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**INDEPENDENT PRODUCTION COST ESTIMATE:
XMI TANK MAIN ARMAMENT EVALUATION.**

11 NOV ~~1977~~

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TECHNICAL REPORT

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ABSTRACT

➤ Parametric estimating of the recurring investment costs for tank main armament systems has recently been improved with new modeling techniques, as well as with an improved data base. This report illustrates the use of such estimating techniques as prepared for the XM1 Tank Main Armament Evaluation (TMAE). It also expands parametric estimating techniques to white phosphorous (WP), antipersonnel (APERS), and target practice discarding sabot (TPDS) rounds.

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INDEPENDENT PRODUCTION COST ESTIMATE:

XMI TANK MAIN ARMAMENT EVALUATION

November 1977

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I. INTRODUCTION

A. Purpose:

Independent As discussed in reference 12, the requirement for an Independent Unit Production Cost (IUPC) was first presented to DRSAR-CPE by informal tasking, 26 Sep 77. The purpose of the IUPC is to provide a test of reasonableness for the engineering cost estimates included in the Cost, Schedule, Logistics, and Standardization (CSLS) impact portion of the XM1 tank main armament evaluation (TMAE) for the XM1 Project Manager. As a test of reasonableness, maximum reliance is placed upon use of parametric estimating techniques. The parametric procedures used emphasize the interrelation between US design philosophy and manufacturing cost. No adjustment has been made to compensate for such differences between the various options, thus the costs can be said to represent Americanized versions of the foreign guns and ammunition for the 120mm options. Reference 1 is used to estimate ammunition parametrically. Where data are available, current production experience is used. Only four of the 24 rounds were not estimated parametrically. The M68 cannon and breech assembly were provided at latest funded cost. The two remaining weapons were estimated parametrically using the data base provided with reference 3.

B. Scope:

CONT.

→ The options covered in this study are: the US option using the 105mm M68 gun, the United Kingdom's ~~(UK)~~ 120mm rifled gun, and the Federal Republic of Germany's GE 120mm smoothbore gun. Each gun is furnished an appropriate family of ammunition. The scope of the weapon ~~IUPC~~ is limited to the recurring unit manufacturing cost of the cannon and breech assemblies including engineering and product assurance support, but excluding first destination transportation. The ammunition cost excludes the cost of Government engineering and quality assurance support, but includes first destination transportation. ←

C. Organization of the Study:

The study results at the summary level are shown and discussed in Section II. The detailed input data in support of the summary are at Section III. Finally, detailed discussion of estimating methodology is provided in Section IV. Unless otherwise noted, all costs are stated in FY 77 dollars.

D. Acknowledgements:

This study could not have been completed without the suggestions and assistance provided by the following individuals. Mrs. Marcia Waldron was responsible for the typing of most of the study, and her meticulous attention to detail and precise rendering of complicated formulas was greatly appreciated. Mrs. Ellen Trollan, Mrs. Paula Gomez, and Mrs. Marlene Manning provided additional typing and clerical support, without which the study could not have been completed.

II. STUDY RESULTS

A. Tables.

Tables 2 through 6 contain study results.

TABLE 1

XM1 TANK MAIN ARMAMENT EVALUATION

| | GUN AVERAGE UNIT COSTS FY 77 \$ |
|-----------------|--|
| UK 120mm | \$ 21,600 |
| GE 120mm | \$ 22,400 |
| US 105mm | \$ 14,500 * |

* US cost based on most recent funded order.

Gun costs rounded to nearest hundred dollars.

TABLE 2

XM1 TANK MAIN ARMAMENT EVALUATION
 COMPLETE ROUND AVERAGE UNIT COSTS FY 77 \$

UK 120MM

| <u>PRODUCTION ENDING AS OF YEAR</u> | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|---|----------------------------|----------------------------|-----------------|----------------------------|---------------|--------------|
| 1983 | \$213 | \$412 | ----- | ----- | \$222 | \$143 |
| 1985 | 198 | 405 | \$167 | \$597 | 215 | 123 |
| 1994 | 186 | 401 | 153 | 524 | 210 | 109 |
| 2007 | (No production after 1994) | (No production after 1994) | 148 | (No production after 1994) | 209 | 105 |

Costs rounded to nearest dollar.

TABLE 3

XM1 TANK MAIN ARMAMENT EVALUATION

COMPLETE ROUND AVERAGE UNIT COSTS FY 77 \$

GE 120MM

| <u>PRODUCTION ENDING AS OF YEAR</u> | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|---|----------------------------|---------------|-----------------|----------------------------|---------------|--------------|
| 1983 | \$214 | \$424 | ----- | ----- | \$225 | \$139 |
| 1985 | 198 | 417 | \$167 | \$597 | 219 | 119 |
| 1994 | 185 | 412 | 153 | 524 | 214 | 105 |
| 2007 | (No production after 1994) | | 148 | (No production after 1994) | 213 | 101 |

Costs rounded to nearest dollar.

TABLE 4
 XMI TANK MAIN ARMAMENT EVALUATION
 COMPLETE ROUND AVERAGE UNIT COSTS FY 77 \$
 US ONLY 105MM

| <u>PRODUCTION ENDING AS OF YEAR</u> | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|---|----------------------------|---------------|-----------------|----------------------------|---------------|--------------|
| 1983 | \$144 | \$270 | \$125 * | \$370 * | \$169 | \$90 |
| 1985 | 137 | 267 | 125 * | 370 * | 167 | 84 |
| 1994 | 133 | 265 | 125 * | 370 * | 165 | 78 |
| 2007 | (No production after 1994) | | 125 * | (No production after 1994) | 163 | 76 |

* Latest procurement costs adjusted to FY 77 \$.
 Costs rounded to nearest dollar.

TABLE 5

XMI TANK MAIN ARMAMENT EVALUATION
 COMPLETE ROUND AVERAGE UNIT COSTS FY 77 \$
 US PHASEOUT 105MM

| <u>PRODUCTION ENDING AS OF YEAR</u> | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|---|-----------|---------------|-----------------|--------------|---------------|--------------|
| 1983 | \$148 | \$270 | \$125 * | ---- | \$170 | \$90 |
| 1985 | 141 | 268 | 125 * | ---- | 168 | 86 |
| 1994 | 138 | 267 | 125 * | ---- | 167 | 83 |
| 2007 | | | | | | |

(No production after 1994)

* Latest procurement costs adjusted to FY 77 \$.
 Costs rounded to nearest dollar.

TABLE 6

XM1 TANK MAIN ARMAMENT EVALUATION

TOTAL AMMUNITION COST PER OPTION FY 77 \$ IN MILLIONS

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> | <u>TOTAL</u> |
|-----------|-------------|---------------|-----------------|--------------|---------------|--------------|--------------|
| <u>US</u> | | | | | | | |
| 105MM | \$125.3 | \$270.9 | \$65.5 | \$ 5.5 | \$1160.3 | \$ 948.8 | \$2576.3 |
| <u>UK</u> | | | | | | | |
| 120MM | \$175.5 | \$486.3 | \$81.6 | \$18.8 | \$1208.1 | \$1073.3 | |
| 105MM | <u>61.9</u> | <u>103.5</u> | <u>8.7</u> | ---- | <u>385.5</u> | <u>108.0</u> | |
| Total | \$237.4 | \$589.8 | \$90.3 | \$18.8 | \$1593.6 | \$1181.3 | \$3711.2 |
| <u>GE</u> | | | | | | | |
| 120MM | \$174.9 | \$500.6 | \$81.6 | \$18.8 | \$1230.7 | \$1031.7 | |
| 105MM | <u>61.9</u> | <u>103.5</u> | <u>8.7</u> | ---- | <u>385.5</u> | <u>108.0</u> | |
| Total | \$236.8 | \$604.1 | \$90.3 | \$18.8 | \$1616.2 | \$1139.7 | \$3705.9 |

B. Discussion of the Results

1. General:

a. The unit costs shown in Table 1 indicate that the greater weight of the 120mm GE cannon and breech assembly overbalances the effects of the higher momentum levels generated by the UK ammunition.

b. Overall, the differences between the two 120mm ammunition options are insignificant. The UK multipurpose and matched practice rounds cost slightly more than the GE equivalents because of higher propellant and transportation costs. The GE APFSDS round offsets this however, because of the use of a heavier penetrator.

2. A number of potential conditions in the ammunition estimates require sensitivity analysis. They are: inflation of tungsten prices, design of the multipurpose round, use of stick vs granular propellant, and use of a DU penetrator rather than tungsten for the 120mm options.

a. Inflation of Tungsten Prices - The 1.17 inflator provided in the referenced inflation guidance (references 4 and 5) understates the inflation of tungsten prices that has actually taken place since FY 75. The reference 1 FY 75 cost of \$10.73, when compared to a FY 77 quote of \$13.75 received by LCWSL, results in a more correct inflator of 1.28.

The effect this has on the APFSDS round is as follows:

(1) The German 120mm APFSDS.

| | <u>Proj. Metal Parts</u> | <u>Total Round</u> | <u>Total Program</u> |
|---------------|--------------------------|--------------------|----------------------|
| Adjusted Est. | \$246.089 | \$432.863 | \$629.0M |
| Original Est. | 225.619 | 412.393 | 604.1M |
| % Increase | 9.1% | 5.0% | 4.1% |

(2) The British 120mm APFSDS.

| | <u>Proj. Metal Parts</u> | <u>Total Round</u> | <u>Total Program</u> |
|---------------|--------------------------|--------------------|----------------------|
| Adjusted Est. | \$231.841 | \$419.895 | \$613.3M |
| Original Est. | 212.556 | 400.610 | 589.8M |
| % Increase | 9.1% | 4.8% | 4.0% |

b. Design of the Multipurpose Round - This round may incur cost increases resulting from designs still under consideration which will effect the cost of explosive fill and LAP. The resulting increases could accumulate to 25 percent and are as follows:

| | <u>US 105mm</u> | <u>UK 120mm</u> | <u>GE 120mm</u> |
|------------------------|-----------------|-----------------|-----------------|
| Estimated unit cost | \$132.630 | \$186.101 | \$185.436 |
| plus 25 percent | 33.158 | 46.525 | 46.359 |
| New unit cost | \$165.788 | \$232.626 | \$231.795 |
| Total program increase | \$156.7 million | \$219.4 million | \$218.6 million |

c. Use of Stick vs Granular Propellant - In order to retain the ballistic integrity of the German 120mm MP and MP-TP rounds, personnel at LCWSL agree that the stick propellant should be used instead of granular propellant. The parametric estimating relationships used in this study consider only granular propellant. Once the manufacturing process for stick propellant has been established in country and stabilized (12-18 months), the stick propellant should be about 50 percent more expensive than the average M30 granular propellant. Current estimated unit costs for these rounds are:

| | | |
|-------------|-----------|--------------|
| | <u>MP</u> | <u>TP-MP</u> |
| Total round | \$185.436 | \$100.615 |
| Propellant | 25.732 | 21.784 |

Increasing the total round unit cost by adding 50 percent more cost for propellant changes the above costs as follows:

| | | |
|------------------------|-----------------|-----------------|
| | <u>MP</u> | <u>TP-MP</u> |
| Total round | \$198.302 | \$111.507 |
| % Increase | 6.9% | 10.8% |
| Total program increase | \$ 12.1 million | \$111.7 million |

d. Use of DU Penetrators for the 120mm Options - The use of tungsten alloy penetrators in the APFSDS round is significantly more costly than DU penetrators. Thus, the extra cost of the two 120mm options may be falsely attributed to bore size change when compared to the cost of the 105mm DU APFSDS round. This is shown below:

| | | |
|--------------|-----------------|-----------------|
| | <u>UK 120mm</u> | <u>GE 120mm</u> |
| Tungsten | \$400.610 | \$412.393 |
| DU | 334.479 | 342.199 |
| % Difference | 19.8% | 20.5% |

Using the DU penetrator rather than tungsten penetrator would produce lower program costs as follows:

| | |
|-----------------------|-------------------------|
| For the German round | \$85.2 million decrease |
| For the British round | \$80.3 million decrease |

Use of a 120mm DU penetrator reduces the cost advantage attributable to the 105mm option as follows:

| | | |
|----|-------------------------------------|-----------|
| | <u>120MM</u> | |
| | <u>Increased Cost From 105mm DU</u> | |
| | <u>Tungsten</u> | <u>DU</u> |
| UK | 51% | 26% |
| GE | 56% | 29% |

III. SUPPLEMENTAL DATA

Supplemental data pertaining to production schedules and requirements, independent variables, and average unit costs follow in Tables 7 through 26 inclusive.

NOTE: A component cost breakout for the US APFSDS round will be provided later in a classified annex.

PRODUCTION SCHEDULES AND REQUIREMENTS

TABLE 7
 AMMUNITION PRODUCTION SCHEDULES

YEAR END CUMULATIVE TOTALS IN THOUSANDS

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|-------------|-----------|---------------|-----------------|--------------|---------------|--------------|
| US Only | | | | | | |
| 1983 | 189.0 | 204.6 | 13.0 | 3.0 | 284.0 | 503.0 |
| 1985 | 567.0 | 613.8 | 39.0 | 9.0 | 852.0 | 1509.0 |
| 1994 | 945.0 | 1023.0 | 226.0 | 15.0 | 3408.0 | 6036.0 |
| 2007 | ----- | ----- | 525.0 | ----- | 7100.0 | 12575.0 |
| US Phaseout | | | | | | |
| 1983 | 90.0 | 77.6 | 8.0 | ----- | 271.0 | 480.0 |
| 1985 | 270.0 | 232.8 | 24.0 | ----- | 665.0 | 1178.0 |
| 1994 | 450.0 | 388.0 | 70.0 | ----- | 1307.0 | 2315.0 |
| 2007 | ----- | ----- | ----- | ----- | ----- | ----- |
| UK/GE | | | | | | |
| 1983 | 98.0 | 127.0 | ----- | ----- | 13.0 | 23.0 |
| 1985 | 294.0 | 381.0 | 46.0 | 10.0 | 186.0 | 330.0 |
| 1994 | 943.0 | 1214.0 | 253.0 | 36.0 | 2097.0 | 3715.0 |
| 2007 | ----- | ----- | 552.0 | ----- | 5789.0 | 10254.0 |

TABLE 8
COMPONENT REQUIREMENTS

YEAR END CUMULATIVE TOTALS IN THOUSANDS

| | <u>UK/GE</u> | <u>US ONLY</u> | <u>US PHASEOUT</u> |
|------------------------|--------------|----------------|--------------------|
| LAP/Projectiles | | | |
| MP | | | |
| 1983 | 98.0 | 189.0 | 90.0 |
| 1985 | 294.0 | 567.0 | 270.0 |
| 1994 | 943.0 | 945.0 | 450.0 |
| 2007 | ----- | ----- | ----- |
| APFSDS | | | |
| 1983 | 127.0 | 204.6 | 77.6 |
| 1985 | 381.0 | 613.8 | 232.8 |
| 1994 | 1214.0 | 1023.0 | 388.0 |
| 2007 | ----- | ----- | ----- |
| WP/SMOKE | | | |
| 1983 | ----- | 13.0 | 8.0 |
| 1985 | 46.0 | 39.0 | 24.0 |
| 1994 | 253.0 | 226.0 | 70.0 |
| 2007 | 552.0 | 525.0 | ----- |
| APERS | | | |
| 1983 | ----- | 3.0 | ----- |
| 1985 | 10.0 | 9.0 | ----- |
| 1994 | 36.0 | 15.0 | ----- |
| 2007 | ----- | ----- | ----- |
| TPFSDS | | | |
| 1983 | 13.0 | 284.0 | 271.0 |
| 1985 | 186.0 | 852.0 | 665.0 |
| 1994 | 2097.0 | 3408.0 | 1307.0 |
| 2007 | 5789.0 | 7100.0 | ----- |
| MP-TP | | | |
| 1983 | 23.0 | 503.0 | 480.0 |
| 1985 | 330.0 | 1509.0 | 1178.0 |
| 1994 | 3715.0 | 6036.0 | 2315.0 |
| 2007 | 10254.0 | 12575.0 | ----- |

TABLE 8 Cont'd

| | <u>UK/GE</u> | <u>US ONLY</u> | <u>US PHASEOUT</u> |
|-------------------------------|--------------|----------------|--------------------|
| Cases/Electric Primers | | | |
| 1983 | 261.0 | 1196.6 | 926.6 |
| 1985 | 1247.0 | 3589.8 | 2369.8 |
| 1994 | 8258.0 | 11653.0 | 4530.0 |
| 2007 | 18788.0 | 22183.0 | ----- |
| Fuzes | | | |
| PIBD (MP) | | | |
| 1983 | 98.0 | 189.0 | 90.0 |
| 1985 | 294.0 | 567.0 | 270.0 |
| 1994 | 943.0 | 945.0 | 450.0 |
| 2007 | ----- | ----- | ----- |
| PD (WP/SMOKE) | | | |
| 1983 | ----- | 13.0 | 8.0 |
| 1985 | 46.0 | 39.0 | 24.0 |
| 1994 | 253.0 | 226.0 | 70.0 |
| 2007 | 552.0 | 525.0 | ----- |
| MT (APERS) | | | |
| 1983 | ----- | 3.0 | ----- |
| 1985 | 10.0 | 9.0 | ----- |
| 1994 | 36.0 | 15.0 | ----- |
| 2007 | ----- | ----- | ----- |

INDEPENDENT VARIABLES

TABLE 9

TANK AMMUNITION STUDY
COUNTRY UK

| BORE SIZE | 120MM | | | | | | | | | | |
|-----------|-------|---------------------|-----------------------|---------------------|---------------|------------------------------|--------------------|----------------------------------|---------------------------------|-----------|--|
| TYPE | STAB | IN-BORE WT (lbs) | IN-FLIGHT WT (lbs) | PENETRATOR MAT'L | CASE MAT'L | MUZZLE VELOCITY ft/sec | MASS ^{1/} | MUZZLE ^{2/} MOMENTUM | KINETIC ^{3/} ENERGY | | |
| MP | Fin | 32.0 | 32.0 | Tu | COMBUSTIBLE | 3845 | .9938 | 3821.12 | 7,346,099 | | |
| MP-TP | Fin | 25.68 | 25.68 | Tu | COMBUSTIBLE | 3800 | .7975 | 3030.56 | 5,758,062 | | |
| WP/SMOKE | Spin | 32.5 | 32.5 | Tu | COMBUSTIBLE | 2400 | 1.0093 | 2422.36 | 2,906,832 | | |
| APERS | Spin | 39.65 | 39.65 | Tu | COMBUSTIBLE | 2700 | 1.2314 | 3324.69 | 4,488,331 | | |
| APFSDS | Fin | 17.5 | 9.8 | Tu | COMBUSTIBLE | 5230 | .5435 | 2842.39 | 7,432,853 | In Bore | |
| TPFSDS | Fin | 13.52 | 7.54 | Tu | COMBUSTIBLE | 5000 | .3043 | 1591.74 | 4,162,398 | In Flight | |
| | | | | | | | .4199 | 2099.38 | 5,248,447 | In Bore | |
| | | | | | | | .2342 | 1170.81 | 2,927,019 | In Flight | |

All rounds have electric primers.

^{1/} Mass is that value determined by dividing projectile weight by the force of gravity, which is 32.2 feet per second per second.

^{2/} Muzzle Momentum is a product of projectile mass and muzzle velocity.

^{3/} Kinetic Energy is the product of muzzle velocity squared and 1/2 the mass.

TABLE 10
TANK AMMUNITION STUDY
COUNTRY GE

| BORE SIZE 120MM | | IN-BORE WT (lbs) | IN-FLIGHT WT (lbs) | PENETRATOR MAT'L | CASE MAT'L | MUZZLE VELOCITY ft/sec | MASS | MUZZLE MOMENTUM | KINETIC ENERGY |
|-----------------|------|---------------------|-----------------------|---------------------|---------------|------------------------------|--------|--------------------|-------------------|
| TYPE | STAB | | | | | | | | |
| MP | Fin | 28.64 | 28.64 | Tu | COMBUSTIBLE | 3740 | .8894 | 3326.51 | 6,220,572 |
| MP-TP | Fin | 22.16 | 22.16 | Tu | COMBUSTIBLE | 3800 | .6882 | 2615.16 | 4,968,795 |
| WP/SMOKE * | Fin | 32.5 | 32.5 | Tu | COMBUSTIBLE | 2400 | 1.0093 | 2422.36 | 2,906,832 |
| APERS * | Fin | 39.65 | 39.65 | Tu | COMBUSTIBLE | 2700 | 1.2314 | 3324.69 | 4,488,331 |
| APFSDS | Fin | 15.9 | 10.4 | Tu | COMBUSTIBLE | 5420 | .4938 | 2676.34 | 7,252,869 |
| | | | | | | | .3230 | 1750.56 | 4,744,015 |
| TPFSDS * | Fin | 13.52 | 7.54 | Tu | COMBUSTIBLE | 5000 | .4199 | 2099.38 | 5,248,447 |
| | | | | | | | .2342 | 1170.81 | 2,927,019 |

All rounds have electric primers.

* Physical characteristics same as UK 120MM round.

TABLE 11

TANK AMMUNITION STUDY
COUNTRY US

BORE SIZE 105MM

| <u>TYPE</u> | <u>STAB</u> | <u>IN-BORE WT (lbs)</u> | <u>IN-FLIGHT WT (lbs)</u> | <u>PENETRATOR MAT'L</u> | <u>CASE MAT'L</u> | <u>MUZZLE VELOCITY ft/sec</u> | <u>MASS</u> | <u>MUZZLE MOMENTUM</u> | <u>KINETIC ENERGY</u> |
|-------------|-------------|-----------------------------|-------------------------------|-----------------------------|-----------------------|---------------------------------------|-------------|----------------------------|---------------------------|
| MP | Fin | 24.8 | 24.8 | DU | STEEL | 3850 | .7702 | 2965.22 | 5,708,043 |
| MP-TP | Fin | 22.35 | 22.35 | DU | STEEL | 3850 | .6941 | 2672.28 | 5,144,144 |
| WP/SMOKE | Spin | 25.0 | 25.0 | DU | STEEL | 2400 | .7764 | 1863.35 | 2,236,025 |
| APERS | Spin | 30.5 | 30.5 | DU | STEEL | 2700 | .9472 | 2557.45 | 3,452,562 |
| APFSDS | | | | | | | | | |
| | | | | | | | | | |
| TPFSDS | Fin | 10.9 | 5.8 | DU | STEEL | 5050 | .3385 | 1709.47 | 4,316,417 |
| | | | | | | | .1801 | 909.63 | 2,296,809 |

----- See Classified Annex -----

In Bore
In Flight

All rounds have electric primers.

AVERAGE UNIT COSTS

COUNTRY
UK

TABLE 12
 COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|---------------|-------------------|----------------|---------------|--------------|
| LAP | \$ 36.70 | \$ 14.70 | ---- | ---- | \$ 14.70 | \$ 10.40 |
| Proj Mpts. | 61.60 | 311.40 | ---- | ---- | 130.10 | 52.60 |
| Fill | 2.10 | N/A | ---- | ---- | N/A | N/A |
| Case | 17.30 | 17.30 | ---- | ---- | 17.30 | 17.30 |
| Propellant | 29.10 | 29.40 | ---- | ---- | 22.70 | 24.30 |
| Primer | 17.20 | 17.20 | ---- | ---- | 17.20 | 17.20 |
| Fuze | 7.90 | N/A | ---- | ---- | N/A | N/A |
| Transportation | 5.30 | 2.90 | ---- | ---- | 2.30 | 4.30 |
| Other Expl. Elements | 36.00 | 19.10 | ---- | ---- | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$213.20 | \$412.00 | ---- | ---- | \$221.50 | \$143.30 |

* No production scheduled for 1983.

Costs rounded to nearest ten cents.

COUNTRY
UK

TABLE 13
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

| | <u>MP</u> | <u>APFSDS</u> | <u>MP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|---------------|-----------------|--------------|---------------|--------------|
| LAP | \$ 36.70 | \$ 14.70 | \$ 41.60 | \$ 52.70 | \$ 14.70 | \$ 10.40 |
| Proj Mpts. | 54.50 | 311.40 | 40.20 | 303.60 | 130.10 | 39.10 |
| Fill | 2.10 | N/A | N/A | N/A | N/A | N/A |
| Case | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 |
| Propellant | 29.10 | 29.40 | 14.60 | 20.20 | 22.70 | 24.30 |
| Primer | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 |
| Fuze | 6.80 | N/A | 11.90 | 178.00 | N/A | N/A |
| Transportation | 5.30 | 2.90 | 5.40 | 6.60 | 2.30 | 4.30 |
| Other Expl. Elements | 36.00 | 19.10 | 25.40 | 7.70 | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$198.30 | \$405.30 | \$166.90 | \$596.60 | \$214.80 | \$123.10 |

Costs rounded to nearest ten cents.

COUNTRY
UK

TABLE 14
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|---------------|-----------------|--------------|---------------|--------------|
| LAP | \$ 36.70 | \$ 14.70 | \$ 41.60 | \$ 52.70 | \$ 14.70 | \$ 10.40 |
| Prof Mpts. | 47.90 | 311.40 | 33.30 | 263.40 | 130.10 | 29.90 |
| Fill | 2.10 | N/A | N/A | N/A | N/A | N/A |
| Case | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 |
| Propellant | 29.10 | 29.40 | 14.60 | 20.20 | 22.70 | 24.30 |
| Primer | 5.80 | 5.80 | 5.80 | 5.80 | 5.80 | 5.80 |
| Fuze | 5.80 | N/A | 9.50 | 149.80 | N/A | N/A |
| Transportation | 5.30 | 2.90 | 5.40 | 6.60 | 2.30 | 4.30 |
| Other Expl. Elements | 36.00 | 19.10 | 25.40 | 7.70 | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$186.00 | \$400.60 | \$152.90 | \$523.50 | \$210.10 | \$109.20 |

Costs rounded to nearest ten cents.

COUNTRY
UK

TABLE 15
COMPONENT AVERAGE UNIT COSTS THROUGH FY 2007

| | <u>MP *</u> | <u>APFSDS *</u> | <u>WP/SMOKE</u> | <u>APERS *</u> | <u>TFSDS</u> | <u>MP-TP</u> |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| LAP | --- | --- | \$ 41.60 | --- | \$ 14.70 | \$ 10.40 |
| Proj Mpts. | --- | --- | 30.50 | --- | 130.10 | 26.70 |
| Fill | --- | --- | N/A | --- | N/A | N/A |
| Case | --- | --- | 17.30 | --- | 17.30 | 17.30 |
| Propellant | --- | --- | 14.60 | --- | 22.70 | 24.30 |
| Primer | --- | --- | 4.50 | --- | 4.50 | 4.50 |
| Fuze | --- | --- | 8.50 | --- | N/A | N/A |
| Transportation | --- | --- | 5.40 | --- | 2.30 | 4.30 |
| Other Expl. Elements | --- | --- | 25.40 | --- | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$186.00 | \$400.60 | \$147.80 | \$523.50 | \$208.80 | \$104.70 |

* No production scheduled after 1994.

Costs rounded to nearest ten cents.

COUNTRY
GE

TABLE 16
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|---------------|-------------------|----------------|---------------|--------------|
| LAP | \$ 36.70 | \$ 13.40 | --- | --- | \$ 13.40 | \$ 9.50 |
| Proj Mpts. | 61.60 | 325.30 | --- | --- | 135.30 | 52.60 |
| Fill | 2.10 | N/A | --- | --- | N/A | N/A |
| Case | 17.30 | 17.30 | --- | --- | 17.30 | 17.30 |
| Propellant | 25.70 | 28.80 | --- | --- | 22.70 | 21.80 |
| Primer | 17.20 | 17.20 | --- | --- | 17.20 | 17.20 |
| Fuze | 12.30 | N/A | --- | --- | N/A | N/A |
| Transportation | 4.80 | 2.60 | --- | --- | 2.30 | 3.70 |
| Other Expl. Elements | 36.00 | 19.10 | --- | --- | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$213.70 | \$423.70 | --- | --- | \$225.40 | \$139.30 |

* No production scheduled for 1983.

Costs rounded to nearest ten cents.

COUNTRY
GE

TABLE 17
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|---------------|-----------------|--------------|---------------|--------------|
| LAP | \$ 36.70 | \$ 13.40 | \$ 41.60 | \$ 52.70 | \$ 13.40 | \$ 9.50 |
| Proj Mpts. | 54.50 | 325.30 | 40.20 | 303.60 | 135.30 | 39.10 |
| Fill | 2.10 | N/A | N/A | N/A | N/A | N/A |
| Case | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 |
| Propellant | 25.70 | 28.80 | 14.60 | 20.20 | 22.70 | 21.80 |
| Primer | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 |
| Fuze | 10.60 | N/A | 11.90 | 178.00 | N/A | N/A |
| Transportation | 4.80 | 2.60 | 5.40 | 6.60 | 2.30 | 3.70 |
| Other Expl. Elements | 36.00 | 19.10 | 25.40 | 7.70 | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$198.20 | \$417.00 | \$166.90 | \$596.60 | \$218.70 | \$119.10 |

Costs rounded to nearest ten cents.

COUNTRY
GE

TABLE 18
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|---------------|-----------------|--------------|---------------|--------------|
| LAP | \$ 36.70 | \$ 13.40 | \$ 41.60 | \$ 52.70 | \$ 13.40 | \$ 9.50 |
| Proj Mpts. | 47.90 | 325.30 | 33.30 | 263.40 | 135.30 | 29.90 |
| Fill | 2.10 | N/A | N/A | N/A | N/A | N/A |
| Case | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 | 17.30 |
| Propellant | 25.70 | 28.80 | 14.60 | 20.20 | 22.70 | 21.80 |
| Primer | 5.80 | 5.80 | 5.80 | 5.80 | 5.80 | 5.80 |
| Fuze | 9.10 | N/A | 9.50 | 149.80 | N/A | N/A |
| Transportation | 4.80 | 2.60 | 5.40 | 6.60 | 2.30 | 3.70 |
| Other Expl. Elements | 36.00 | 19.10 | 25.40 | 7.70 | 17.20 | 17.20 |
| Total U. C. FY 77 | \$ 185.40 | \$ 412.30 | \$ 152.90 | \$ 523.50 | \$ 214.00 | \$ 105.20 |

Costs rounded to nearest ten cents.

COUNTRY
GE

TABLE 19
COMPONENT AVERAGE UNIT COSTS THROUGH FY 2007

| | <u>MP *</u> | <u>APFSDS *</u> | <u>WP/SMOKE</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-------------|-----------------|-----------------|----------------|---------------|--------------|
| LAP | --- | --- | \$ 41.60 | --- | \$ 13.40 | \$ 9.50 |
| Proj Mpts. | --- | --- | 30.50 | --- | 135.30 | 26.70 |
| Fill | --- | --- | N/A | --- | N/A | N/A |
| Case | --- | --- | 17.30 | --- | 17.30 | 17.30 |
| Propellant | --- | --- | 14.60 | --- | 22.70 | 21.80 |
| Primer | --- | --- | 4.50 | --- | 4.50 | 4.50 |
| Fuze | --- | --- | 8.50 | --- | N/A | N/A |
| Transportation | --- | --- | 5.40 | --- | 2.30 | 3.70 |
| Other Expl. Elements | --- | --- | 25.40 | --- | 17.20 | 17.20 |
| Total U. C. FY 77 \$ | \$185.40 | \$412.30 | \$147.80 | \$523.50 | \$212.70 | \$100.70 |

* No production scheduled after 1994.

Costs rounded to nearest ten cents.

COUNTRY
US ONLY

TABLE 20
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

| | <u>MP</u> | <u>APFSDS *</u> | <u>WP/SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|-----------------|-------------------|----------------|---------------|--------------|
| LAP | \$ 27.70 | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | 37.40 | --- | --- | --- | 109.80 | 28.10 |
| Fill | 1.50 | --- | --- | --- | N/A | N/A |
| Case | 13.80 | --- | --- | --- | 13.80 | 13.80 |
| Propellant | 19.10 | --- | --- | --- | 15.50 | 17.70 |
| Primer | 6.20 | --- | --- | --- | 6.20 | 6.20 |
| Fuze | 4.30 | --- | --- | --- | N/A | N/A |
| Transportation | 4.10 | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | 30.20 | --- | --- | --- | 11.40 | 11.40 |
| Total U. C. FY 77 \$ | \$144.30 | \$269.50 | \$124.90 | \$369.80 | \$169.30 | \$89.80 |

* WP/SMOKE and APERS total costs represent latest procurement costs:
APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

COUNTRY
US ONLY

TABLE 21
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

| | <u>MP</u> | <u>APFSDS *</u> | <u>WP/SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|-----------------|-------------------|----------------|---------------|--------------|
| LAP | \$ 27.70 | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | 33.10 | --- | --- | --- | 109.80 | 24.90 |
| Fill | 1.50 | --- | --- | --- | N/A | N/A |
| Case | 12.90 | --- | --- | --- | 12.90 | 12.90 |
| Propellant | 19.10 | --- | --- | --- | 15.50 | 17.70 |
| Primer | 4.80 | --- | --- | --- | 4.80 | 4.80 |
| Fuze | 3.70 | --- | --- | --- | N/A | N/A |
| Transportation | 4.10 | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | 30.20 | --- | --- | --- | 11.40 | 11.40 |
| Total U. C. FY 77 \$ | \$137.10 | \$267.20 | \$124.90 | \$369.80 | \$167.00 | \$84.30 |

* WP/SMOKE and APERS total costs represent latest procurement costs;
APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

COUNTRY
US ONLY

TABLE 22
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

| | <u>MP</u> | <u>APFSDS *</u> | <u>WP/SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|-----------------------------|-----------------|-----------------|-------------------|-----------------|-----------------|----------------|
| LAP | \$ 27.70 | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | 31.30 | --- | --- | --- | 109.80 | 21.30 |
| Fill | 1.50 | --- | --- | --- | N/A | N/A |
| Case | 11.80 | --- | --- | --- | 11.80 | 11.80 |
| Propellant | 19.10 | --- | --- | --- | 15.50 | 17.70 |
| Primer | 3.50 | --- | --- | --- | 3.50 | 3.50 |
| Fuze | 3.50 | --- | --- | --- | N/A | N/A |
| Transportation | 4.10 | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | 30.20 | --- | --- | --- | 11.40 | 11.40 |
| Total U. C. FY 77 \$ | \$132.70 | \$264.80 | \$124.90 | \$369.80 | \$164.60 | \$78.30 |

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

COUNTRY
US ONLY

TABLE 23
COMPONENT AVERAGE UNIT COSTS THROUGH FY 2007

| | <u>MP *</u> | <u>APFSDS *</u> | <u>WP / SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-------------|-----------------|---------------------|----------------|---------------|--------------|
| LAP | --- | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | --- | --- | --- | --- | 109.80 | 19.70 |
| Fill | --- | --- | --- | --- | N/A | N/A |
| Case | --- | --- | --- | --- | 11.20 | 11.20 |
| Propellant | --- | --- | --- | --- | 15.50 | 17.70 |
| Primer | --- | --- | --- | --- | 2.90 | 2.90 |
| Fuze | --- | --- | --- | --- | N/A | N/A |
| Transportation | --- | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | --- | --- | --- | --- | 11.40 | 11.40 |
| Total U. C. FY 77 \$ | \$132.70 | \$264.80 | \$124.90 | \$369.80 | \$163.40 | \$75.50 |

* WP/SMOKE and APERS total costs represent latest procurement costs;
APFSDS component breakout provided in classified annex;
No production of MP, APFSDS, and APERS rounds scheduled after 1994.

Costs rounded to nearest ten cents.

TABLE 24
 COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

COUNTRY
US PHASEOUT

| | <u>MP</u> | <u>APFSDS *</u> | <u>WP/SMOKE *</u> | <u>APERS *</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|-----------------------------|-----------------|-----------------|-------------------|----------------|-----------------|----------------|
| LAP | \$ 27.70 | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | 40.60 | --- | --- | --- | 109.80 | 28.20 |
| Fill | 1.50 | --- | --- | --- | N/A | N/A |
| Case | 14.00 | --- | --- | --- | 14.00 | 14.00 |
| Propellant | 19.10 | --- | --- | --- | 15.50 | 17.70 |
| Primer | 6.50 | --- | --- | --- | 6.50 | 6.50 |
| Fuze | 4.70 | --- | --- | --- | N/A | N/A |
| Transportation | 4.10 | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | 30.20 | --- | --- | --- | 11.40 | 11.40 |
| Total U. C. FY 77 \$ | \$148.40 | \$270.00 | \$124.90 | --- | \$169.80 | \$90.40 |

* WP/SMOKE and APERS total costs represent latest procurement costs;
 APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

TABLE 25
COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

COUNTRY
US PHASEOUT

| | <u>MP</u> | <u>APFSDS</u> * | <u>WP/SMOKE</u> * | <u>APERS</u> * | <u>TPFSDS</u> | <u>MP-TP</u> |
|----------------------|-----------|-----------------|-------------------|----------------|---------------|--------------|
| LAP | \$ 27.70 | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | 36.00 | --- | --- | --- | 109.80 | 25.60 |
| Fill | 1.50 | --- | --- | --- | N/A | N/A |
| Case | 13.30 | --- | --- | --- | 13.30 | 13.30 |
| Propellant | 19.10 | --- | --- | --- | 15.50 | 17.70 |
| Primer | 5.30 | --- | --- | --- | 5.30 | 5.30 |
| Fuze | 4.10 | --- | --- | --- | N/A | N/A |
| Transportation | 4.10 | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | 30.20 | --- | --- | --- | 11.40 | 11.40 |
| | | | | | | |
| | | \$268.10 | \$124.90 | | | |
| Total U. C. FY 77 \$ | \$141.30 | | | | \$167.90 | \$85.90 |

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

COUNTRY
US PHASEOUT

TABLE 26

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

| LAP | MP | APFSDS * | WP/SMOKE * | APERS * | TFPDS | MP-TP |
|----------------------|----------|----------|------------|---------|----------|---------|
| | \$ 27.70 | --- | --- | --- | \$ 10.80 | \$ 8.90 |
| Proj Mpts. | 34.00 | --- | --- | --- | 109.80 | 23.70 |
| Fill | 1.50 | --- | --- | --- | N/A | N/A |
| Case | 12.70 | --- | --- | --- | 12.70 | 12.70 |
| Propellant | 19.10 | --- | --- | --- | 15.50 | 17.70 |
| Primer | 4.50 | --- | --- | --- | 4.50 | 4.50 |
| Fuze | 3.80 | --- | --- | --- | N/A | N/A |
| Transportation | 4.10 | --- | --- | --- | 1.80 | 3.70 |
| Other Expl. Elements | 30.20 | --- | --- | --- | 11.40 | 11.40 |
| Total U. C. FY 77 \$ | \$137.60 | \$266.70 | \$124.90 | --- | \$166.50 | \$82.60 |

* WP/SMOKE and APERS total costs represent latest procurement costs;
APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

METHODOLOGY

IV. Methodology

A. Average Unit Cost for Gun Manufacture

1. Cost estimating relationship.

a. The data base utilized for this estimate is included in reference 3. In reference 3, estimating relationships correlating applied momentum to cost and cannon weight to cost are used independently. Neither of these relationships give satisfactory results for this estimate because the UK and GE cannons exchange rankings of momentum and weight. The reference 3 data base was subjected to multilinear regression with both weight and momentum as independent variables to solve this problem. The results are:

$$W = A + BX + CY \quad \text{Where:}$$

W = Unit cost in FY 72 \$ (excluding Product Assurance and Engineering Support)

X = Weight in pounds of the cannon breech assembly (less muzzle brake and bore evacuation)

Y = Momentum in lb/secs for highest momentum generated

A = 4113.83

B = 1.2067

C = 0.4134

Statistics:

Coefficients of Determination

Multiple = .976

Partial

WX·Y = .2911

WY·X = .1048

XY = .976

Standard error of the estimate = 1675

N = 8

b. Independent Variables: The weights of the cannon and breech assemblies for the UK and GE options are taken from reference 8 as 3912 and 4282 pounds respectively. The momentums in lbs/secs are calculated at 3821.12 for UK and 3326.51 for GE on the basis of the round variables provided in Section III, paragraph B of this report.

2. Inflation.

Historical inflation for general items of ordnance has not moved as fast as that for cannon manufacture. Therefore, it is necessary to construct a special inflation rate to escalate from FY 72 to FY 76. The most reasonable proxy for actual price movement is the change in Wholesale Price Index (WPI) Code 1015-1053, Closed Die Forging Alloy Steel. The amount of change through the period FY 72 to FY 76 has been 75 percent comparing reference 10 and reference 11. An additional 10.07 percent is forecast between FY 76 and FY 77 (reference 5). The total multiplier then becomes 1.9262 (1.75 X 1.1007) to be applied on the output of the gun cost estimating relationships described above.

3. Adjustment for Smoothbore Gun.

The 120mm UK gun is a rifled gun similar to the items in the data base. The 120mm GE gun is of a smoothbore configuration, and its costs require adjustment. Reference 7 places the cost of rifling at 4.3 percent of the 120mm tube manufacturing cost and the cost of other processes contributing to the smoothbore configuration (including chrome plate, grinding and honing) at 11.6 percent of tube cost. Since the tube is 1/3 the cost of the total cannon breech assembly cost, the cost of rifling can be extracted from the CER by multiplying by .9857 -

$$\frac{1}{3} \times .043 = .0143, 1 - .0143 = .9857.$$

The smooth bore cost can be added to the cost of cannon, less rifling through the multiplier 1.0402 -

$$\frac{1}{3} \times .116 = .0387, 1 - .0387 = .9613, \frac{1}{.9613} = 1.0402.$$

Thus, the one step multiplier to convert output of the CER to the smoothbore configuration is the product of .9857 and 1.0402, or 1.0253.

4. Adjustment for Bore Evacuation System.

Reference 7 provides that the UK bore evacuator, and the GE evacuator are 2.5 percent and 0.7 percent of the total costs respectively -

$$\frac{1}{(1-.025)} = 1.0256, \frac{1}{(1-.007)} = 1.007.$$

5. Costs for Product Assurance and Engineering Support.

These costs were extracted and used as is from the Watervliet Arsenal engineering cost estimate. The GE cost is \$1,228 and the UK cost is \$1,020.

B. AMMUNITION MANUFACTURING COSTS

1. General Approach

a. The basic methodology for developing the ammunition portion of the estimate was derived from reference 1. The ammunition was broken out into the individual components that would be procured. These elements were then costed by applying Cost Estimating Relationships (CER's) developed in reference 1. Section IV, paragraph B2, gives a complete list of the CER's that were taken from the study. It also indicates the pages upon which the detailed description of the CER's and their associated statistics can be found.

b. Since the ammunition study (reference 1) did not develop LAP and projectile costs for APERS, TPDS, and WP rounds, complexity factors were developed for this study based upon the relationships between weighted average costs of HEAT LAP's and projectiles compared to buys of APERS and WP rounds. These complexity factors are also listed in Section IV, paragraph B2. A detailed description of their development is given in Section IV, paragraph B3. It should be noted that it was decided that the costs of LAP for TPDS and APDS rounds would be essentially identical.

c. A final requirement for developing complete round costs involved the necessity of estimating costs for certain explosive elements for which CER's are not contained within reference 1. Failure to include these costs would have resulted in a significant underpricing of the ammunition. For this reason, the current ammunition component price list (reference 9) was utilized to extract current costs for explosive elements from US 105mm rounds in production. The M456A1 (HEAT), the M392A2 (APDS), the M416 (WP), the M494 (APERS), the M742 (TPDS), and M490 (TP) were the sources for this data. It was assumed that these costs would remain relatively constant for the new family of US tank rounds. In order to project costs for the 120mm, the HE Fill CER ($\ln Z = 14.3343 + 3.1763 \ln \text{bore size}$) was used to calculate the percentage difference between 105mm and 120mm rounds. A factor of 1.51 (rounded) was applied to the US rounds to estimate the corresponding German and English rounds. In addition, it should be noted that the US HEAT round Other Explosive Elements category contains a Full Frontal Area Impact Switch with a current cost of \$18.834. It was assumed that the US would want this technology to be incorporated in the corresponding 120mm rounds, so this cost was also applied.

d. After all of the equations in Section IV, paragraph B2, had been calculated, utilizing the variables and production schedules provided in Section III (A and B), the results were converted to FY 77 dollars by application of inflation factors in references 4 and 5. All results were then placed in the matrix provided on the following page (Figure 1). This matrix became the basis for the cost tables in Section III-C of the study. It includes the identification number of the appropriate equation for each component, and it also identifies the requirement for throughput data provided in Section IV, paragraph B4.

AMMUNITION COST DEVELOPMENT MATRIX

| | <u>MP</u> | <u>APFSDS</u> | <u>WP/SMOKE</u> | <u>APERS</u> | <u>TPFSDS</u> | <u>MP-TP</u> |
|--------------------------|-----------|---------------|-----------------|--------------|---------------|--------------|
| LAP | 1 | 4 | 2 | 3 | 4 | 5 |
| Proj. Mpts. | 6 | 9 | 7 | 8 | 11 | 10 |
| Fill | 12 | N/A | N/A | N/A | N/A | N/A |
| Case | | | | | | |
| Steel | 13 | 13 | 13 | 13 | 13 | 13 |
| Combustible | 14 | 14 | 14 | 14 | 14 | 14 |
| Propellant | 15 | 15 | 15 | 15 | 15 | 15 |
| Primer | 16 | 16 | 16 | 16 | 16 | 16 |
| Fuze | 17 | N/A | 18 | 19 | N/A | N/A |
| Transportation | 20 | 20 | 20 | 20 | 20 | 20 |
| Other Explosive Elements | | | | | | |
| Throughput | | | | | | |

Numbers in matrix are keyed to Section IV, paragraph B2..

FIGURE 1

2. COST ESTIMATING RELATIONSHIPS

a. LAP Costs

(1) Equation No. 1 - MP (HEAT)

$$\ln Z = -6.8639 + 2.1143 \ln X$$

Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, pp 112-113.

(2) Equation No. 2 - WP/SMOKE

MP LAP unit cost (FY 74 \$) from Equation No. 1 times 1.1388 complexity factor. See Section IV, Paragraph B(3) of this study.

(3) Equation No. 3 - APERS

MP LAP unit cost (FY 74 \$) from Equation No. 1 times 1.4334 complexity factor. See Section IV, Paragraph B(3) of this study.

(4) Equation No. 4 - APFSDS/TPFSDS (AP)

$$\ln Z = 2.9272 - 0.000002941 X + 0.9583 \ln Y$$

Where: Z = Estimated unit cost in FY 74 dollars
X = Average annual production rate in thousands
Y = Projectile mass

Ref. #1, pp 113-114.

(5) Equation No. 5 - MP-TP (TP)

$$\ln Z = 4.1000 - 0.3247 \ln X + 0.6453 \ln Y$$

Where: Z = Estimated unit cost in FY 74 dollars
X = Average annual production rate in thousands
Y = Projectile mass

Ref. #1, pp 114-115.

b. Projectile Costs

(1) Equation No. 6 - MP (HEAT)

Theoretical first unit cost (FY 74 \$) of \$90.61 for 105mm;

Theoretical first unit cost (FY 74 \$) of \$138.65 for 120mm;

92.6% composite learning rate applies.

Ref. #1, p 117.

(2) Equation No. 7 - WP/SMOKE

HEAT theoretical first unit cost (FY 74 \$) from Equation No. 6 times .6007 complexity factor.

92.6% composite learning rate applies.

See Section IV, Paragraph B(3) of this study.

(3) Equation No. 8 - APERS

HEAT theoretical first unit cost (FY 74 \$) from Equation No. 6 times 3.8289 complexity factor.

92.6% composite learning rate applies.

See Section IV, Paragraph B(3) of this study.

(4) Equation No. 9 - APFSDS (APDS)

$$Z = \text{Antiln} (3.1417 + 0.009529X) + (116.91 + 52.80T \left(\frac{Y}{0.2640} \right) + 16.73 \left(\frac{Y}{0.2640} \right)^{0.6667})$$

Where: Z = Estimated unit cost in FY 76 dollars

X = Full bore size in millimeters

Y = In-flight projectile mass

T = Material type conditional code

= 0 if depleted uranium core

= 1 if tungsten alloy core

Ref. #1, pp 123-123.

(5) Equation No. 10 - APFSDS

APFSDS estimated unit cost (FY 76 \$) from Equation No. 9 with depleted uranium core times .5303 complexity factor.

See Section IV, Paragraph B(3) of this study.

(6) Equation No. 11 - MP-TP (TP)

$$\text{Ln}Z = -5.5868 + 2.1305 \text{Ln}X$$

Where: Z = Estimated theoretical first unit cost in FY 74 dollars

X = Bore size in millimeters

Ref. #1, p 124.

c. Explosive Fill

Equation No. 12 - MP (HEAT)

$$\text{LnZ} = -12.3829 + 2.6706 \text{ LnX}$$

Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, p 126.

d. Cases

(1) Equation No. 13 - Steel

$$\text{LnZ} = 1.0625 + 0.02063 X + 0.2022 Y$$

Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Bore size in millimeters
Y = Projectile mass

94.3% composite learning rate applies.

(2) Equation No. 14 - Combustible

$$\text{LnZ} = 1.2865 + 0.01015 X$$

Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, p 134.

e. Propellants

Equation No. 15 - Propellants

$$\text{LnZ} = -10.5840 + 0.01571 X + 0.7416 \text{ LnY}$$

Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters
y = Kinetic energy

Ref. #1, pp 135-137.

f. Primers

Equation No. 16 - Electric

$$\text{LnZ} = -14.1220 + 4.0538 \text{ LnX} - 0.9031 \text{ LnY}$$

Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Round application bore size in millimeters
Y = Round application projectile mass

80.3% composite learning rate applies.

Ref #1, p 139.

g. Fuzes

(1) Equation No. 17 - MP (PIB)

$$\ln Z = -52.3486 + 11.5814 \ln X - 4.0205 \ln Y$$

Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Round application bore size in millimeters
Y = Round application projectile mass

91.1% composite learning rate applies.

Ref. #1, pp 143-144.

(2) Equation No. 18 - WP/SMOKE (PD)

$$\ln Z = 14.0768 - 2.2258 \ln X + 1.0590 \ln Y$$

Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Round application bore size in millimeters
Y = Round application projectile mass

91.1% composite learning rate applies.

Ref. #1, pp 141-142.

(3) Equation No. 19 - APERS (MT)

Theoretical first unit cost (FY 74 \$) of \$376.35

91.1% composite learning rate applies.

Ref. #1, p 144.

h. Transportation

Equation No. 20 - Transportation

$$\ln Z = 1.5214 + 1.0029 \ln X$$

Where: Z = Estimated unit cost in FY 75 dollars
X = Projectile mass

Ref. #1, pp 149-150.

3. COMPLEXITY FACTORS

a. This study draws heavily upon references 1 and 2. It should be noted that both references 1 and 2 refer to generic titles for the various round families. Hence, the MP and MP-TP categories, as referred to in this report, are denoted in references 1 and 2 as HEAT and TP. Correspondingly, WP/SMOKE rounds are referred to as WP. The APFSDS and TPFSDS rounds are respectively called APDS and TPDS in references 1 and 2. In order to facilitate tracking with the basic references, this methodology section utilizes the generic descriptions found in references 1 and 2. Reference 2 contains unit cost-quantity data for LAP costs and projectile metal parts production for selected ammunition items between FY 57 and FY 75. All costs pertaining to HEAT, APERS, WP, TPDS, and APDS rounds were extracted. In addition, a file search was conducted in DRSAR-PDC records pertaining to LAP and projectile metal parts costs. Additional information for FY 76 and FY 77, and for several earlier buys not listed in the annex, was compiled. All of this data was then converted into unit costs in FY 76 dollars. In order to facilitate comparison of the rounds under study, the data were then purified by the deletion of obviously inconsistent cost-quantity information (i.e., an FY 72 buy of M456A1 projectiles was deleted because it had an average unit cost of \$436.72 in FY 76 dollars, while the average unit cost of all other orders was \$44.34). A weighted average unit cost for each round in the data base was then developed so that individual rounds could be compared readily (see Charts 1 and 2).

b. These weighted averages were used as the basis for the developing of complexity/conversion factors. Reference 2 contains a CER for estimating the LAP and actual costs for the 105mm and 120mm HEAT projectile parts. It was decided to use an analogy process, comparing the HEAT with the WP and APERS rounds, to develop factors which could be used to convert the projected costs for a HEAT round to projected APERS and WP costs. Similarly, a conversion factor was developed for the CER for APDS rounds projectile metal parts by comparing the APDS metal parts cost to the TPDS metal parts cost.

Complexity Factor 1 - A complexity factor of 1.1338 was developed to convert output from the HEAT LAP cost CER to that of a WP round. This was done by comparing the average cost of the only WP tank round on which data was available, the 105mm M416, to the normalized weighted average cost of HEAT rounds in the data base. Two of the rounds on which data was available, the 76mm M496 and the 90mm M431A2, are obsolete rounds that were produced in only limited quantities. They were removed from the data base in order not to skew the results. This left the following rounds in the data base (see Table 27).

CHART 1

LAP COSTS FY 76 \$

| <u>HEAT</u> | <u>APERS</u> | <u>WP</u> | <u>TPDS</u> | <u>APDS</u> |
|--------------------------------------|------------------------|------------------------|------------------------|-----------------------------|
| \$15.157 M344A1 w/o Fuze 106mm | \$22.549 M580-90mm | \$22.504 M416-105mm | \$10.736 M724-105mm | \$11.760 M391A1/A2-105mm |
| \$16.415 M371E1-90mm | \$23.550 M581-106mm | | | |
| \$16.826 M456-105mm | \$33.626 M494-105mm | | | |
| \$18.197 M344A1 w Fuze 106mm | | | | |
| \$31.969 M496-76mm | | | | |
| \$36.092 M431A2-90mm | | | | |
| \$65.525 M409-152mm | | | | |

CHART 2

PROJECTILE METAL PARTS COSTS FY 76 \$

| <u>HEAT</u> | <u>APERS</u> | <u>WP</u> | <u>TPDS</u> | <u>APDS</u> |
|----------------------------|---------------------------|--------------------------|----------------------------|--------------------------------|
| \$21.231 M371A1 - 90mm | \$113.807 M580 - 90mm | \$24.461 M416 - 105mm | \$76.713 M724A1 - 105mm | \$144.652 M392A1/A2 - 105mm |
| \$36.548 M344A1 - 106mm | \$165.369 M494 - 105mm | | | |
| \$44.337 M456A1 - 105mm | \$170.568 M581 - 106mm | | | |
| \$51.574 M496 - 76mm | | | | |
| \$71.848 M431 - 90mm | | | | |
| \$147.086 M409 - 152mm | | | | |

TABLE 27

| <u>Bore Size</u> | <u>Nomenclature</u> | <u>Wtd Avg Price</u> | <u>Quantity</u> | <u>Normalized Wtd Avg Price</u> |
|------------------|---------------------|----------------------|-----------------|---------------------------------|
| 90mm | M371F1 | \$16.415 | 619,432 | \$22.735 |
| 105mm | M456 | 16.826 | 975,095 | 16.826 |
| 106mm | M344A1 w/o Fuze | 15.157 | 61,515 | 14.860 |
| 106mm | M344A1 w Fuze | 18.197 | 801,366 | 17.840 |
| 152mm | M409 | 65.525 | 303,893 | 29.975 |

In order to normalize this data in terms of 105mm costs, it was necessary to utilize the HEAT LAP CER = Ln Est. U.C. in FY 74 \$ = -6.8639 + (2.1143 X Ln Bore Size). Since the independent variable in this equation is bore size, it was felt that the data could be normalized by finding the CER projected differences for the bore sizes involved. These results were obtained:

TABLE 28

| <u>Bore Size</u> | <u>Est U.C.</u> | <u>Conversion Factor Based on 105mm</u> |
|------------------|-----------------|---|
| 90mm | \$14.155 | 1.385 |
| 105mm | 19.609 | 1.000 |
| 106mm | 20.006 | .980 |
| 152mm | 42.866 | .457 |

By applying the conversion factors developed in this manner, normalized weighted average prices were obtained (see Table 27). The weighted average of these normalized prices is \$19.849. This compares to the average cost of \$22.504 for the M416 WP round (Chart 1). The latter figure is 1.1338 times the normalized average HEAT round LAP cost.

Complexity Factor 2 - A complexity factor of 1.4334 was developed to convert output from the HEAT LAP cost CER to that of an APERS round. The same methodology was followed as for complexity factor 1. The normalized average cost of \$19.849 for the HEAT round was compared to the normalized weighted average cost of \$28.451 for the APERS round. Table 29 summarizes the conversion process.

TABLE 29

| <u>Bore Size</u> | <u>Nomenclature</u> | <u>Wtd Avg Price</u> | <u>Quantity</u> | <u>Normalized Wtd Avg Price</u> |
|------------------|---------------------|----------------------|-----------------|---------------------------------|
| 90mm | M580 | \$22.549 | 96,976 | \$31.231 |
| 105mm | M494 | 33.626 | 19,223 | 33.626 |
| 106mm | M581 | 23.550 | 68,828 | 23.088 |

In order to normalize this data in terms of 105mm costs, the conversion factors developed in Table 28 were used. The average weighted unit APERS LAP cost of \$28.451 is 1.4334 times the standardized LAP cost of HEAT rounds.

Complexity Factor 3 - In order to convert projected costs of APDS to TPDS projectiles, an analogy was made between the M724A1 105mm TPDS projectile and the M392A1 APDS projectile. The average cost of the M724A1 is \$76.713. Since the M392A1 projectile has an average cost of \$144.652, the M724A1 projectile is .5303 times as expensive as the APDS round. This complexity factor is utilized for converting an estimated APDS DU projectile to a TPDS projectile.

Complexity Factor 4 - A complexity factor of .6007 was developed to convert HEAT projectile theoretical first unit costs to WP projectile theoretical first unit costs. This was accomplished by comparing the average cost of the only WP tank round projectile on which data was available, the 105mm M416, to the normalized weighted average cost of HEAT projectiles in the data base. As was the case in the development of complexity factor 1, the obsolete M431 and M436 projectile costs were deleted. A normalized weighted average unit cost of \$40.723 was developed using the same procedures described for complexity factor 1. The HE projectile CER: $\ln \text{Theoretical First Unit Cost FY 74 } \$ = -1.6983 + (1.3739 \times \ln \text{Bore Size})$ was used as the basis for the conversion, since no HEAT CER is available.

Complexity Factor 5 - A complexity factor of 3.8289 was derived to convert HEAT projectile theoretical first unit costs to APERS projectile theoretical first unit costs. The same methodology was utilized as for complexity factor 2. The normalized average cost of HEAT projectiles of \$40.723 was compared to the normalized weighted average cost of APERS projectiles in the data base. This weighted cost of \$155.926 is 3.8289 times the HEAT projectile cost.

4. THROUGHPUT

Other Explosive Elements

| | <u>105MM FY 77 \$</u> | <u>120MM FY 77 \$</u> |
|---------------------------------|-----------------------|-----------------------|
| HEAT | | |
| Nitroguanidine | \$ 7.101 | |
| Liner | 2.141 | |
| Benite | 1.542 | |
| M13 Tracer | .593 | |
| | <hr/> | |
| Full Frontal Area Impact Switch | \$11.377 | \$17.185 |
| | 18.834 | 18.834 |
| | <hr/> | <hr/> |
| TOTAL | \$30.211 | \$36.019 |

HEAT-TP

| | | |
|----------------|----------|----------|
| Nitroguanidine | \$ 7.101 | |
| Liner | 2.141 | |
| Benite | 1.542 | |
| M13 Tracer | .593 | |
| | <hr/> | |
| TOTAL | \$11.377 | \$17.185 |

APDS

| | | |
|----------------|----------|-----------|
| Nitroguanidine | \$ 7.101 | |
| Benite | 3.034 | |
| Black Powder | .001 | |
| M13 Tracer | .593 | |
| Liner | 1.929 | |
| | <hr/> | |
| TOTAL | \$12.658 | \$ 19.120 |

Other Explosive Elements

| | <u>105MM FY 77 \$</u> | <u>120MM FY 77 \$</u> |
|-----------------|-----------------------|-----------------------|
| TPDS | | |
| Nitroguanidine | \$ 5.471 | |
| Benite | 3.034 | |
| Black Powder | .214 | |
| M13 Tracer | .593 | |
| Liner | 2.084 | |
| TOTAL | <u>\$11.396</u> | |
| WP | | \$17.213 |
| XM175 Burster | \$12.903 | |
| M48 Burster | 1.367 | |
| TNT | .053 | |
| Comp. B. | .126 | |
| Black Powder | .099 | |
| M12 Tracer | 2.270 | |
| TOTAL | <u>\$16.818</u> | |
| APERS | | \$25.404 |
| XM86 Detonators | \$ 3.805 | |
| M7 Relay | .135 | |
| M87 Detonators | .368 | |
| M9 Propellant | .198 | |
| M13 Tracer | .593 | |
| TOTAL | <u>\$ 5.099</u> | \$ 7.702 |

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