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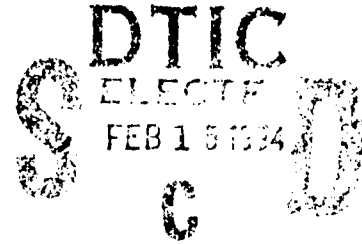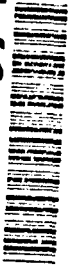
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Independent Cost Estimate
for
Full Scale Development and Production
of a
Future Military Transport Aircraft
by
Use of the Parametric Model FASTE

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INDEPENDENT COST ESTIMATE FOR FULL SCALE DEVELOPMENT AND PRODUCTION OF A FUTURE MILITARY TRANSPORT AIRCRAFT BY USE OF THE PARAMETRIC MODEL FASTE

In 1992 the "Industrieanlagen-Betriebsgesellschaft" (IABG), Munich, was tasked by the German Ministry of Defense (BMVg) with the performance of an independent development and procurement cost estimate for a new military transport aircraft, called "Future Large Aircraft" (FLA). At this time the FLA program was in the state of pre-feasibility studies.

Under consideration of the early phase of the project it was decided to make use of the parametric FASTE model which allows project cost estimating even if little information about the project is available.

The presentation shows the approach chosen by the cost estimators including analysis and preparing of reference data. The basic principle and input parameters of the FASTE model are discussed. Finally the results of trade-off-investigations in order to identify the effect of the variation of some key parameters on the expected costs are presented and described.

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Abstract

In 1992 the "Industrieanlagen - Betriebsgesellschaft" (IABG), Ottobrunn near Munich, was tasked by the German Ministry of Defense (BMVg) with the performance of an independent development and procurement cost estimate for a new military transport aircraft, called "Future Large Aircraft" (FLA).
At this time the FLA program was in the state of pre feasibility studies.

Under consideration of the early phase of the project it was decided to make use of the parametric FASTE model which allows project cost estimating even if little detailed information about a project is available.

The paper shows the approach chosen by the cost estimators including analysis and preparing of reference data.
The basic principle and input parameters of the FASTE model are discussed.
Finally the results of trade-off investigations in order to identify the effects of the variation of some key parameters on the expected costs are presented and described.

1. Introduction

At the end of the eighties the demand for a new European military transport aircraft arose in Europe.

This aircra ~alled Future Large Aircraft (FLA), is to replace the C-160 Transall which now has been . vice for more than 30 years and has no longer the capability to fulfill the requireme.it? ature military air transport, especially with regard to payload and range.

Seven European nations (Germany, France, Italy, Spain, Belgium, Portugal and Turkey) established and passed an "Outline European Staff Target" (OEST) which formed the basis of initial feasibility studies conducted by an international industrial consortium called "European Future Large Aircraft Group" (EUROFLAG).

Since early statements about the costs of future weapon systems get more and more important for the governments the "Industrieanlagen - Betriebsgesellschaft" (IABG), Ottobrunn near Munich, was tasked by the German Ministry of Defense (BMVg) to perform an independent development and procurement cost estimate for the FLA program being at this time in the state of pre feasibility studies.

It was decided to make use of the parametric cost estimating model FASTE because of severe time and funding restraints governing the performance of the task.

2. Short Description of the FASTE - Model

FASTE (Freiman Analysis of System Technique - Equipment) is a PC - capable parametric cost estimating model for equipment and/or hardware systems.

It allows project cost estimating even if little detailed information about a project is available.

Its basic principle is to derive the costs of a new system from the known costs and technical and economic conditions of one or more historical reference projects.

This is achieved by calibrating the model with the historical data and subsequent cost estimating runs.

In the following the most important input parameters of the FASTE model will be discussed.

PLATFORM

PLATFORM is the variable that defines the equipment stability of a system in terms of quality, reliability, maintainability, safety and performance under certain stress and environmental conditions.

PLATFORM values vary from 1.0 (ground based system) to 2.5 (manned space system).

For "military aviation" the PLATFORM value is about 1.8.

TYEAR

The TYEAR variable defines the technological year of the project effort.

By specifying the TYEAR, for example set to be 1980, the model assumes that the know-how, equipment, resources, and general level of technology are equivalent to those which were prevalent in 1980.

WEIGHT

If the weight of one unit of a specified equipment is known it can be entered in lbs or kg.

In contrast to various other cost estimating models the weight is not always required as an input .

ENTYPE

ENTYPE expresses the kind of technology of the equipment.
The higher the level of technology the lower the ENTYPE value.
The parametric value of the ENTYPE variable ranges from 40 to 140.
For example, the ENTYPE value for "aircraft systems" is about 50.
The appropriate value for ENTYPE can be defined from special tables or be computed by a special calculation procedure.

PMX

PMX is the resources and experience factor used as a component of the MXTYPE complexity factor. PMX is the variable that describes the organizational resources, skills, experience etc.
PMX can be used for adjusting the model to a specific productivity environment and is obtained by calibration or by a special calculation procedure.

MXTYPE

MXTYPE is one of the key factors in the FAST methodology and represents the composite complexity value for an equipment / a system.
MXTYPE is composed of three elements, PLATFORM, ENTYPE and PMX, which were defined above.
The MXTYPE value is obtained by calibration or by special calculation procedures.

QUANTITY (Prod.)

This quantity indicates the total number of units that are expected to be produced (in forward cost studies) or that have been produced (in calibration studies).

ENG. PROTOTYPES

This quantity indicates the number of engineering prototype units which are expected to be produced (in forward cost studies) or have been produced (in calibration studies).
The prototype quantity may be entered as a decimal number, e.g 3.5, allowing for partial units accounting for breadboard and brassboard models as well as various sub-assemblies.

START - DATES - FINISH

The input of start and finish dates of the specific effort is applicable to both production and engineering cost studies.
The start date must always be entered. Finish date input is optional, so its value will be calculated by the model when left blank.

PERFORMANCE CHARACTERISTICS ("cost drivers")

In contrast to other cost estimating models FASTE allows the user himself to define other cost relevant parameters if he considers weight not to be the main cost driver.
The user can enter one primary and up to three secondary performance characteristics from 12 "pre-defined characteristics" as cost drivers in FASTE.
This could be, for example, power (in HP), energy (in KJ) or flow (in cubicmeter/sec).
Furthermore, if all of the pre-defined characteristics are not applicable to his specific system, he is allowed to define an additional characteristic to be the cost driver.

In our FLA cost estimate the term (max. payload * range at max. payload) was used as the primary cost driver.

From the entered cost drivers the FASTE system computes the "FASTE Equivalent" and the "Weight Factor".

If - by calibration - these FASTE Equivalents and Weight Factors of two reference systems have been determined the user is able to define the corresponding values for the new system (for which the costs are to be estimated) by inter- or extrapolation.

The so derived FASTE Equivalent and Weight Factor of the new system can now be used as inputs in the forward cost study.

EMX

EMX is the complexity factor used for engineering (development) cost studies.
The EMX value is normally obtained by calibration.

NEWDES

NEWDES is used to indicate the amount of required new design effort.
NEWDES is entered as a decimal number, e.g. 0.75, which would mean that 75% of the design is new.

LEVEL

LEVEL is the variable that describes the difficulty of the work to be performed with respect to the character of the resources, skills and experience of those assigned to the performance of the effort.
The average value of LEVEL is 1.0.

Additional to the FASTE input parameters mentioned above there are remaining input parameters that, for example, deal with different materials, escalation rates, economic conditions, the amount of G&A expenses and profit etc.

Let us now take a brief view on the approach chosen by the cost estimators when performing the cost estimate for full scale development and production of the Future Large Aircraft.

3. Approach

The first step was to analyze the situation concerning the availability of appropriate reference data.

After identification of two suitable reference projects the cost data of these two systems were analyzed and escalated to constant economic conditions.

Now they could be used, in combination with the corresponding technical and schedule data of the reference projects, to calibrate the FASTE model.

The results of these calibration runs together with all the other parameters specific for the new aircraft (FLA) were used as inputs for the cost estimating runs for production and development.

After calibration the model calculated the estimated costs for development and production of the FLA and the optimal full scale development and production schedules to which these costs are related to.

After the development and procurement cost estimate was done the FASTE model was finally used to conduct trade-off investigations in order to identify the effects on costs by varying some key parameters, such as number of aircraft to be produced, number of prototypes, development and production schedules.

4. Analysis and Preparation of Reference Data

In order to be able to collect suitable reference data for the calibration of the FASTE model it was neccessary to investigate a number of available documents and informations about existing transport aircraft.

The following aircraft could be identified as basically suitable reference systems, regarding that the reference aircraft should be relatively "close" to the FLA concerning payload and range:

- Transall C-160

- Mc Donnell Douglas C-17

- Lockheed C-141 Starlifter

- Lockheed C-130 Hercules

In a next step the documents concerning these aircraft were analyzed, considering the availability of cost, technical and program data.
For the Lockheed C-141 Starlifter and the C-130 Hercules reliable cost data could not be identified.
For the Transall C-160 which was procured by the German Airforce from 1967 to 1972 detailed information could be gained about procurement cost and technical and program data.
Concerning the development cost of the C-160 Transall no reliable informations were available.

Regarding the Mc Donnell Douglas C-17 informations about the actual development payments per year as well as the planned development cost up to the end of full scale development could be obtained.
Further the planned procurement cost of the C-17 in "then year $" could be identified.
Sufficient technical and schedule data of the C-17 also were available.

The reference cost data mentioned above were now prepared and escalated to constant economic conditions in a manner that they could be used in combination with the corresponding technical and schedule data as input data for the calibration runs of the FASTE model.

5. Cost Estimate by Use of the FASTE - Model

According to the structure of the FASTE model the production cost estimate was conducted first.
Subsequently the development cost estimate was established.

5.1 Production Cost

For the production cost estimate two suitable reference systems had been identified, namely

- Transall C-160 and
- Mc Donnell Douglas C-17

That allowed us to perform the production cost estimate on the basis of a self-defined primary cost driver / performance characteristic.
Proceeding on the fact that the main operational requirement for a transport aircraft is to carry a specified payload over a specified distance it was decided to use the term

(max. payload * range at max. payload)

as primary cost driver in the production cost estimate.

So two calibration studies had to be performed:

- calibration with Transall data and
- calibration with C-17 data

Values for the following parameters both for the Transall and the C-17 were obtained from the calibration process:

- PMX
- MXTYPE
- FASTE Equivalent
- Weight Factor

These results were now used as a basis for the determination of the relevant input parameters for the FLA production cost estimate.
As mentioned above "(max. payload * range at max. payload)" was defined as primary cost driver.
This figure was known for the two reference systems, Transall and C-17, and for the FLA as well, for which the costs should be estimated.
Now two "curves" could be plotted on each of two sheets of log-log paper.
The first graph showed the FASTE Equivalents on its y-axis and "(max. payload * range at max. payload)" on its x-axis.
The second graph had the Weight Factors on its y-axis and "(max. payload * range at max. payload)" on its x-axis.
The reason for using a log-log graph is because the functions being plotted are hyperbolic in nature, and so they will plot as straight lines. If linear graph paper were used the plotted functions would be curves requiring several more than two points to plot the accurate curve shapes.
Now the values of FASTE Equivalent and Weight Factor specific to the FLA could be determined by interpolation.
With these projected values of FASTE Equivalent and Weight Factor the forward cost study for the new aircraft could be conducted with these two values as inputs.
On the assumption that there is no essential difference in general complexities between the C-17 and the FLA the MXTYPE value of the C-17, obtained by calibration, was also used as input for the FLA production cost estimating run.

With these values of FASTE Equivalent, Weight Factor and MXTYPE in combination with the FLA specific technical and program data the forward cost study delivered the following results:

- production cost for the given number of aircraft
- "optimal" finish date of production
- estimated empty weight of FLA

5.2 Full Scale Development Cost

The cost estimate for full scale development of the FLA was conducted after having performed the production cost estimate.

Since there has been identified only one appropriate reference system concerning full scale development cost (the C-17) the performance of a cost estimate based on a self-defined cost driver was not feasible in this case.

Because of this fact the empty weight of the aircraft was used as the main cost driver.

So only one calibration study had to be performed using as inputs the analyzed cost data as well as the technical and program data of full scale development of the C-17.

As result of this calibration run the value for the engineering complexity factor

EMX

for the C-17 was obtained.

The forward cost study for full scale development was executed after having entered the specified empty weight of the FLA and the EMX that was assumed to be equal to that of the C-17 together with the FLA specific technical and program data.

It delivered the following results:

- full scale development cost of the FLA
- "optimal" finish date of development.

6. Parameter Variations

The costs established by the FASTE model represented "optimal" costs, i.e. the model computed an optimal schedule for full scale development and production to which the minimum development and production costs are related to.

For that reason finally trade-off investigations were conducted in order to identify the effects of the variation of some key parameters on the costs.

These investigations included

- variation of number of aircraft to be produced
- variation of production schedule
- variation of development schedule
- variation of development schedule and number of prototypes

Variation of number of aircraft to be produced:

For different numbers of aircraft to be produced FASTE production cost estimating runs were conducted without changing any other input data.

So the interdependence of the average manufacturing cost and the number of aircraft to be produced could be easily quantified.

Variation of production schedule:

The effects of different production schedules on the production costs were determined for a given number of aircraft to be produced.
Several production cost estimating runs, each with a different production finish date while retaining the residual input data, delivered the relationship of production costs vs. production schedule.

Variation of development schedule:

By retention of the residual input data different development finish dates were entered.
So the effects of different development schedules on the full scale development costs were identified.

Variation of development schedule and number of prototypes:

Beside the duration of full scale development the number of equivalent prototypes to be built is also of importance for the development costs.
Therefore an additional investigation was conducted in order to demonstrate the impact of different development schedules in combination with different numbers of engineering prototypes on the full scale development costs.

7. Conclusions

In order to conduct the independent cost estimate for full scale development and production of the FLA it was decided to make use of the parametric cost estimating model FASTE.
So the cost estimators were in the position to perform this task in an early phase of the FLA project during a relatively short period of time.
In contrast to various other cost estimating models FASTE allows the user himself to define essential cost drivers (performance characteristics) if he considers the weight of an equipment or system not to be the main cost driver.
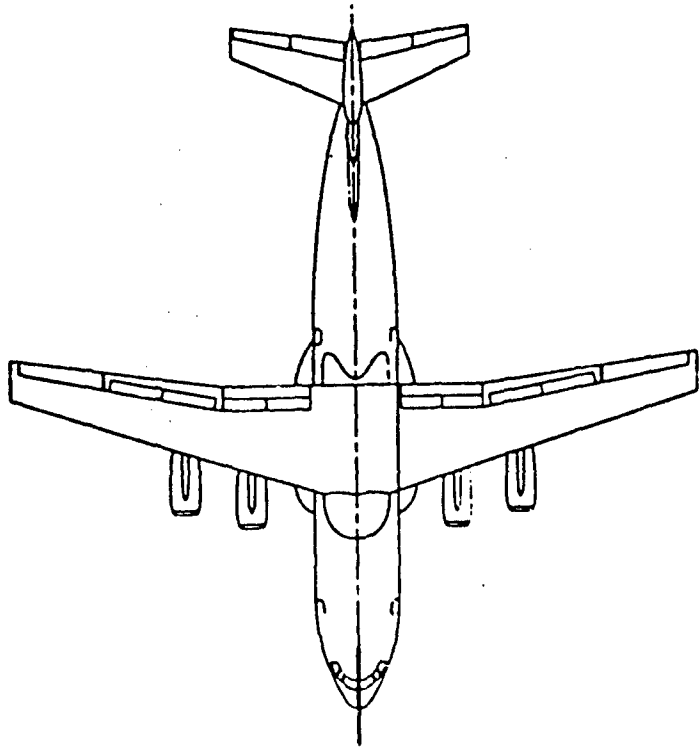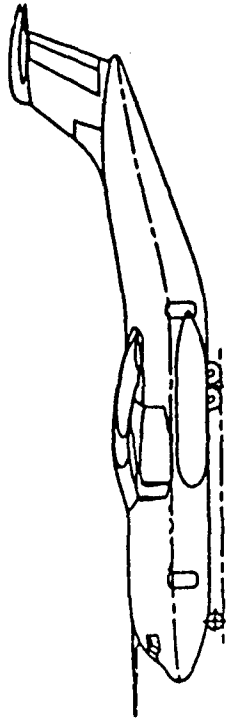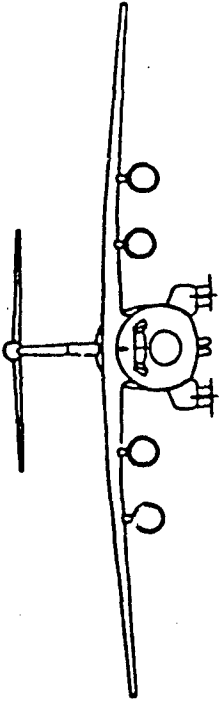This represents a very interesting approach and offers great flexibility.
Nevertheless the quality of the results of the cost estimate strongly depends on the availability and quality of reference data.

Future Large Aircraft (FLA)
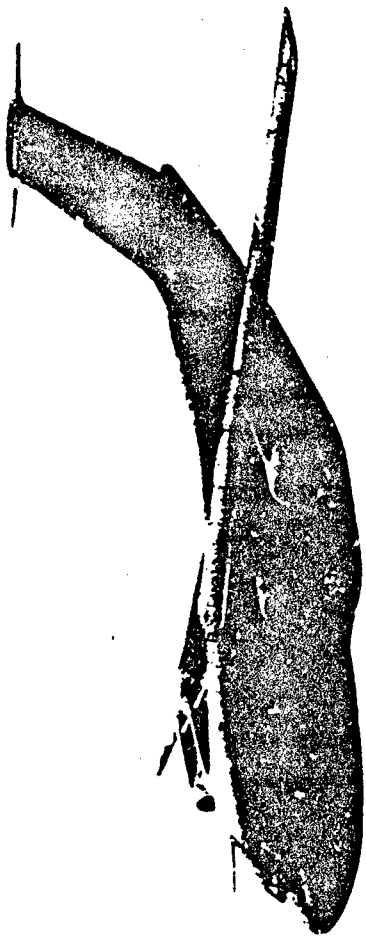
Future Large Aircraft (FLA)

FASTE

"Freiman Analysis of System Technique - Equipment"

A parametric cost estimating model for equipment / hardware system

Useful for early cost estimating

Basic principle

estimating the costs of a new system after calibration with
historical data of one or more appropriate reference systems

FASTE Parameters

PLATFORM

defines the equipment stability of a system in terms of quality, reliability, maintainability, safety and performance under certain stress and environmental conditions

TYEAR

defines the technological year of the project effort (know-how, general level of technology)

WEIGHT

the weight of one unit of equipment is not always a required input

ENTYPE

expresses the technology of the equipment the higher the level of technology the lower the ENTYPE value

FASTE Parameters

PMX

resources and experience factor
indicates the organizational resources, skills, experience etc.
obtained by calibration or special calculation procedure

MXTYPE

represents the composite complexity value for an equipment/system
composed by PLATFORM, ENTYPE and PMX
obtained by calibration or special calculation procedure

QUANTITY (Prod.)

indicates the total number of units expected to be produced

ENG. PROTOTYPES

indicates the number of equivalent engineering prototype units
may be entered as a decimal number, e.g. 3.5

FASTE Parameters

START-DATES-FINISH

start and finish dates of production or development
start date must always be entered, finish date input is optional

PERFORMANCE CHARACTERISTICS ("Cost Drivers")

FASTE allows the user to define cost drivers by himself
12 "pre-defined characteristics" usable as cost drivers are available
e.g. power (HP) or flow (cubicmeter/sec)

1 primary and up to 3 secondary cost drivers can be defined
other cost drivers can be defined if pre-defined characteristics are not applicab
use of "FASTE-Equivalent" and associated "Weight Factor"

EMX

complexity factor for engineering cost studies
obtained by calibration

FASTE Parameters

NEWDES

indicates the amount of required new design effort, e.g. 0.7

LEVEL

describes the difficulty of the work to be performed with respect to the character of the resources, skills and experience of those assigned to the performance of the effort

Other Input Fields

take into account, e.g. different materials, escalation rates, economic conditions, G&A expenses and profit etc.

Approach

1. Analysis of available reference data

2. Selection of suitable reference systems

3. Collection, evaluation and preparation of reference data

4. Calibration of the FASTE model

5. Cost estimating runs

6. Trade-off investigations

Analysis and Preparation of Reference Data

1. Selection of suitable reference systems
(max. payload, range at max. payload)

Transall C-160

- production cost data
- technical and schedule data

Mc Donnell Douglas C-17

- actual development payments and planned development cost data
- planned procurement cost data
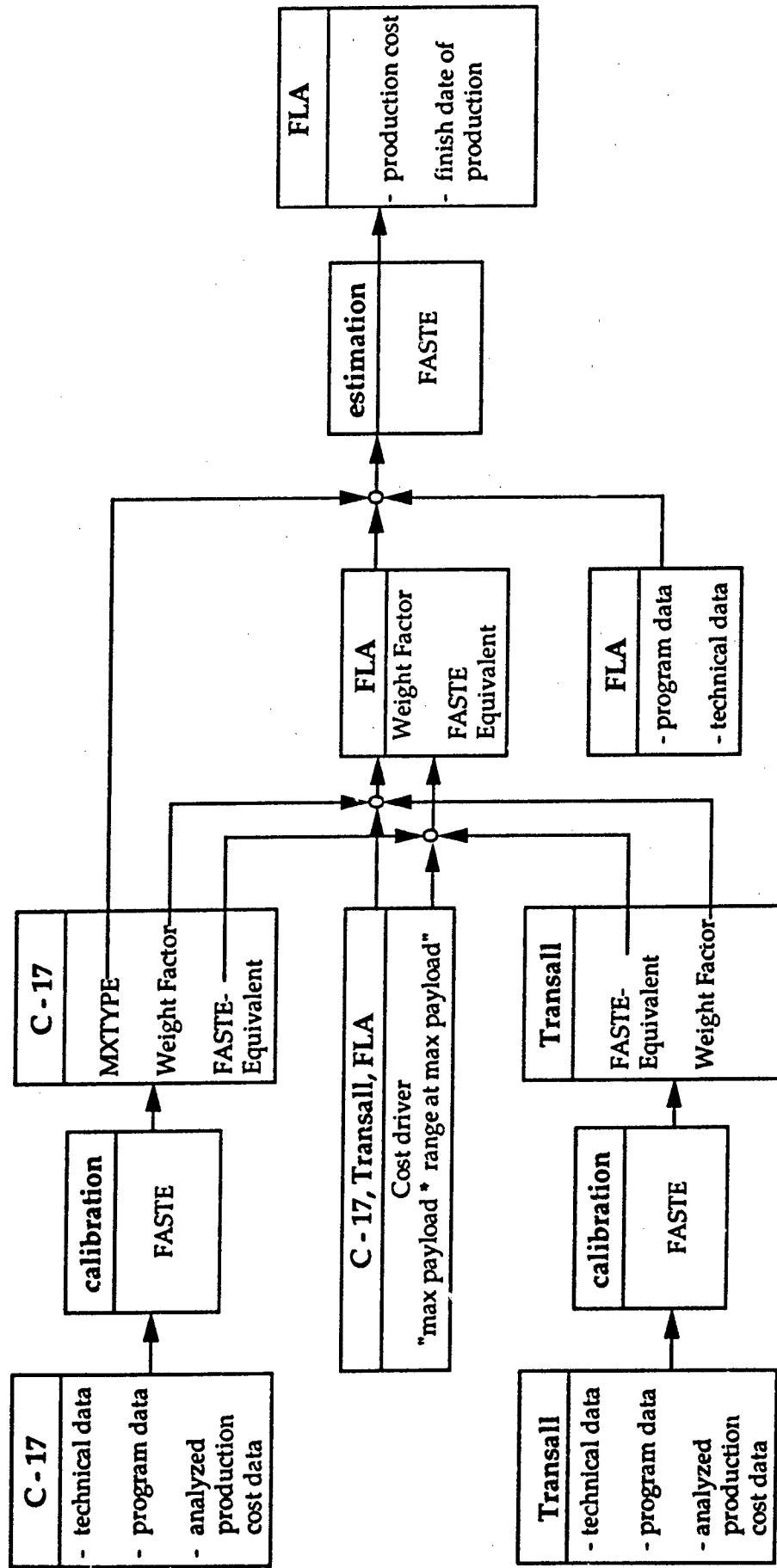- technical and schedule data

2. Preparation of reference data

constant economic conditions
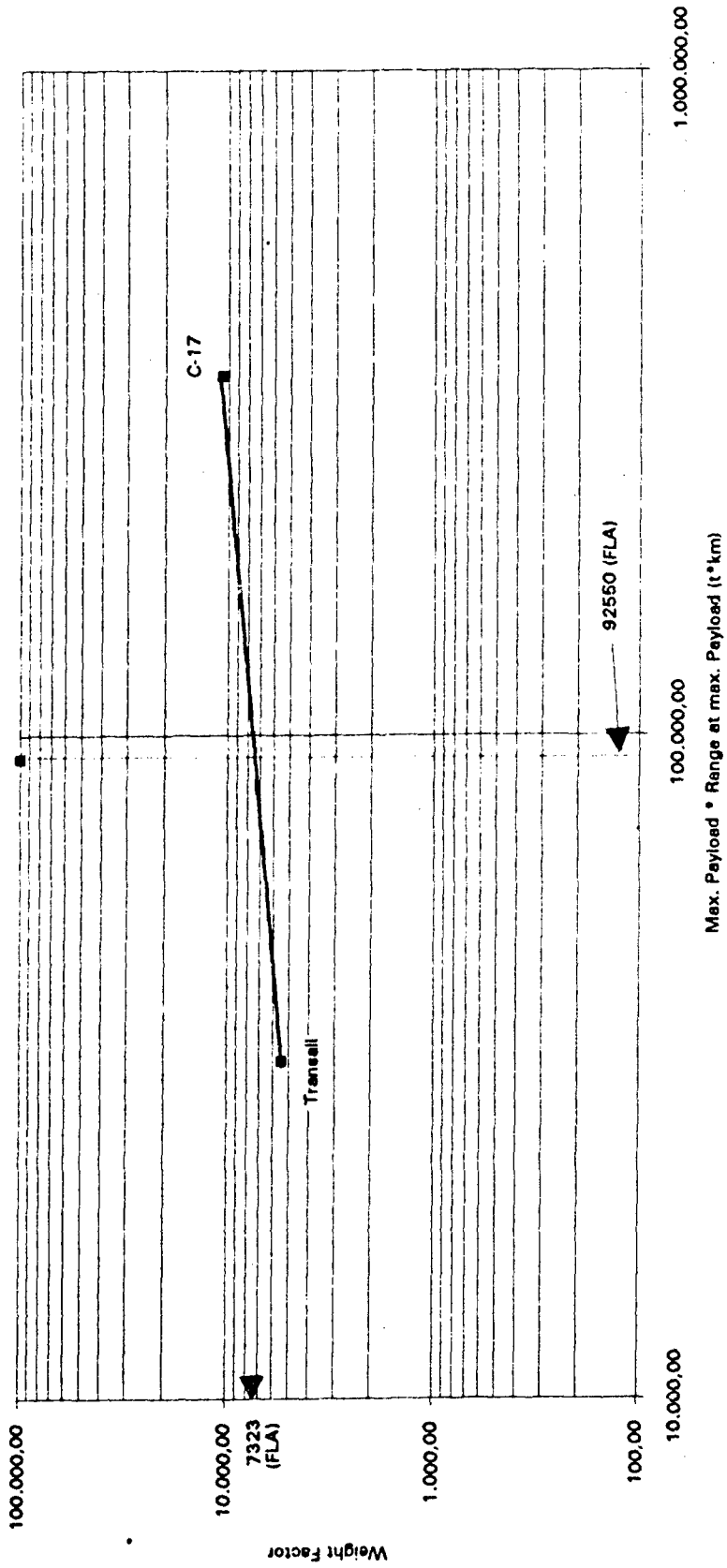analyzed data usable for calibration of the FASTE model

Range at max. Payload vs. max. Payload of Various Transport Aircraft
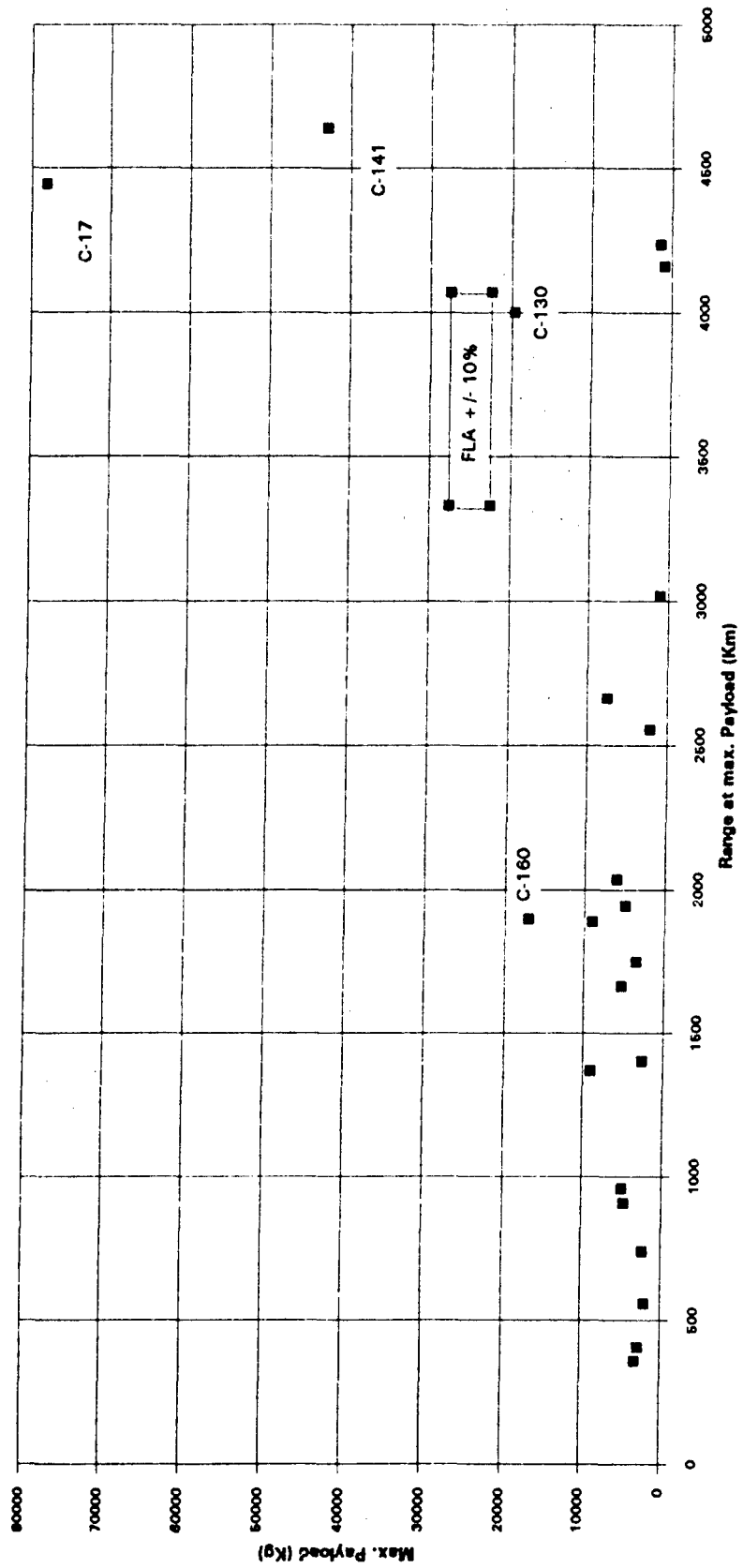
FLA Production Cost Estimate

Determination of Weight Factor for the FLA (Production)

Axes:
- Y-axis: Weight Factor — 100.000,00 / 10.000,00 (7323 (FLA)) / 1.000,00 / 100,00
- X-axis: Max. Payload • Range at max. Payload (t*km) — 10.000,00 / 100.000,00 / 1.000.000,00

Labels on plot: C-17, Transall, 92550 (FLA)

Determination of FASTE Equivalent for the FLA (Production)

FASTE Equivalent

222989 (FLA)

C-17

Transall

92550 (FLA)

Max. Payload * Range at max. Payload (t*km)

1.000.000   100.000   10.000
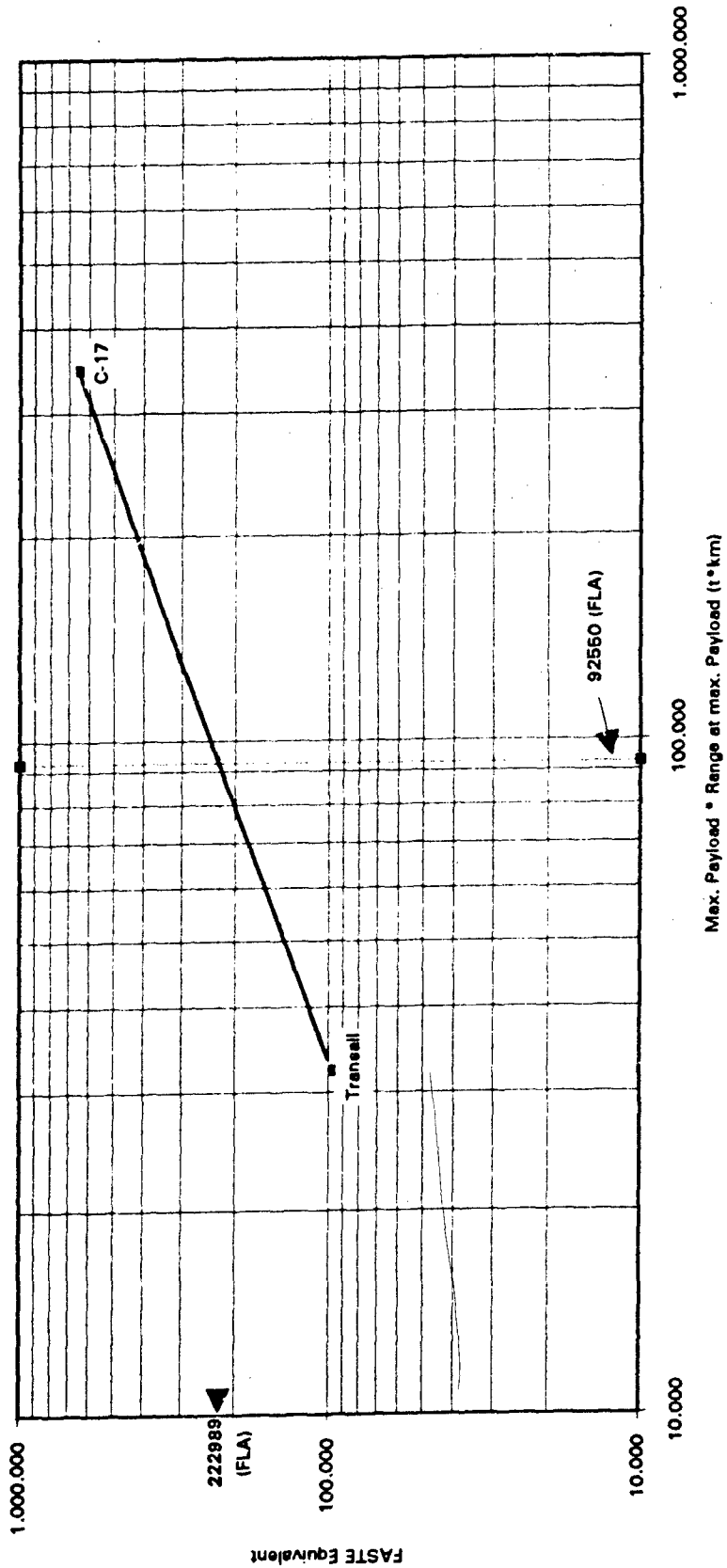
FLA Development Cost Estimate
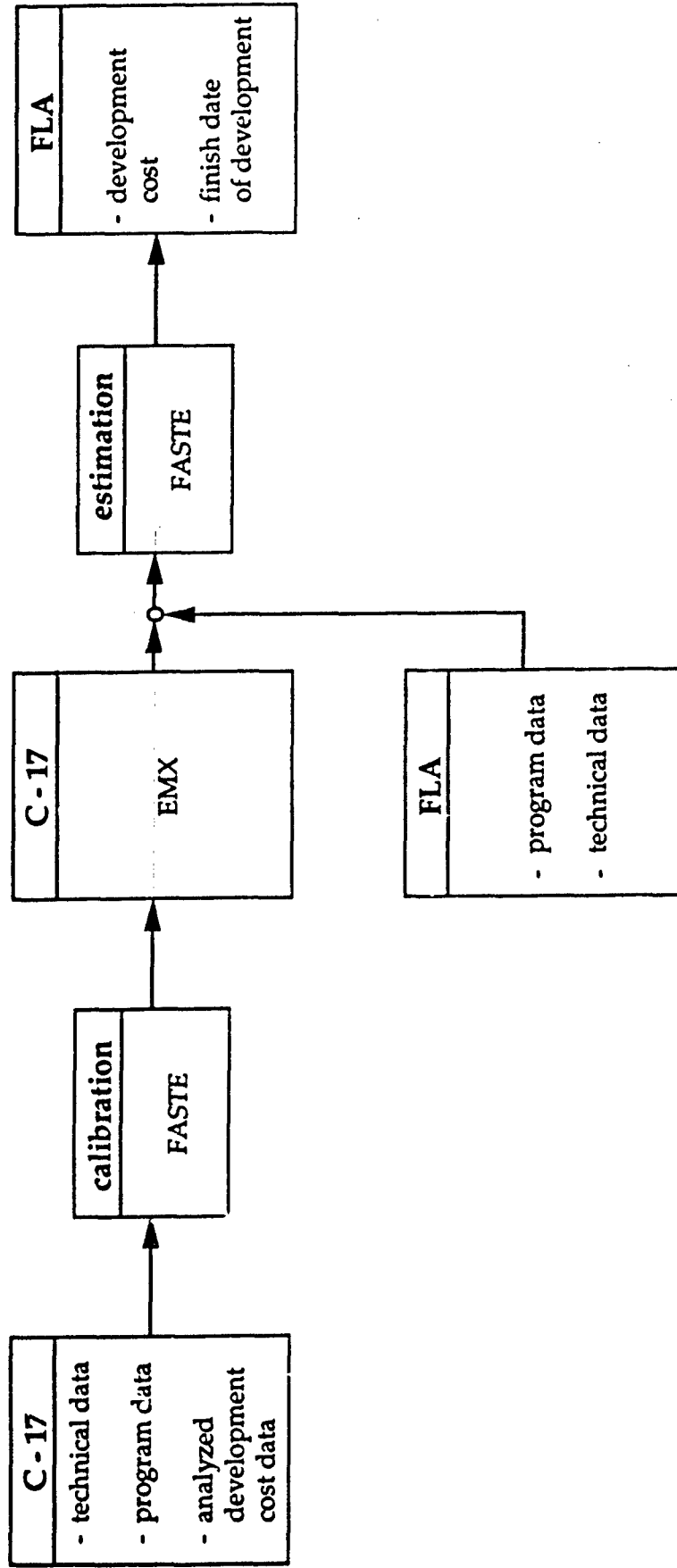
Average Manufacturing Cost/Aircraft vs. Number of Aircraft to be produced

Y-axis: Average Manufacturing Cost/Airc aft (%)

X-axis: Number of Aircraft to be produced

Variation of Development Schedule

4.5 equivalent Prototypes

Development Start Jan. 1995,

100%

"FASTE - Optimum"

Full Scale Development Cost (%)

Development Finish Date

220 200 180 160 140 120 100 80 60 40 20 Dec. 1999

2000 2001 2002 2003 2004 2005

Variation of Production Schedule

Production Start Jun 2001
300 Aircraft

"FASTE - Optimum"

100%

Production Cost (%)

150 130 110 90 70 50

January 2005   2006   2007   2008   2009   2010   2011   2012

Production Finish Date
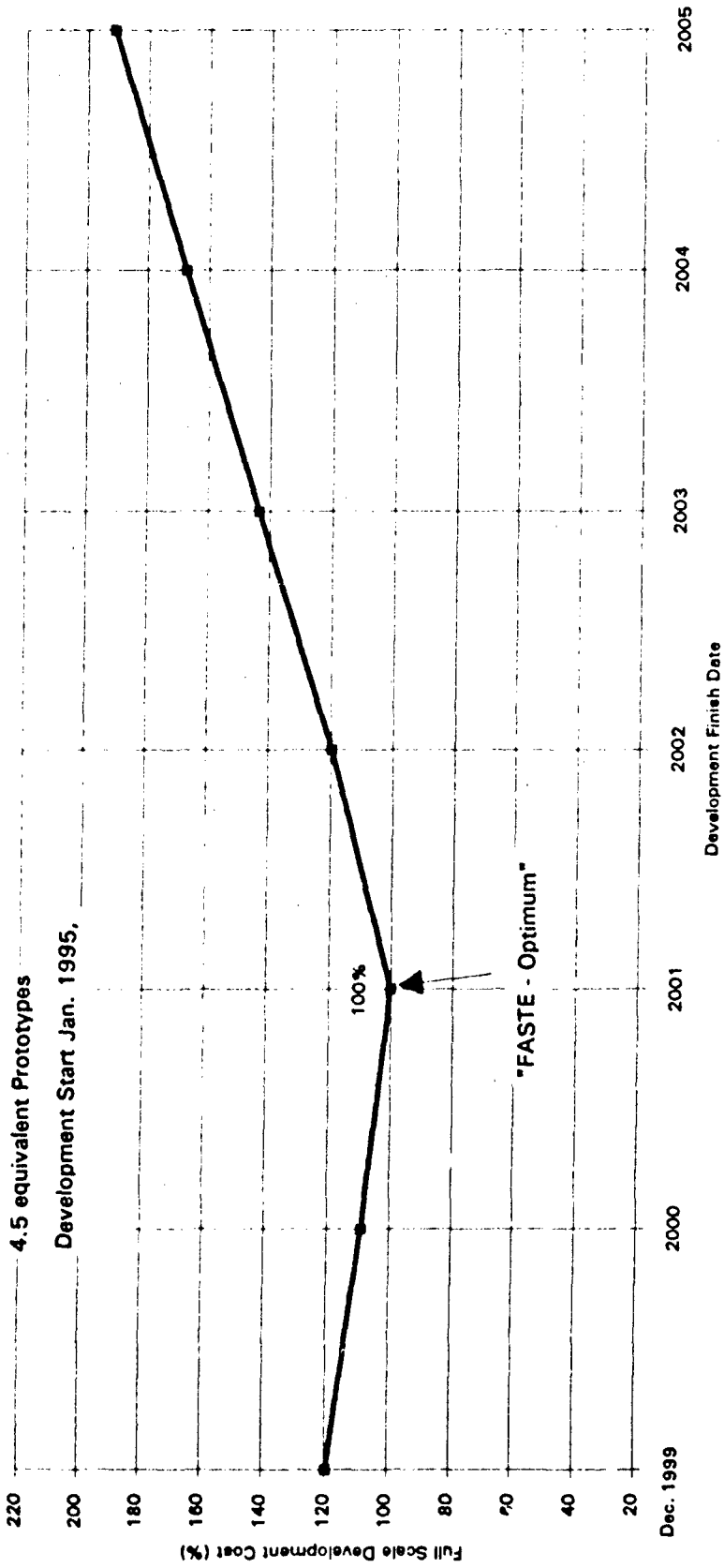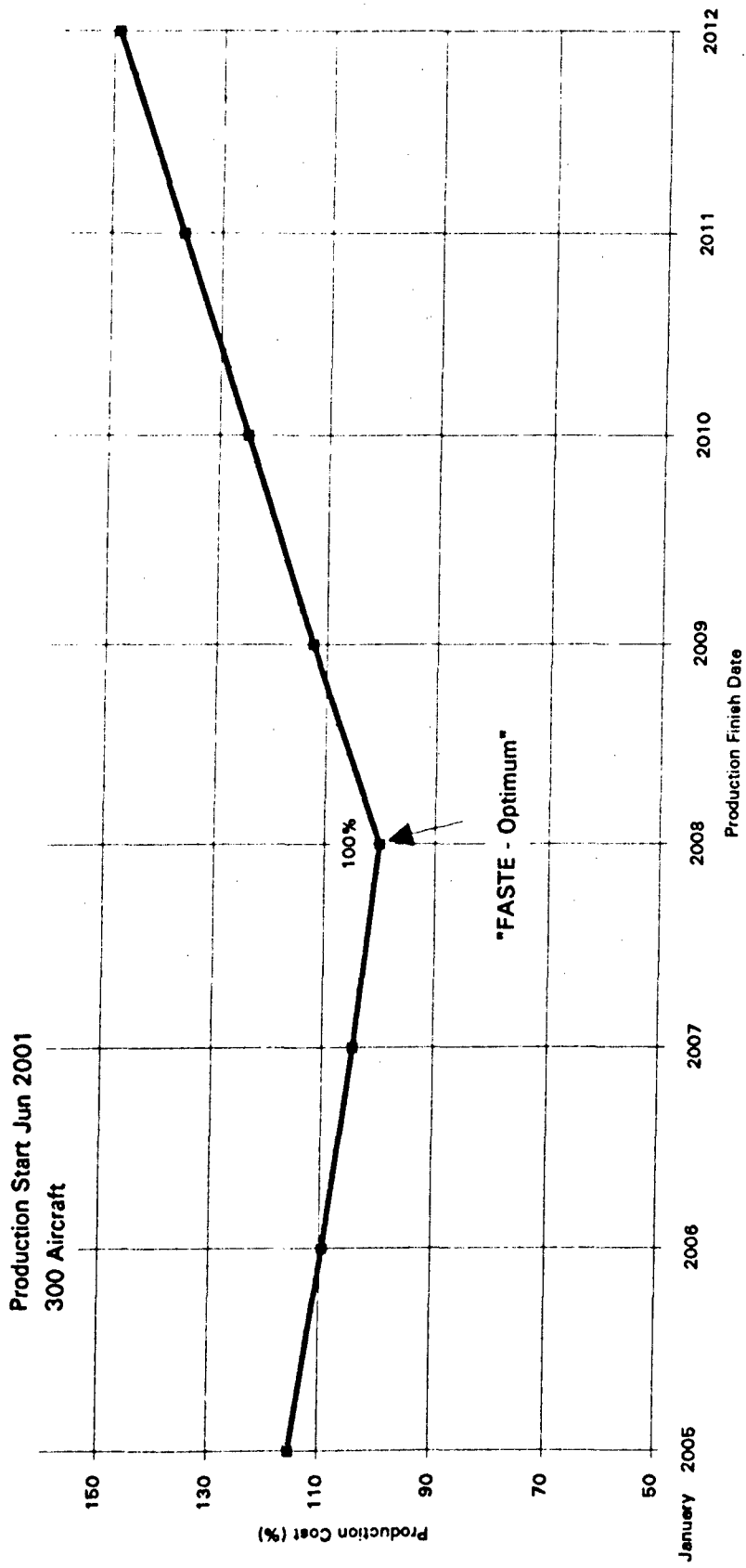
Variation of Development Schedule and Number of equivalent Prototypes

Development Start Jan. 1995

Full Scale Development Cost (%)

200

180

160

140

120

100%

100

80

60

40

20

Dec. 2000 — 2001 — 2002 — 2003 — 2004

Development Finish Date

Legend:
- 5.5 equiv. Prototypes
- 4.5 equiv. Prototypes
- 3.5 equiv. Prototypes