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TARGET MISSILE AIRFRAME COSTS

William P. Anderson
Cost Analysis Division

March 1979

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama

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A parametric method of estimating the production cost for a proposed TARGET Missile Airframe is presented in this report. A cost estimating relationship (CER) has been developed based upon an independent variable, the estimated airframe weight in pounds. The independent variable (Y) in the CER, $Y = (A+Bx)^2$, represents the average unit production cost for the first 700 airframes produced in terms of FY 77 constant dollars. The methodology used in developing this CER as well as a presentation of data and TARGET Missile Technical Descriptions, is included for the benefit of the cost estimator.

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Mr. Paul Gattis, TARGETS Management Office, MIRCOM, for historical procurement data
Mr. Don Smith, Northrop Corporation, Huntsville, Alabama, for MQM-74C data
Mr. Ross McGinnis, Beech Aircraft Corporation, Wichita, Kansas, for MQM-107A and AQM-37A data
Mr. Ted Sells, Eglin Air Force Base, Florida, for BQM-34A data.

CONTENTS

1. INTRODUCTION

This study was performed by the Cost Analysis Division, Comptroller, U. S. Army Missile Materiel Readiness Command, and is intended to be used in estimating the average unit cost for the first 700 airframes produced for a new target missile system where the estimated airframe weight falls within the range of the data points of the target missile systems discussed herein.

2. PURPOSE

The purposes of this study are to (1) document a fundamental relationship which provides the basis for predicting the airframe production cost of a new target missile system, and (2) record and normalize to an FY77 base the historical production costs and airframe weights of target missile systems for future cost estimating purposes.

3. SCOPE OF STUDY

This study analyzes the airframe production cost of target missile systems for which historical cost data could be obtained. The definition of airframe as used herein is consistent with the aircraft airframe definition in MIL-STD-881-A, Work Breakdown Structures for Defense Materiel Items. It includes, for example, the basic structure (wing, empennage, fuselage, and associated manual flight control system), the air induction system, starters, exhausts, fuel control systems, inlet control systems, alighting gear, environmental controls, racks, mounts, cables, and distribution boxes, etc., which are inherent to and nonseparable from the assembled structure, dynamic systems, rotor group and other equipment homogeneous to the airframe.

Production costs include all costs associated with manufacturing the airframe as well as those necessary to process, assemble, and integrate the components in a workable system.

The target missile systems which have been included in the data base for this study consist of the following:

- MQM-74C (CHUCKER)
- MQM-61A (CARDINAL), formerly known as the Model 1025
- MQM-42 (REDHEAD/ROADRUNNER)

- MQM-107A, formerly known as the Variable Speed Training Target System
- AQM-37A
- BQM-34A (FIREBEE)

4. STUDY METHODOLOGY

This study was limited to an analysis of the relationship between an independent variable, airframe weight in pounds and dependent variable, historical production costs. This relationship was studied considering several variations of the independent variable. A nonlinear relationship between airframe weight and production cost proved to be the best estimator. The weight of the airframe of a proposed Target Missile System can usually be determined or estimated from preliminary design data, analogy with similar systems, or other technical data in existence prior to formal in-process reviews.

A. STATISTICAL EVALUATION

In order to measure the goodness of fit of the CER equation to the data, certain statistical indicators have been utilized. The coefficient of variation, coefficient of determination, mean absolute percent deviation and confidence established by the F test were used as the basis for determining the best form of the equation. Definition of these statistical indicators is as follows.

(1) COEFFICIENT OF DETERMINATION. The coefficient of determination is the proportion of total variance in the dependent variable that is explained by the independent variable. It provides a relative measure of the average degree of improvement in estimating the magnitudes of the dependent variable by taking into account the magnitudes of the independent variable. The derived value (r^2) falls within the range of 0 (no correlation among the variables) to 1 (perfect correlation among the variables).

(2) COEFFICIENT OF VARIATION. The coefficient of variation (cv) can be looked on as a relative standard error. It is a ratio of the standard error of the estimate to the mean of the actual dependent variable.

The coefficient of variation is useful as a summary statistic for a single regression, but is probably most useful for comparing the relative worth of different regressions. As a rule of thumb, a regression resulting in a good fit should have a coefficient of variation of 0.20 or less.

(3) MEAN ABSOLUTE PERCENT DEVIATION. The mean absolute percent deviation is interpreted as the average percent that the CER values deviate from the actual values.

(4) F TEST. The F Test is a test of significance used to determine whether the relationship of the dependent variable to the independent variable may have occurred by chance. The hypothesis being that r^2 is not significantly different from a zero at a given confidence level when Fcrit $\geq$ Fcal, therefore, the relationship of the variables could not be considered casual.

B. AIRFRAME COST ESTIMATING RELATIONSHIP (CER)

A screening program of ten different equation forms was performed using the independent variable, airframe weight. The results of this screening program are shown in Appendix A. Equation forms which yielded the best results in terms of goodness of fit are shown in Table 1.

TABLE 1. CER STATISTICS

CER Form	Coefficient of Determination	Coefficient of Variation	Mean Absolute % Variation	F Test Calculate
$y = A + Bx$	0.896	0.204	0.200	34.461
$Lny = A + Bx$	0.844	0.021	0.230	21.641
$y = (A + Bx)^2$	0.883	0.100	0.169	30.188

where:

y = average Unit Production Cost for the first 700 target missile airframes produced, in FY 77 constant dollars

A = regression coefficient

B = regression coefficient

x = airframe weight (lb)

F critical (95%) = 7.71

F critical (99%) = 21.20

The equation form selected as most desirable for a cost estimating relationship is

$$y = (A+Bx)^2.$$

This equation form provides close to the best Coefficient of Determination, the best Coefficient of Variation and Mean Absolute Percent Deviation, and a relatively good F score at the 99 percent confidence level. Utilizing this equation results in the following CER:

$$y = (95.704 + 0.249x)^2.$$

5. DATA AND SOURCES

The data used in developing this cost estimating relationship was obtained from several sources. A summary of the data and each item contained in the data base follows.

A. MQM-74C (CHUCKER)

The cost data for the MQM-74C was obtained from Mr. Don Smith at Northrop Corporation, Huntsville. The airframe weight is 175 lb while the average unit airframe cost for a lot of 200 in FY 79 dollars is $22,500. With continuous production of 800 units having been produced prior to this lot, the lot range associated with the $22,500 unit price extended from unit 801 through unit 1000. Utilizing this data, an inflation adjustment factor of 0.8202 (see Appendix B), and an assumed learning slope of 87.4 percent, the average unit production cost of $23,864 was calculated for the first 700 units.

B. MQM-61A (1025)

The MQM-61A is a relatively slow, propeller-powered target developed for the Navy in the 1950's by Beech Aircraft Corporation, Wichita, Kansas. Also known as the 1025, it is a high-wing monoplane with a V-tail and is controlled remotely by radio. The vehicle has a McCulloch six-cylinder, two-cycle, super-charged, internal combustion engine which develops 120 BHP at 4100 rpm at sea level, to drive an all-metal, two-blade, variable-pitch, constant-speed propeller.

The weight of the MQM-61A airframe (234 lb) was obtained from the TARGETS Management Office, MIRCOM. Historical production cost data was acquired from MIRCOM Cost Analysis Division, Comptroller, files. A summary of this data is shown in Table 2. A regression analysis of the lot and cost data adjusted to FY 77 constant dollars utilizing the curvilinear equation form $y = Ax^{\beta}$, yields a theoretical first unit production cost of $42,571 and a total cost production slope of 89.2 percent. Utilizing this information, the average unit production cost for the first 700 production units is calculated as $16,869.

TABLE 2. MQM-61A AIRFRAME PRODUCTION COST

Contract No.	Qty.	FY Procured	Current Year $ AUC	FY 77 Adjust Factor	FY 77 $ AUC
ORD 1566	200	1961	$11,608	1.684	$19,584
ORD 1615	90	1961	13,553	1.684	22,823
ORD 1637	200	1961	8,363	1.684	14,083
ORD 1637	38	1961	8,387	1.684	14,124

C. MQM-42 (REDHEAD/ROADRUNNER)

The REDHEAD/ROADRUNNER Target Missile is powered by a normal shock inlet ramjet that is pylon-mounted on top of the missile. Interchangeable, low-aspect-ratio, fixed-delta wings are mounted close to the missile center of gravity. Interchangeable, movable tail surfaces are mounted aft at a 34-deg cathedral angle. These tail surfaces operate together for pitch control and differentially for lateral-directional control. A small fixed fin is mounted on top of the ramjet to provide an adequate lateral stability margin through the transonic region. A small trim tab is located in the aft portion of the engine pylon for lateral directional trim. A solid-propellant booster mounted under the missile body is used to launch the missile. The booster falls away from the missile after burnout.

The airframe weight for the MQM-42 (349 lb) was obtained from the TARGETS Management Office. Historical cost data was derived from a previous study of airframe cost prepared by the Cost Analysis Division of the U. S. Army Missile Command. This study reflected the average unit cost of $26,000 for 700 airframes in FY 72 dollars. This data was adjusted to FY 77 dollars by applying the inflation adjustment factor of 1.328 as shown in Appendix B. The average unit cost for the first 700 MQM-42 airframes is $34,528.

D. MQM-107A (STREAKER)

The MQM-107A is approximately 17 ft long, has a 10 ft wing span, and a fuselage diameter of 15 in. With fuel and booster, the vehicle weighs 1067 lbs. The fuselage construction is aluminum with bonded honeycomb wing and tail surface, and plastic nose and tail cones. The airframe was designed with constant attention to minimizing initial fabrication and refurbishment costs. The simplicity and modularity of its construction demonstrates the success of this attention. The airframe may be divided into seven major parts -- the nose section, fuel tankage, aft section, wing, empennage, engine nacelle, and aerodynamic fairings. The forward section of the fuselage houses the crushable nose cone, electronics compartment, payload section, and smoke oil tank. The center section is the fuel tank and the rear area is the recovery system.

The weight of the MQM-107A airframe (365 lb) was supplied by the MIRCOM TARGETS Management Office. Historical cost data was obtained from Mr. Ross McGinnis, Beech Aircraft Corporation, producer of the MQM-107A. To date 317 units have been produced at an average unit cost of $34,435 FY 77 dollars. Utilizing a production slope of 87.4 percent and the curvilinear equation form $y = Ax^{\beta}$, the average unit production cost for the first 700 units is estimated to be $29,579, FY 77 dollars.

E. AQM-37A

The AQM-37A is a Navy-developed, liquid-rocket-propelled, air-launched, supersonic, nonrecoverable target. The system has been deployed to Havy ships and is being used for air defense missile and manned aircraft training operations. The Army has used a modified AQM-37A for support for air defense missile test and evaluation at White Sands Misssile Range (WSMR).

The weight of the AQM-37A airframe (190 lb) was furnished by the MIRCOM TARGETS Management Office. Historical cost data was provided by Mr. Ross McGinnis, Beech Aircraft Corporation, producer of the AQM-37A. Historical cost data for a quantity of 415 units yielded an average unit production lot cost of $14,325 in FY 77 dollars. A total of 3300 units have been manufactured prior to this production lot; therefore, this lot represented units 3301 through 3715. Utilizing this data and an assumed learning slope of 87.4 percent, the average unit production cost of $24,257 was calculated for the first 700 units.

F. BQM-34A (FIREBEE)

The BQM-34A FIREBEE is a high-speed, subsonic, remotely controlled target manufactured by Teledyne Ryan Aeronautical Company, San Diego, California. The vehicle is of midwing construction, is propelled by a single Contiental J69-T-29, 1700 lb thrust turbojet engine, and weighs approximately 2300 lb with fuel. During flight the target is controlled through all normal flight maneuvers necessary for the performance of its mission. It is recovered by use of a parachute recovery system initiated by either direct command of the remote control operator or automatically by loss of power or loss of control-transmission carrier.

Both historical cost data and the target missile airframe weight were obtained from Mr. Ted Sells at Eglin Air Force Base, Florida. The airframe weight for this target is 642 lb and the calculated average unit cost for the 700 production units in FY 77 dollars is $69,053. This average unit production cost was calculated using a derived total cost production slope of 85.6 percent and a theoretical first unit cost of $232,878 from the historical data shown in Table 3.

TABLE 3. BQM-34A AIRFRAME PRODUCTION COSTS

Production	Qty.	FY Procured	Current Yr. $ AUC	FY 77 Adjust Factor	FY 77 $ AUC
1st Procurement	75	1959	64,141	1.689	108,334
2nd Procurement	240	1960	49,705	1.692	84,101
3rd Procurement	235	1961	31,687	1.684	53,361
4th Procurement	219	1962	32,984	1.684	55,545

6. DATA ADJUSTMENTS

Historical data, especially for older systems procured prior to the mid-1960's, seldom can be found in readily usable form. Often it is necessary to adjust or normalize available data by using established techniques in order to convert the data to usable form within a common framework. In the analysis of data from which this CER was derived, two basic adjustments were made. First, all cost data was adjusted to FY 77 dollars utilizing historical cost factors developed from actual missile procurements. The FY 77 price level was selected for this study since it is the latest base year developed from inflation studies of Army missile procurement. These historical factors are shown in Appendix B. Second, adjustments have been made to procurement data to compensate for learning efficiencies gained through previous or follow-on procurement. Adjustments to contract cost data associated with a particular production lot quantity have been made through the application of regression analysis to the logarithmic transformation of the historical lot cost and quantity data. Utilizing the following equation, the data in Table 2 and Table 3 yielded a historical total production cost slope of 89.2 percent for the MQM-61A and 85.6 percent for the BQM-34A.

$$B = \frac{N \cdot \Sigma\,(\text{Log } x \cdot \text{Log } y) - (\Sigma \text{ Log } x \cdot \Sigma \text{ Log } y)}{N \cdot \Sigma\,(\text{Log } x)^2 - (\Sigma \text{ Log } x)^2}$$

where

B = the exponential slope of the learning curve

N = the number of data points

x = the algebraic lot midpoint of the lot quantity

y = the average unit cost for the production lot.

For the MQM-74C, MQM-107A and AQM-37A Target missiles where sufficient historical data could not be found to determine the total production cost slope, 87.4 percent was used, which is the average of the MQM-61A and BQM-34A slopes.

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APPENDIX A

REGRESSION ANALYSIS RESULTS

This appendix contains the results of applying regression analysis in ten separate equation forms to the historical data on six target missiles. The results of the best of these regression analyses (equation forms 1, 3 and 6) are suitable for predicting the airframe costs of a target missile where the estimated airframe weight will fall between 175 lb and 642 lb.

Two-Variable Screening Program

x = Airframe weight (lb)

y = Average Unit Production Cost for the first 700 Target missile airframes produced, in FY 77 constant dollars

Input Data

Target	x	y
BMQ-34A	642	$69,053
MQM-61A	234	16,869
MQM-74C	175	23,864
MQM-42	349	34,528
MQM-107A	365	29,579
AQM-37A	190	24,257

Output Data

Equation Form 1 $y = A + Bx$

A = 53.996
B = 101.190

Coefficient of Determination (r^2) = 0.89562
Coefficient of Variation (CV) = 0.20369

Equation Form 2 $y = A + B\ (LNx)$

A = -156280.433
B = 33321.881
r^2 = 0.76712
CV = 0.30424

Equation Form 3 $LNy = A + Bx$

A = 9.478

$B = 0.003$
$r^2 = 0.84381$
$CV = 0.02052$

Equation Form 4 $y = 1/(A + Bx)$

$A = 0.000$
$B = -0.000$
$r^2 = 0.68589$
$CV = 0.25608$

Equation Form 5 $y = A\ x^{\beta}$

$A = 241.405$
$B = 0.847$
$r^2 = 0.75198$
$CV = 0.02585$

Equation Form 6 $y = (A + Bx)^2$

$A = 95.704$
$B = 0.249$
$r^2 = 0.88260$
$CV = 0.09996$

Equation Form 7 $y = (A + B\sqrt{x})$

$A = -33282.221$
$B = 3773.384$
$r^2 = 0.83983$
$CV = 0.25231$

Equation Form 8 $y = (A + B\sqrt{x})^2$

$A = 12.914$
$B = 9.325$
$r^2 = 0.83591$
$CV = 0.11818$

Equation Form 9 $y = \sqrt{A + Bx}$

$A = -1579736181.953$
$B = 9082501.090$
$r^2 = 0.87770$
$CV = 0.47851$

Equation Form 10 $y = \sqrt{A + Bx^2}$

$A = -128010547.617$
$B = 11469.847$

$r^2 = 0.96016$
$CV = 0.27312$

A graphical portrayal of the selected form, $y = (A + Bx)^2$, for the Cost Estimating Relationship and the data points is shown in the following figure.

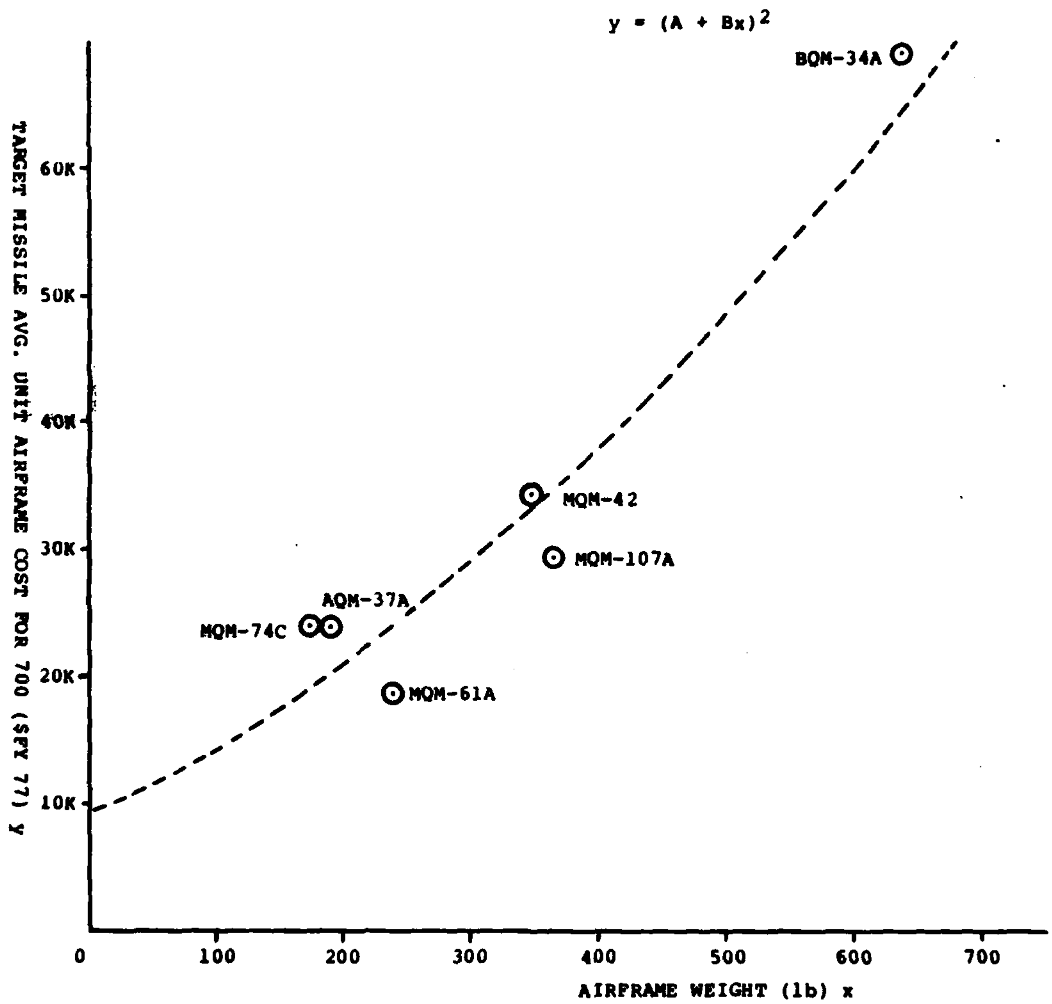

Figure A-1. Graph of $y = (A + Bx)^2$ for Cost Estimating Relationship.

APPENDIX B

HISTORICAL INFLATION INDICES

The following Historical Inflation Indices were developed from a study of missile system contracts and are used for adjusting pricing of missiles prior to FY 77 to an FY 77 Base Year Price Level.

Fiscal Year	Missile Index
1977	1.000
1976	1.070
1975	1.109
1974	1.161
1973	1.276
1972	1.328
1971	1.383
1970	1.429
1969	1.445
1968	1.522
1967	1.534
1966	1.546
1965	1.621
1964	1.658
1963	1.669
1962	1.684
1961	1.684
1960	1.692
1959	1.689
1958	1.733

The factor of 0.8202 for adjusting the MQM-74C from $ FY 79 to a base year of FY 77 was taken from the Missile Indices attached to DRCCP-ER letter dated 28 December 1977; subject: Inflation Guidance. The number 0.8202 is the reciprocal of the index (1.2192) for inflating from FY 77 to FY 79.

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