFEX
       NAMELIST /ERRPRT/ CWHR,CWHFU,CWH
       XFUZE=KFUZE
 1     CWHR=WA1*((WB1+WC1*WWH+WD1*XFUZE)*WE1+WF1)
 2     CWHFU=WA2*(1.28*(WB2+WC2*SQRT(WWH))*WD2/600.+WE2)
 3     CWH=CWHR+CWHFU
       IF (IPRCST .NE. 0) WRITE (6,ERRPRT)
       RETURN
       END


       SUBROUTINE PLRCST
C
C          LIQUID ROCKET PROPULSION COST
C
       REAL NOZWT,MP
       COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCCMI,
      1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,
      2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,
      3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG
       COMMON /COSTIN/    PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,
      1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,
      2PRIB12,PRIE12,PRIA13,PRIF13,PRIA14,PRIE14,PRIA15,PRIF15,PRIA16,
      3PRIF16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIF19,PRIA20,
      4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
      5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
      6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
      7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNF14,PRNA15,PRNA16,
      8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
      9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
      APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
      BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
      CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
      DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
      EPEA3,PEB3,PEA4,PEF4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,
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FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,
GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
 COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,
2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
8PRND16,PRNB17,PRNC17,PRND17,PRNF17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
 COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
5WA2,WD2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
 COMMON /COSTIN/   AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
1AFD3,AFE3,AFF3,AFF4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
7GF5,GG5,CFTTAB(11),PFTTAB(11)
 COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCOML,CCOMM,
1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
2 CGT,CGTOT,CIGN,CIRJFU,       CIRJRD,       CLF,CLFL,CLGG,CLI,CLM,
3                CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
4 CMV,CNOZ,CNRJFU,        CNRJRD,       CP,CPAFI,CPENG,CPL,CPLC,
5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTFB,CTIRJ,CTJFU,
8 CTJLF,CTJLFL,CTJRD,CTJT,          CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
A CPRB,CPLB,CIGNB,CSAB,PROFEX
 DIMENSION PLB14A(3)
 NAMELIST /ERRPRT/ CLTC,CMTC,CTC,CLTP,CMTP,CLGG,CMGG,CTP,CLM,CMM,
1 CM,CGT,CPS,CT,CP,CPL,CSA,CLRFU,                 CLRRD,CLRT
 DATA PLB14A/2165.,16499.,7191./
 PLB14U=PLB14A(METAL)
 PLC14U=.2608
 IF (PLB14 .NE. 0.) PLB14U=PLB14
 IF (PLC14 .NE. 0.) PLC14U=PLC14
1     CLTC=PLA1*PLB1*WTC**PLC1/1000.
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2     CMTC=PLA2*1.35*WTC**PLB2/1000.
3     CTC=PLA3*(CLTC+CMTC)+PLB3
4     CLTP=PLA4*PLB4*(WTP-WGG-WSC)**PLC4/1000.
5     CMTP=PLA5*1.35*(WTP-WGG-WSC)**PLB5/1000.
6     CLGG=PLA6*PLB6*(WGG+WSC)**PLC6/1000.
7     CMGG=PLA7*1.35*(WGG+WSC)**PLB7/1000.
8     CTP=PLA8*(CLTP+CMTP+CLGG+CMGG)+PLB8
9     CLM=PLA9*PLB9*WLV**PLC9/1000.
10    CMM=PLA10*1.35*WLV**PLB10/1000.
11    CM=PLA11*(CLM+CMM)+PLB11
12    CGT=PLA12*1.059*VGT**PLB12/1000.
13    CPS=PLA13*(CGT+PLB13+PLC13)+PLD13
14    CT=PLA14*PLB14U*1.1*WT**PLC14U/1000.+PLD14
15    CP=PLA15*(PLB15*(PLC15/WO)**PLD15*WO+PLE15*(PLC15/WF)**PLD15*WF)
     1 /1000.+PLF15
16    CPL=PLA16*PLB16*1.1*(PLC16/WP)**PLD16*WP+PLE16
17    CSA=PLA17
18    CLRFU=(PLA18*1.15*PLB18*(CTC+CTP+CM+CPS+CT+CP+CPL+CSA)+PLA18*PLC18
     1 )*(1.+PLPC)
      CPFU=CLRFU
      PROFPR=CLRFU*PLPC/(1.+PLPC)
21    CLRRD=PLA21*(PLB21*(1.462*PLD21*FMAX+PLE21)+PLC21)*(1.+PLPC)
      CRPS=CLRRD
22    CLRT=CLRRD+CLRFU
      CLTC=CLTC*PLA18
      CMTC=CMTC*PLA18
      CTC=CTC*PLA18
      CLTP=CLTP*PLA18
      CMTP=CMTP*PLA18
      CLGG=CLGG*PLA18
      CMGG=CMGG*PLA18
      CTP=CTP*PLA18
      CLM=CLM*PLA18
      CMM=CMM*PLA18
      CM=CM*PLA18
      CGT=CGT*PLA18
      CPS=CPS*PLA18
      CT=CT*PLA18
      CP=CP*PLA18
      CPL=CPL*PLA18
      CSA=CSA*PLA18
      IF (IPRCST .NE. 0) WRITE (6,ERRPRT)
      RETURN
      END


      SUBROUTINE PEBCST
C
C         EXTERNAL BOOSTER PROPULSION COST
C
      COMMON   /CONLY/ KPUTG,  DIAFRT,  SOMMOR(8)
      REAL NOZWT,MP
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,
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2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,     PEBC0090
3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WC,WP,DP,WN,METAL,NCONFG              PEBC0100
  COMMON /COSTIN/   PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,  PEBC0110
1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,    PEBC0120
2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,     PEBC0130
3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,     PEBC0140
4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,     PEBC0150
5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,    PEBC0160
6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,     PEBC0170
7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,     PEBC0180
8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,     PEBC0190
9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,     PEBC0200
APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,    PEBC0210
BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,PEBC0220
CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,    PEBC0230
DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,     PEBC0240
EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,   PEBC0250
FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,PEBC0260
GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,     PEBC0270
HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR       PEBC0280
  COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,PEBC0290
1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,    PEBC0300
2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,     PEBC0310
3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,     PEBC0320
4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2PEBC0330
5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9PEBC0340
6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,    PEBC0350
7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,     PEBC0360
8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4PEBC0370
9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,   PEBC0380
APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,   PEBC0390
BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,   PEBC0400
CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,   PEBC0410
DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4PEBC0420
E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,PEBC0430
FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26              PEBC0440
  COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,  PEBC0450
1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,   PEBC0460
2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,   PEBC0470
3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,     PEBC0480
4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,  PEBC0490
5WA2,WD2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,PEBC0500
6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,    PEBC0510
7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST             PEBC0520
  COMMON /COSTIN/   AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,    PEBC0530
1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,   PEBC0540
2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,   PEBC0550
3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,PEBC0560
4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,    PEBC0570
5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,    PEBC0580
6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,    PEBC0590
7GF5,GG5,CFTTAB(11),PFTTAB(11)                                       PEBC0600
  COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCOML,CCOMM,    PEBC0610
1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,                       PEBC0620
2 CGT,CGTOT,CIGN,CIRJFU,      CIRJRD,      CLF,CLFL,CLGG,CLI,CLM,    PEBC0630
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     3          CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,          PEBC0640
     4 CMV,CNOZ,CNRJFU,       CNRJRD,        CP,CPAFI,CPENG,CPL,CPLC,      PEBC0650
     5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,         PEBC0660
     6 CPTOOL,CRAFI,CRDFV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,        PEBC0670
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,          PEBC0680
     8 CTJLF,CTJLFL,CTJRD,CTJT,          CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR, PEBC0690
     9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,      PEBC0700
     A CPRB,CPLB,CIGNB,CSAB,PROFEX                                         PEBC0710
      NAMELIST /ERRPRT/ CCLB,CCMB,CTCB,CLIB,CNOZB,CPRB,CPLB,CIGNB,CSAB,    PEBC0720
     1 CEBFU,CEBRD,CTEB                                                    PEBC0730
      DSLIK = D                                                            PEBC0740
      D = D * DIAFRT                                                       PEBC0750
      I=CASEM                                                              PEBC0760
      CFMU=CFTTAB(I)                                                       PEBC0770
      PFMU=PFTTAB(I)                                                       PEBC0780
      IF (CFM .NE. 0.) CFMU=CFM                                            PEBC0790
      IF (PFM .NE. 0.) PFMU=PFM                                            PEBC0800
1     CCLB=PEA1*CFMU*(PEB1/WMC)**PEC1*WMC                                  PEBC0810
2     CCMB=1.1*PEA2*PFMU*(PEB2/WMC)**PEC2*WMC                              PEBC0820
3     CTCB=PEA3*(CCLB+CCMB)+PEB3                                           PEBC0830
4     CLIB=1.1*PEA4*PEB4*(PEC4/VBI)**PED4*VBI+PEE4                         PEBC0840
5     CNOZB=1.1*PEA5*PEB5*(PEC5+PED5*DTHRT+PEE5*RNOZI)*NOZWT+PEF5          PEBC0850
6     CPRB=PEA6*PEB6*MP/1000.*(PEC6/MP)**PED6+PEE6                         PEBC0860
7     CPLB=1.1*PEA7*PEB7*MP*(PEC7/MP)**PED7+PEE7                           PEBC0870
8     CIGNB=PEA8                                                           PEBC0880
9     CSAB=PEA9                                                            PEBC0890
10    CEBFU=ZXNB*(PEA10*(PEB10*(CTCB+CLIB+CNOZB+CPRB+CPLB+CIGNB+CSAB)      PEBC0900
     1 +PEC10)*(1.+PEBC))                                                  PEBC0910
      PROFEX=CEBFU*PEBC/(1.+PEBC)                                          PEBC0920
11    CEBRD=PEA11*(PEB11*PEC11*(D*WM)**PED11*1.462+PEF11)*(1.+PEBC)        PEBC0930
12    CTEB=CEBRD+CEBFU                                                     PEBC0940
      CCLB=CCLB*PEA10                                                      PEBC0950
      CCMB=CCMB*PEA10                                                      PEBC0960
      CTCB=CTCB*PEA10                                                      PEBC0970
      CLIB=CLIB*PEA10                                                      PEBC0980
      CNOZB=CNOZB*PEA10                                                    PEBC0990
      CPRB=CPRB*PEA10                                                      PEBC1000
      CPLB=CPLB*PEA10                                                      PEBC1010
      CIGNB=CIGNB*PEA10                                                    PEBC1020
      CSAB=CSAB*PEA10                                                      PEBC1030
      IF (IPPCST .NE. 0) WRITE (6,ERRPRT)                                  PEBC1040
      D = DSLIK                                                            PEBC1050
      RETURN                                                               PEBC1060
      END                                                                  PEBC1070

      SUBROUTINE PSRCST                                                    PSRC0010
C                                                                          PSRC0020
C          SOLID SUSTAINER PROPULSION COST                                 PSRC0030
C                                                                          PSRC0040
      COMMON /CONLY/ KINDPS,DIAFRT,SWMC,SDTHRT,SRNOZI,SWM,SCMMOR(4)        PSRC0050
      REAL NOZWT,MP                                                        PSRC0060
      COMMON /COMVLS/ WTANK,VFXIN,VREQ,GGW,HPPUMP,WTFUEL,WCCMM,VCCMI,      PSRC0070
     1 P5,Y1,WNOZ,KEM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,     PSRC0080
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2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,
3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG
 COMMON /COSTIN/   PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,
1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,
2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,
3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,
4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,
8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,
FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,
GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
 COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIF11,
2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
CPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
 COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
5WA2,WD2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
 COMMON /COSTIN/   AFF1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
2AFC6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,[illegible],AFI9,
3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
7GF5,GG5,CFTTAB(11),PFTTAB(11)
 COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCOML,CCOMM,
1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
2 CGT,CGTOT,CIGN,CIRJFU,      CIRJRD,      CLF,CLFL,CLGG,CLI,CLM,
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     3          CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,           PSRC0640
     4 CMV,CNOZ,CNRJFU,       CNRJRD,       CP,CPAFI,CPENG,CFL,CPLC,         PSRC0650
     5 CPMFGL,CPMFGM,CPQA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,          PSRC0660
     6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,         PSRC0670
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,           PSRC0680
     8 CTJLF,CTJLFL,CTJRD,CTJT,        CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,    PSRC0690
     9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,       PSRC0700
     A CPRB,CPLB,CIGNB,CSAB,PROFEX                                         PSRC0710
      NAMELIST /ERRPRT/ CBLC,CBMC,CCASE,CLI,CNOZ,CPRC,CPLC,CSA,CIGN,        PSRC0720
     1 CSRFU,CSRRD,CSRT                                                     PSRC0730
      ZS = WMC                                                              PSRC0740
      ZSS = DTHRT                                                           PSRC0750
      ZSSS = RNOZI                                                          PSRC0760
      ZSSSS = WM                                                            PSRC0770
      WMC = SWMC                                                            PSRC0780
      DTHRT = SDTHRT                                                        PSRC0790
      RNOZI = SRNOZI                                                        PSRC0800
      WM = SWM                                                              PSRC0810
    1 CBLC=PSA1*1.1*(PSB1/WMC)**PSC1*WMC                                    PSRC0820
    2 CBMC=1.1*PSA2*(PSB2/WMC)**PSC2*WMC                                    PSRC0830
    3 CCASE=PSA3*(CBLC+CBMC)+PSB3                                           PSRC0840
    4 CLI=PSA4*PSB4*1.1*(PSC4/DP)**PSD4*DP+PSE4                             PSRC0850
    5 CNOZ=PSA5*PSB5*3.3*WN*(PSC5+PSD5*DTHRT+PSE5*RNOZI)+PSF5               PSRC0860
    6 CPRC=PSA6*WP*(PSB6/(PSC6*WP))**PSD6*PSF6/PSE6+PSG6                    PSRC0870
    7 CPLC=PSA7*1.1*PSB7*WP*(PSC7/(PSD7*WP))**PSE7+PSF7                     PSRC0880
    8 CSA=PSA8                                                              PSRC0890
    9 CIGN=PSA9                                                             PSRC0900
   10 CSRFU=PSA10*(1.+PSPC)*(PSB10*1.15*(CCASE+CLI+CNOZ+CPRC+CPLC+CSA       PSRC0910
     1 +CIGN)+PSC10)                                                        PSRC0920
      CPFU=CSRFU                                                            PSRC0930
      PROFPR=CSRFU*PSPC/(1.+PSPC)                                           PSRC0940
   11 CSRRD=PSA11*(1.+PSPC)*(PSB11*PSC11*(D*WM)**PSD11*1.462+PSE11)         PSRC0950
      CRPS=CSRRD                                                            PSRC0960
   12 CSRT=CSRFU+CSRRD                                                      PSRC0970
      CBLC=CBLC*PSA10                                                       PSRC0980
      CBMC=CBMC*PSA10                                                       PSRC0990
      CCASE=CCASE*PSA10                                                     PSRC1000
      CLI=CLI*PSA10                                                         PSRC1010
      CNOZ=CNOZ*PSA10                                                       PSRC1020
      CPRC=CPRC*PSA10                                                       PSRC1030
      CPLC=CPLC*PSA10                                                       PSRC1040
      CSA=CSA*PSA10                                                         PSRC1050
      CIGN=CIGN*PSA10                                                       PSRC1060
      IF (IPRCST .NE. 0) WRITE (6,ERRPRT)                                   PSRC1070
      WMC = ZS                                                              PSRC1080
      DTHRT = ZSS                                                           PSRC1090
      RNOZI = ZSSS                                                          PSRC1100
      WM = ZSSSS                                                            PSRC1110
      RETURN                                                                PSRC1120
      END                                                                   PSRC1130

      SUBROUTINE PIRCST                                                     PIRC0010
C                                                                           PIRC0020
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C          INTEGRAL RAMJET PROPULSION COST
C
      REAL NOZWT,MP
      COMMON /COMVLS/ WTANK,VFXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASFM,
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG
      COMMON /COSTIN/  PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIF4,PRIA5,
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,
     3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIF19,PRIA20,
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
     7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
     BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEF6,PEA7,PEE7,PEA8,PEA9,
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSF4,
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
      COMMON /COSTIN/    PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
     4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
     5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
     6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
     7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
     8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
     9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
     APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
     BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
     CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
     DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
     E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
     FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
      COMMON /COSTIN/    PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
     1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
     2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
     3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
     4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
     5WA2,WC2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
     6KLE6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
     7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
      COMMON /COSTIN/    AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
     1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
     2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
     3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
     4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
     5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
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     6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GF5,
     7GF5,GG5,CFTTAB(11),PFTTAB(11)
      COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCCML,CCCMM,
     1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
     2 CGT,CGTOT,CIGN,CIRJFU,       CIRJRD,        CLF,CLFL,CLGG,CLI,CLM,
     3           CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
     4 CMV,CNOZ,CNRJFU,      CNRJRD,        CP,CPAFI,CPENG,CFL,CPLC,
     5 CPMFGL,CPMFGM,CPOA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
     6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRFTO,CRJC,CRMFGL,CRMFGM,CRQA,
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
     8 CTJLF,CTJLFL,CTJRD,CTJT,         CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
     9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
     A CPRB,CPLB,CIGNB,CSAB,PROFEX
      NAMELIST /ERRPRT/ CTL,CTM,CT,CEXIN,CGT,CREG,CMV,CPSN2,CPSSGG,
     1 CPSMGG,CPSRAM,CLF,CLFL,CBLC,CBMC,CLI,CNOZ,CPRC,CPLC,CIGN,CSA,
     2 CBOOC,CIRJFU,           CIRJRD,CTIRJ,CPS
      CFTU=CFTTAB(MATTK)
      PFTU=PFTTAB(MATTK)
      I=CASEM
      CFCASU=CFTTAB(I)
      PFCASU=PFTTAB(I)
      IF (CFT .NE. 0.) CFTU=CFT
      IF (PFT .NE. 0.) PFTU=PFT
      IF (CFCASE .NE. 0.) CFCASU=CFCASE
      IF (PFCASE .NE. 0.) PFCASU=PFCASE
1     CTL=1.059*PRIA1*PRIB1*CFTU*WTANK**PRIC1
2     CTM=1.059*PRIA2*PRIB2*PFTU*WTANK**PRIC2
3     CT=PRIA3*(CTL+CTM)+PRIB3
      CEXIN = 0.0
      IF ( VEXIN .EQ. 0.0 ) GO TO 9991
4     CEXIN=1.1*PRIA4*PRIB4*(PRIC4/VEXIN)**PRID4*VEXIN+PRIE4
9991  CONTINUE
      IF(KFM.NE.1) GO TO 1000
5     CGT=1.059*PRIA5*PRIB5*VREQ**PRIC5/1000.
6     CREG=PRIA6
7     CMV=PRIA7
8     CPSN2=PRIA8*(CGT+CREG+CMV)+PRIB8
1000  IF(KFM.NE.3) GO TO 2000
9     CPSSGG=1.1*PRIA9*PRIB9*(PRIC9*(PRID9/GGW)**PRIE9*GGW+PRIF9)+PRIG9
2000  IF(KFM.NE.2) GO TO 3000
10    CPSMGG=PRIA10
3000  IF(KFM.NE.4) GO TO 4000
11    CPSRAM=1.1*PRIA11*(PRIB11*(PRIC11+PRID11*HPPUMP)-PRIE11*HPPUMP
     1 **PRIF11)+PRIG11
4000  CONTINUE
      CPS=0.
      IF (KFM .EQ. 1) CPS=CPSN2
      IF (KFM .EQ. 2) CPS=CPSMGG
      IF (KFM .EQ. 3) CPS=CPSSGG
      IF (KFM .EQ. 4) CPS=CPSRAM
12    CLF=PRIA12*PRIB12*(PRIC12/WTFUEL)**PRID12*WTFUEL/1000.+PRIE12
13    CLFL=1.1*PRIA13*PRIB13*(PRIC13/WTFUEL)**PRID13*WTFUEL+PRIF13
14    CBLC=1.1*PRIA14*PRIB14*CFCASU*(PRIC14/WMC)**PRID14*WMC+PRIE14
15    CBMC=1.1*PRIA15*PRIB15*PFCASU*(PRIC15/WMC)**PRID15*WMC+PRIE15
16    CLI=1.1*PRIA16*PRIB16*(PRIC16/VBI)**PRID16*VBI+PRIE16
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17    CNOZ=1.1*PRIA17*PRIB17*(PRIC17+PRID17*2.*R5+PRIE17*Y1)*NOZWT          PIRC1130
     1 +PRIF17                                                              PIRC1140
18    CPRC=PRIA18*PRIB18/1000.*(PRIC18/MP)**PRID18*MP+PRIE18                 PIRC1150
19    CPLC=1.1*PRIA19*PRIB19*(PRIC19/MP)**PRID19*MP+PRIE19                   PIRC1160
20    CIGN=PRIA20                                                            PIRC1170
21    CSA=PRIA21                                                             PIRC1180
22    CBODC=PRIA22*(CBLC+CBMC+CLI+CNOZ+CPRC+CPLC+CIGN+CSA)+PRIB22            PIRC1190
23    CIRJFU=PRIA23*(1.+PRJC)*(1.15*PRIB23*(CT+CEXIN+CPS+CLF+CLFL+CBCOC)PIRC1200
     1 +PRIC23)                                                             PIRC1210
      CPFU=CIRJFU                                                           PIRC1220
      PROFPR=CIRJFU*PRJC/(1.+PRJC)                                          PIRC1230
26    CIRJRD=(1.+PRJC)*PRIA26*(PRIB26*1.184*PRID26*DCOM+PRIC26)             PIRC1240
      CRPS=CIRJRD                                                           PIRC1250
27    CTIRJ=CIRJFU+CIRJRD                                                   PIRC1260
      CTL=CTL*PRIA23                                                        PIRC1270
      CTM=CTM*PRIA23                                                        PIRC1280
      CT=CT*PRIA23                                                          PIRC1290
      CEXIN=CEXIN*PRIA23                                                    PIRC1300
      CGT=CGT*PRIA23                                                        PIRC1310
      CREG=CREG*PRIA23                                                      PIRC1320
      CMV=CMV*PRIA23                                                        PIRC1330
      CPSN2=CPSN2*PRIA23                                                    PIRC1340
      CPSSGG=CPSSGG*PRIA23                                                  PIRC1350
      CPSMGG=CPSMGG*PRIA23                                                  PIRC1360
      CPSRAM=CPSRAM*PRIA23                                                  PIRC1370
      CPS=CPS*PRIA23                                                        PIRC1380
      CLF=CLF*PRIA23                                                        PIRC1390
      CLFL=CLFL*PRIA23                                                      PIRC1400
      CBLC=CBLC*PRIA23                                                      PIRC1410
      CBMC=CBMC*PRIA23                                                      PIRC1420
      CLI=CLI*PRIA23                                                        PIRC1430
      CNOZ=CNOZ*PRIA23                                                      PIRC1440
      CPRC=CPRC*PRIA23                                                      PIRC1450
      CPLC=CPLC*PRIA23                                                      PIRC1460
      CIGN=CIGN*PRIA23                                                      PIRC1470
      CSA=CSA*PRIA23                                                        PIRC1480
      CBODC=CBODC*PRIA23                                                    PIRC1490
      IF (IPRCST .NE. C) WRITE (6,ERRPRT)                                   PIRC1500
      RETURN                                                                PIRC1510
      END                                                                   PIRC1520

      SUBROUTINE PNRCST                                                     PNRC0010
C                                                                           PNRC0020
C         NON-INTEGRAL RAMJET SUSTAINER PROPULSION COST                     PNRC0030
C                                                                           PNRC0040
      REAL NOZWT,MP                                                         PNRC0050
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCCMM,VCOMI,       PNRC0060
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNDZI,NCZWT,MP,CASFM,      PNRC0070
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDFT,CA,WCS,       PNRC0080
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG                 PNRC0090
      COMMON /COSTIN/   PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,     PNRC0100
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,      PNRC0110
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIF15,PRIA16,       PNRC0120
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3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,
4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
7PRNA12,PRNB12,PRNE12,PRNA13,PRNE13,PRNA14,PRNE14,PRNA15,PRNA16,
8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
BPLB15,PLE15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,
FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,
GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
 COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRID11,PRIE11,
2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
4PRIE17,PRIC18,PRID18,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
 COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
5WA2,WD2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
6KLF6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
 COMMON /COSTIN/   AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
7GF5,GG5,CFTTAB(11),PFTTAB(11)
 COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCCMI,CCOML,CCOMM,
1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
2 CGT,CGTOT,CIGN,CIRJFU,        CIRJRD,          CLF,CLFL,CLGG,CLI,CLM,
3           CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
4 CMV,CNOZ,CNRJFU,        CNRJRD,         CP,CPAFI,CPENG,CPL,CPLC,
5 CPMFGL,CPMFGM,CPOA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRETO,CRJC,CRMFGL,CRMFGM,CROA,
7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
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      8 CTJLF,CTJLFL,CTJRD,CTJT,         CTL,CTM,CTNRJ,CTP,CWF,CWHFU,CWHR,
      9 CBODC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNCZB,
      A CPRB,CPLB,CIGNB,CSAB,PROFEX
        NAMELIST /ERRPRT/ CTL,CTM,CT,CEXIN,CGT,CREG,CMV,CPSN2,CPSSGG,
      1 CPSMGG,CPSRAM,CLF,CLFL,CCOML,CCOMM,CCOMI,CNOZ,CRJC,CNRJFU,
      2                  CNRJRD,CTNRJ,CPS
        CFTU=CFTTAB(MATTK)
        PFTU=PFTTAB(MATTK)
        I=CASEM
        CFCU=CFTTAB(I)
        PFCU=PFTTAB(I)
        IF (CFT .NE. 0.) CFTU=CFT
        IF (PFT .NE. 0.) PFTU=PFT
        IF (CFC .NE. 0.) CFCU=CFC
        IF (PFC .NE. 0.) PFCU=PFC
1       CTL=1.059*PRNA1*PRNB1*CFTU*WTANK**PRNC1
2       CTM=1.059*PRNA2*PRNB2*PFTU*WTANK**PRNC2
3       CT=PRNA3*(CTL+CTM)+PRNB3
        CEXIN = 0.0
        IF ( VEXIN .EQ. 0.0 ) GO TO 9991
4       CEXIN=1.1*PRNA4*PRNB4*(PRNC4/VEXIN)**PRND4*VEXIN+PRNE4
9991    CONTINUE
        IF(KFM.NE.1) GO TO 1000
5       CGT=1.059*PRNA5*PRNB5*VREQ**PRNC5/1000.
6       CREG=PRNA6
7       CMV=PRNA7
8       CPSN2=PRNA8*(CGT+CREG+CMV)+PRNB8
1000    IF(KFM.NE.3) GO TO 2000
9       CPSSGG=1.1*PRNA9*PRNB9*(PRNC9*(PRND9/GGW)**PRNE9*GGW+PRNF9)+PRNG9
2000    IF(KFM.NE.2) GO TO 3000
10      CPSMGG=PRNA10
3000    IF(KFM.NE.4) GO TO 4000
11      CPSRAM=1.1*PRNA11*(PRNB11*(PRNC11+PRND11*HPPUMP)-PRNE11*HPPUMP
      1 **PRNF11)+PRNG11
4000    CONTINUE
        CPS=0.
        IF (KFM .EQ. 1) CPS=CPSN2
        IF (KFM .EQ. 2) CPS=CPSMGG
        IF (KFM .EQ. 3) CPS=CPSSGG
        IF (KFM .EQ. 4) CPS=CPSRAM
12      CLF=PRNA12*PRNB12*(PRNC12/WTFUEL)**PRND12*WTFUEL/1000.+PRNE12
13      CLFL=1.1*PRNA13*PRNB13*(PRNC13/WTFUEL)**PRND13*WTFUEL+PRNE13
14      CCOML=PRNA14*PRNB14*1.1*CFCU*(PRNC14/WCOMM)**PRND14*WCOMM
15      CCOMM=1.1*PRNA15*PRNB15*PFCU*(PRNC15/WCOMM)**PRND15*WCOMM
16      CCOMI=1.1*PRNA16*PRNB16*(PRNC16/VCOMI)**PRND16*VCOMI
17      CNOZ=1.1*PRNA17*PRNB17*(PRNC17+PRND17*R5+PRNE17*Y1)*WNOZ
18      CRJC=PRNA18*(CCOML+CCOMM+CCOMI+CNOZ)+PRNB18
19      CNRJFU=PRNA19*(1.+PRJC)*(1.15*PRNB19*(CT+CEXIN+CPS+CLF+CLFL+CRJC)
      1 +PRNC19)
        CPFU=CNRJFU
        PROFPR=CNRJFU*PRJC/(1.+PRJC)
22      CNRJRD=(1.+PRJC)*PRNA22*(PRNB22*1.184*PRND22*DCOM+PRNC22)
        CRPS=CNRJRD
23      CTNRJ=CNRJFU+CNRJRD
        CTL=CTL*PRNA19
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      CT=CT*PRNA19
      CEXIN=CEXIN*PRNA19
      CGT=CGT*PRNA19
      CREG=CREG*PRNA19
      CMV=CMV*PRNA19
      CPSN2=CPSN2*PRNA19
      CPSSGG=CPSSGG*PRNA19
      CPSMGG=CPSMGG*PRNA19
      CPSRAM=CPSRAM*PRNA19
      CPS=CPS*PRNA19
      CLF=CLF*PRNA19
      CLFL=CLFL*PRNA19
      CCOML=CCOML*PRNA19
      CCOMM=CCOMM*PRNA19
      CCOMI=CCOMI*PRNA19
      CNOZ=CNOZ*PRNA19
      CRJC=CRJC*PRNA19
      IF (IPRCST .NE. 0) WRITE (6,ERRPRT)
      RETURN
      END


      SUBROUTINE PTJCST
C
C         TURBOJET PROPULSION COST
C
      REAL NOZWT,MP
      COMMON /COMVLS/ WTANK,VEXIN,VREQ,GGW,HPPUMP,WTFUEL,WCOMM,VCOMI,
     1 R5,Y1,WNOZ,KFM,MATTK,A,DCOM,WMC,VBI,DTHRT,RNOZI,NOZWT,MP,CASEM,
     2 FNET,WT,WF,FMAX,S,T4,METTJ,ZXNB,D,WM,FC,PPEAK,BSP,NDET,QA,WCS,
     3 WWH,WTC,WTP,WGG,WSC,WLV,VGT,WO,WP,DP,WN,METAL,NCONFG
      COMMON /COSTIN/   PRIA1,PRIA2,PRJC,PRIA3,PRIB3,PRIA4,PRIE4,PRIA5,
     1PRIA6,PRIA7,PRIA8,PRIB8,PRIA9,PRIG9,PRIA10,PRIA11,PRIG11,PRIA12,
     2PRIB12,PRIE12,PRIA13,PRIE13,PRIA14,PRIE14,PRIA15,PRIE15,PRIA16,
     3PRIE16,PRIA17,PRIF17,PRIA18,PRIB18,PRIE18,PRIA19,PRIE19,PRIA20,
     4PRIA21,PRIA22,PRIB22,PRIA23,PRIB23,PRIC23,PRIA24,PRIC24,PRIA25,
     5PRIB25,PRIA26,PRIB26,PRIC26,PRNA1,PRNA2,PRNA3,PRNB3,PRNA4,PRNE4,
     6PRNA5,PRNA6,PRNA7,PRNA8,PRNB8,PRNA9,PRNG9,PRNA10,PRNA11,PRNG11,
     7PRNA12,PRNB12,PRNE12,PRNA13,PRNF13,PRNA14,PRNE14,PRNA15,PRNA16,
     8PRNA17,PRNA18,PRNB18,PRNA19,PRNB19,PRNC19,PRNA20,PRNC20,PRNA21,
     9PRNB21,PRNA22,PRNB22,PRNC22,PLPC,PLA1,PLA3,PLB3,PLA4,PLA6,PLA8,
     APLB8,PLA9,PLA11,PLB11,PLA13,PLB13,PLC13,PLD13,PLA14,PLD14,PLA15,
     BPLB15,PLF15,PLF15,PLA16,PLE16,PLA17,PLA18,PLB18,PLC18,PLA19,PLA20,
     CPLB20,PLA21,PLB21,PLC21,PTA1,PTD1,PTA4,PTB4,PTA5,PTB5,PTE5,PTA6,
     DPTE6,PTA7,PTB7,PTC7,PTJC,PTA8,PTD8,PTA9,PTB9,PTA10,PTB10,PTC10,
     EPEA3,PEB3,PEA4,PEE4,PEA5,PEF5,PEA6,PEB6,PEE6,PEA7,PEE7,PEA8,PEA9,
     FPEA10,PEB10,PEC10,PEA11,PEB11,PEE11,PEBC,PSPC,PSA3,PSB3,PSA4,PSE4,
     GPSA5,PSF5,PSA6,PSF6,PSG6,PSA7,PSF7,PSA8,PSA9,PSA10,PSB10,PSC10,
     HPSA11,PSB11,PSE11,CFT,PFT,CFCASE,PFCASE,CFC,PFC,CFM,PFM,IYEAR
      COMMON /COSTIN/   PRIB1,PRIC1,PRIB2,PRIC2,PRIB4,PRIC4,PRID4,PRIB5,
     1PRIC5,PRIB9,PRIC9,PRID9,PRIE9,PRIF9,PRIB11,PRIC11,PRIC11,PRIF11,
     2PRIF11,PRIC12,PRID12,PRIB13,PRIC13,PRID13,PRIB14,PRIC14,PRID14,
     3PRIB15,PRIC15,PRID15,PRIB16,PRIC16,PRID16,PRIB17,PRIC17,PRID17,
     4PRIF17,PRIC18,PRID19,PRIB19,PRIC19,PRID19,PRIB24,PRNB1,PRNC1,PRNB2
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     5,PRNC2,PRNB4,PRNC4,PRND4,PRNB5,PRNC5,PRNB9,PRNC9,PRND9,PRNE9,PRNF9
     6,PRNB11,PRNC11,PRND11,PRNE11,PRNF11,PRNC12,PRND12,PRNB13,PRNC13,
     7PRND13,PRNB14,PRNC14,PRND14,PRNB15,PRNC15,PRND15,PRNB16,PRNC16,
     8PRND16,PRNB17,PRNC17,PRND17,PRNE17,PRNB20,PLB1,PLC1,PLA2,PLB2,PLB4
     9,PLC4,PLA5,PLB5,PLB6,PLC6,PLA7,PLB7,PLB9,PLC9,PLA10,PLB10,PLA12,
     APLB12,PLB14,PLC14,PLC15,PLD15,PLB16,PLC16,PLD16,PLB19,PLC19,PTB1,
     BPTC1,PTA2,PTB2,PTA3,PTB3,PTC5,PTD5,PTB6,PTC6,PTD6,PTB8,PTC8,PEA1,
     CPEB1,PEC1,PEA2,PEB2,PEC2,PEB4,PEC4,PED4,PEB5,PEC5,PED5,PEE5,PEC6,
     DPED6,PEB7,PEC7,PED7,PEC11,PED11,PSA1,PSB1,PSC1,PSA2,PSB2,PSC2,PSB4
     E,PSC4,PSD4,PSB5,PSC5,PSD5,PSE5,PSB6,PSC6,PSD6,PSE6,PSB7,PSC7,PSD7,
     FPSE7,PSC11,PSD11,PRND22,PLD21,PLE21,PTD10,PTE10,PRID26
      COMMON /COSTIN/   PROFIT,QD,R,AFA1,AFB1,AFC1,AFD1,AFI1,AFA2,AFB2,
     1AFG2,AFA3,AFB3,AFG3,AFA4,AFB4,AFC4,AFD4,AFJ4,AFA5,AFB5,AFC5,AFH5,
     2AFA6,AFB6,AFG6,AFA7,AFC7,AFD7,AFA8,AFB8,AFC8,AFD8,AFI8,AFA9,AFB9,
     3AFC9,AFD9,AFJ9,AFA10,AFB10,AFC10,AFH10,AFA11,AFB11,AFG11,AFA12,
     4AFC12,AFD12,AFA13,AFB13,AFC13,AFA14,AFB14,AFC14,KFUZE,WA1,WE1,WF1,
     5WA2,WD2,WE2,KGAIN,CA1,CE1,CF1,CA2,CE2,CF2,CA3,CE3,CF3,GA1,GB1,GF1,
     6KLF6,KGT6,KSTAB,KAGATE,NCHAN,KSGATE,GA2,GB2,GK2,GA3,GB3,GQ3,GA4,
     7GB4,GM4,GA5,GB5,GH5,KG,KC,KW,KA,KP,IGTYPE,ICTYPE,IPRCST
      COMMON /COSTIN/   AFE1,AFF1,AFG1,AFH1,AFC2,AFD2,AFE2,AFF2,AFC3,
     1AFD3,AFE3,AFF3,AFE4,AFF4,AFG4,AFH4,AFI4,AFD5,AFE5,AFF5,AFG5,AFC6,
     2AFD6,AFE6,AFF6,AFB7,AFE8,AFF8,AFG8,AFH8,AFE9,AFF9,AFG9,AFH9,AFI9,
     3AFD10,AFE10,AFF10,AFG10,AFC11,AFD11,AFE11,AFF11,AFB12,WB1,WC1,WD1,
     4WB2,WC2,CB1,CC1,CD1,CB2,CC2,CD2,CB3,CC3,CD3,GC1,GD1,GE1,GC2,GD2,
     5GE2,GF2,GG2,GH2,GI2,GJ2,GC3,GD3,GE3,GF3,GG3,GH3,GI3,GJ3,GK3,GL3,
     6GM3,GN3,GP3,GC4,GD4,GE4,GF4,GG4,GH4,GI4,GJ4,GK4,GL4,GC5,GD5,GE5,
     7GF5,GG5,CFTTAB(11),PFTTAB(11)
      COMMON /CSTPRV/ CBLC,CBMC,CCASE,CCFU,CCL,CCM,CCOMI,CCOML,CCOMM,
     1 CCONT,CCRD,CEBFU,CEBRD,CETJ,CEXIN,CGFU,CGRD,
     2 CGT,CGTOT,CIGN,CIRJFU,      CIRJRD,      CLF,CLFL,CLGG,CLI,CLM,
     3             CLRFU,CLRRD,CLRT,CLTC,CLTP,CM,CMGG,CMM,CMTC,CMTP,
     4 CMV,CNOZ,CNRJFU,      CNRJRD,      CP,CPAFI,CPENG,CPL,CPLC,
     5 CPMFGL,CPMFGM,CPOA,CPR,CPRC,CPS,CPSMGG,CPSN2,CPSRAM,CPSSGG,
     6 CPTOOL,CRAFI,CRDEV,CREG,CRENG,CRETO,CRJC,CRMFGL,CRMFGM,CRQA,
     7 CRTOOL,CSA,CSRFU,CSRRD,CSRT,CT,CTAFI,CTC,CTEB,CTIRJ,CTJFU,
     8 CTJLF,CTJLFL,CTJRD,CTJT,      CTL,CTM,CTNRJ,CTP,CWH,CWHFU,CWHR,
     9 CBOOC,CRPS,CPFU,PROFPR,PRFUAF,PRRAF,CCLB,CCMB,CTCB,CLIB,CNOZB,
     A CPRB,CPLB,CIGNB,CSAB,PROFEX
      DIMENSION CFTARY(3),PFTARY(3)
      NAMELIST /ERRPRT/ CETJ,CTL,CTM,CT,CTJLF,CTJLFL,CTJFU,
     1         CTJRD,CTJT
      DATA CFTARY/.2,1.,1./
      DATA PFTARY/.257,2.571,1./
      CFTU=CFTARY(METTJ)
      PFTU=PFTARY(METTJ)
      PTB1U=1.52
      PTC1U=.6
      IF (T4 .GE. 2060.) PTB1U=3.08
      IF (T4 .GT. 2360.) PTB1U=5.64
      IF (CFT .NE. 0.) CFTU=CFT
      IF (PFT .NE. 0.) PFTU=PFT
      IF (PTB1 .NE. 0.) PTB1U=PTB1
      IF (PTC1 .NE. 0.) PTC1U=PTC1
1     CETJ=PTA1*PTB1U*FNET**PTC1U*1.222+PTD1
2     CTL=1.059*PTA2*CFTU*WT**PTB2
```

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3     CTM=1.059*PTA3*PFTU*WT**PTB3                                      PTJC0880
4     CT=PTA4*(CTL+CTM)+PTB4                                            PTJC0890
5     CTJLF=PTA5*PTB5*(PTC5/WF)**PTD5*WF/1000.+PTE5                     PTJC0900
6     CTJLFL=1.1*PTA6*PTB6*(PTC6/WF)**PTD6*WF+PTE6                      PTJC0910
7     CTJFU=PTA7*(1.+PTJC)*(1.15*PTB7*(CFTJ+CT+CTJLF+CTJLFL)+PTC7)      PTJC0920
      CPFU=CTJFU                                                        PTJC0930
      PROFPR=CTJFU*PTJC/(1.+PTJC)                                       PTJC0940
10    CTJRD=PTA10*(PTB10*1.462*PTD10*FMAX**PTE10+PTC10)*(1.+PTJC)       PTJC0950
      CRPS=CTJRD                                                        PTJC0960
11    CTJT=CTJFU+CTJRD                                                  PTJC0970
      CFTJ=CFTJ*PTA7                                                    PTJC0980
      CTL=CTL*PTA7                                                      PTJC0990
      CTM=CTM*PTA7                                                      PTJC1000
      CT=CT*PTA7                                                        PTJC1010
      CTJLF=CTJLF*PTA7                                                  PTJC1020
      CTJLFL=CTJLFL*PTA7                                                PTJC1030
      IF (IPRCST .NE. 0) WRITE (6,ERRPRT)                               PTJC1040
      RETURN                                                            PTJC1050
      END                                                               PTJC1060
```

Table 1. Module Index