The appropriate use of contract types in development contracts
(A systems approach with emphasis on the European space sector)

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ABSTRACT

Development contracts are relatively new and are closely related to recent technological developments. The traditional types of contract (firm fixed price and pure cost reimbursement) were found to be an inadequate means of controlling the expenditure and management of such developments.

An historical review shows that as a result of a gradual heuristic process a number of 'intermediate' types of contract have come into being, most of them containing 'incentive provisions'. These variants originated mainly in the USA, where they were used for government procurements, and have only hesitantly been adopted elsewhere. ESA, the European Space Agency, has been almost the only promoter of these innovative types of contract in Europe. It was for this reason that ESA was chosen as the pilot environment for the purposes of this study.

A systematic modelling approach has been followed. A general contract model and its characteristics have been established, while specific models have been developed for the three contractual parameters of major influence (cost, delivery time and performance). As a result of this approach, it has been possible to establish specific formulas for cost and delivery incentives. Qualitative guidelines are presented for performance and multiple incentives.

Finally, a model is presented in the form of a decision tree. This makes it possible to select objectively the most appropriate type of contract while taking into account the various environmental influencing factors together with the interests of both parties (client and contractor). In addition, the model and its underlying rationale help to bridge the communication gap that separates technical staff and contract administrators.

In this study, the model has been successfully tested and has shown itself to be a valid and practical tool that greatly assists the users in making a correct choice of contract type on the basis of systematic and logical considerations.
PREFACE

The text of this report is almost identical to that of a doctoral thesis. The study of which it is the outcome was undertaken during the period 1984 - 1987 in the Faculties of Mechanical Engineering and Aerospace Engineering in the Section of Industrial Organisation and Management of the University of Technology, Delft, The Netherlands.

The study was guided by Prof.ir. J. in 't Veld, who acted as 'Promotor'. There is no doubt that the numerous discussions the author has had with him, his suggestions and his encouragements have been a powerful influence in achieving the result contained in these pages.

Useful comments have also been made by the other members of the promotion committee: Prof. dr. ir. H.F. van Beek, Prof. drs. W. Bloemendal, Prof. dr. G.G. Bos, Prof. dr. ir. O.H. Gerlach (and his co-operator drs. A. de Graaff), and Prof. mr. dr. M.M. Mendel. Prof. drs. W. Bloemendal in particular has spent a considerable effort in commenting on the manuscript, in the process also introducing very valuable practical inputs (representing industry's point of view).

A lot of patience was required from my wife, Lieve, since many evenings and weekends were devoted to writing this text, which should have been devoted to her.

In addition to all this, much help with the processing of the text was received from both Catja and Trix, who spent many hours in front of somber word-processing screens.

Last but not least, I gratefully acknowledge the assistance of ESA in supporting this study. Special emphasis should be given to the support given by Mr. W. Siemers as well as to the contribution made by Mr. S. Kahn in ensuring the liaison with ESA (he was also a member of the promotion committee). The ESTEC Library staff, led by Mrs. E. Oldroyd, were most helpful in acquiring obscure references and in building up a relevant database. Members of Mr. N. Longdon's ESA Publications Division, especially Mr. W.R. Burke as dedicated editor, have made this study presentable.
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CHAPTER 1
INTRODUCTION

1.1 REASON FOR THIS STUDY

Development contracts are relatively new and are currently becoming increasingly important. Initially, the types of contract used for development were identical to classical procurement contracts. Later, it became evident that other types of contract were needed to cope with the characteristic aspects of development contracts. The main reason for the present study was to highlight this recent development and to suggest further improvements, from a technical point of view.

Although a wide variety of definitions exists, a number of elements are essential for each contract. Essential prerequisites are:

— competent parties;
— a proper subject matter;
— an offer and acceptance thereof (i.e. agreement between the two parties);
— agreed consideration (mode and terms of payment).

For the purposes of the present study, we shall consider a contract to be an agreement between two parties, whereby one party commits itself to deliver (clearly specified) goods, software or services to a second party, within a certain delivery time and for an agreed price. The party delivering goods is, in this study, called the contractor; the party ordering the goods is called the client.

It then becomes evident, however, that in the first instance the two parties have different interests. If it were possible, the client would aim for a perfect product at a minimum expenditure within a minimum delivery time, while the contractor would try to deliver an acceptable product (i.e. one meeting the specifications) with a maximum profit at a convenient time (for him).

Note, however, that in reality the situation will not be so extreme. The client will try to obtain for himself an optimum balance between price, delivery time and performance; the contractor will also try to reach such an optimum for himself, but will consider other elements too, such as continuity, technological spin-off etc.

In this context, both parties will try to promote their own interests by introducing contract conditions that will protect their final goals. One of the most important elements in this discussion will be the choice of the type of contract.

Traditionally, the client will often prefer a firm fixed price arrangement as, in his opinion, this will represent a minimum (budgetary) risk. Whenever the risk is difficult to quantify, however, the contractor will be hesitant to accept (part of) this risk and will, therefore, prefer a cost-reimbursement type of contract.

Nevertheless, under normal circumstances, both parties will try to find a concensus for this
conflict. It is this drive towards agreement that has generated a number of intermediate types of contract. Certainly, during the last two decades, a number of heuristic contract types have been developed as a result of this bargaining process. Thus, most contract types have originated, initially, in response to typical circumstances. A number of results and experiences are now available and, consequently, there is a need for re-evaluation and even reconsideration.

On the other hand, no systematic survey of the overall interrelationship of these contract types has yet been made. If a ‘firm fixed price’ on the one hand and a ‘cost plus percentage fee price’ on the other hand are considered as two extremes, the results of this study will show that a number of intermediate solutions exist that may be acceptable to both parties.

In view of this, the present study has been undertaken as a systematic approach to solving the problem of deciding which type of contract to choose. As a result, a methodology will be presented which will enable the appropriate contract type to be determined in advance, in contrast to the heuristic methodology used hitherto.

1.2 OBJECTIVES OF THIS STUDY

It is necessary to distinguish clearly between choosing a type of contract and choosing a contractor. This study will not deal with the latter aspect. In this specific area of hi-tech development contracts, the client has a very restricted choice of contractors. A number of constraints are, for example:

— of a technological nature: in certain areas of advanced technology, the number of valid competitors is very limited;
— of a political nature: the client will definitely take into account certain elements such as level of employment, priority for local suppliers, social considerations, confidentiality, and so on. This effect will be greater if the client is a government or military institution;
— due to agreements: such as geographical return, EEC quota and so on.

A combination of these constraints often results in so-called direct negotiations (sole source procurement), where the selected contractor is known in advance.

We shall not concentrate on this contract awarding process. In other words, we assume that the contractor has been selected and that negotiations have been initiated. It is evident that, under such circumstances, the client’s negotiator is faced with a difficult task and can only try to make the best of it. The client will try to protect his interests by insisting on an acceptable type of contract.

We noted earlier that, in most cases, the contractor will aim for a cost reimbursement contract. In a number of cases, the client will have to admit that this type of contract is the only possibility. Nevertheless, he will still try to include the necessary safeguards against cost and schedule overruns. Incentives represent an attractive compromise: the contractor obtains his main objective (in the basic contract type) and the client can include his safeguards.

Besides this important consensus aspect (Kahn, an ESA official, often calls incentives the lubricant of the negotiation mechanism), there is also a budgetary interest for the client. As we shall show in Chapter 3, McNamara stated that the choice of a more appropriate type of contract would result in a yearly budget saving of ten percent. Antagonists have shown that this figure was rather overoptimistic, but it is generally accepted that savings in the order of three to four percent are feasible. In view of the fact that the clients we are discussing are mainly governments (or delegated bodies), it is evident that such savings are worth aiming for. Such relatively small savings (in percentage) represent important absolute savings (in monetary terms).
The techniques described in this study can therefore provide governments with attractive alternatives in terms of budget savings; they will, ultimately, be interesting to individual taxpayers.

It is not possible to measure the effect of such incentives accurately. In theory, one should perform experiments in which the same procurement is initiated in duplicate by the same client with the same contractor, but with two different types of contract. Obviously, in practice, such experiments are not feasible.

In view of the impossibility of implementing such real-life experiments, we shall use modelling techniques to demonstrate the effect of different incentives.

1.3 LIMITATIONS

In order to avoid misunderstanding, it must be clearly stated that legal aspects explicitly fall outside the scope of this study.

The essence of a contract is applicable in a wide variety of circumstances and conditions. The implementation, therefore, can also differ widely. In this case, specifically two areas will be considered.

First of all, we shall concentrate on ‘development contracts’ as opposed to serial product procurement. Indeed, it is inevitable in the first area, where specifications are sometimes relatively unclear and risks relatively high, that major discussions on the type of contract should exist. In serial contracts, where the product is known to both parties, the price will generally be the major point of discussion (besides delivery time, acceptance procedures and financial/administrative arrangements).

Furthermore, we shall lay emphasis on governmental and supranational clients. In general, they will be the main partner initiating these large development contracts. Moreover, the control mechanisms and procurement strategy will be considerably different from those applied in production contracts and the purchase of smaller elements.

These two provisos do not exclude the use of the results of this study in other areas. Nevertheless, the validity of the models will then have to be examined carefully, as other parameters may be involved. Furthermore, experience has shown that the need for a wider range of contract types does not in general exist in these commercial areas. On the occasions when the need does arise, it is the aim of this study to prove that the results will give a useful input and guideline.

1.4 PILOT ENVIRONMENT

As we mentioned earlier, we wish to evaluate experience obtained with several types of contract. A number of studies have made use of experience in the USA, mainly concerning defence acquisitions. In the course of this study, it will be shown that this experience cannot be extrapolated unreservedly to our European context (see also Section 10.3).

In Europe, however, only the space industry in general and ESA, the European Space Agency, in particular, can claim to have experience with the implementation of different types of contract over the last twenty years. This experience, however, has to be systematically analysed.

As, furthermore, commercial contracts are not the basic objective of ESA, in principle most contracts concluded can be classified as development contracts. The ESA environment can,
therefore, be considered as a typical example of our problem area. Any model can only be properly validated, if it can be tested against reality; this explains the choice of this typical environment, for which data were available and accessible.

These elements and the major characteristics of this pilot environment will be outlined in Chapter 4.

1.5 LIMITATION OF TERMINOLOGY

The terms which are frequently used in this area will be described in the next chapter and are summarised in a glossary. One specific term, however, is also often used in another context, i.e. ‘incentive contracting’. In order to avoid any confusion, we shall briefly summarise some other areas in which this term is found. Certainly, the use of computerised databanks may lead to the appearance of articles belonging to one of the categories mentioned below.

The term incentive (contracting) is also used in connection with:

1) ‘Labour Incentive Contracts’, whereby personnel are rewarded in tangible ways for their cost-reducing activities, or ‘Manager’s Incentive Contracts’, which are contracts containing an incentive clause, linking the manager’s salary to his company’s (department’s) result. This area belongs to personnel management studies. A survey article on this topic has been written by Lehman [1].

2) The element ‘Performance Incentives for Higher Education’ can also be found in recent literature. Here, a portion of the funds that state-run colleges and universities receive is related to the excellence of the services for which they are chartered. We can refer here to Bogue and Brown [2].

3) Finally, there is also an extensive literature on ‘Government Incentive Contracts with Private Enterprises’. In this case, reference is made to financial agreements, e.g. tax reductions, granted by governments as compensation for certain performances. See, in this context, also Hildebrandt [3] for further information.

These areas are mentioned here briefly to avoid possible confusion. They are not, however, dealt with in this study.

1.6 SCIENTIFIC METHODOLOGY

As mentioned above, one of the primary objectives of this study was to develop the subject in a systematic way. The idea underlying the study originated from an extensive literature search. When the need was felt to have a more scientific approach to this subject, an extensive search, using computerised databanks (as NASA STAR, ABI, PASCAL etc.), was performed. Other scientific studies, however, merely concentrated on describing the (statistical) outcome of different contract types and did not adequately cover contract type suitability. Typical examples are Orkand [4] and Belden [5]. We find here techniques — or their application — for the evaluation of a posteriori results of the use of certain types of contract. No adequate systematic approach on an a priori basis (i.e. evaluation of the initial suitability) is presented.

As for the basic methodology, reference is made to the systems approach developed by In 't Veld [6] and to specific elements studied by De Leeuw [7]. We can, therefore, also regard this study as a typical extension and practical application of these fundamental works.
1.7 COMPOSITION OF THE STUDY

We shall start with a clear definition of the terminology used. This will be done in the description of the different types of contract that constitutes Chapter 2. Since it is necessary to (re-)evaluate the results of past experience, a brief historical overview of contract types will be given and relevant literature will be summarised; this will be done in Chapter 3. The main results will be tested against a pilot environment; consequently, some major characteristics of this environment need to be described; this is the subject of Chapter 4.

In Chapter 5 we shall describe the systematic approach followed. Basically, for each element a model will be developed and illustrated (if possible quantitatively) within the pilot environment.

Chapters 6, 7 and 8 will follow this approach for cost-related, delivery-time-related and performance-related incentives, respectively. These three incentives will be combined in Chapter 9.

Before a final systematic classification can be given, a number of environmental and related factors that might influence the final choice, will have to be explained; this will be done in Chapter 10. In Chapter 11 we can then finally combine all previous elements into a single decision tree. The results of the study will be evaluated and validated in Chapter 12.

The last chapter will summarise the most significant overall results of the study. The study can thus be considered to consist of two parts: the first (chapters 1 - 5) describing the background information collected from literature, the second (from Chapter 6 onwards) describing the suggested improvements.

1.8 REFERENCES

CHAPTER 2
CONTRACT TYPES

2.1 INTRODUCTION

Traditionally, two different types of contracts were used:

— A Cost Plus Fee price contract, in which all justified costs are paid and the fee is added as a fixed percentage. The final price, in this case, is therefore determined by postcalculation.

— A Firm Fixed Price contract, in which no further allowance for adjustments is made. The price of this contract is therefore determined by precalculation.

A typical element of the intermediate types of contract, which we shall describe in this chapter, is the link between precalculation and postcalculation. Besides describing the different variants, we shall also indicate typical areas of applicability, in order to establish a preliminary answer to the obvious question: Why do we need so many types of contract?

The main sources from which the descriptions of these various types of contract have been drawn are:

— DOD and NASA Incentive Contracting Guide [1]; this document, which can be considered as the major guideline, is currently being updated;

— Armed Services Procurement Regulation [2]; this gives more general details, laying emphasis on contract negotiations;

— U.K. Ministry of Defence: Incentive (target cost) Contracting [3]; a more synoptic guide, largely similar to the previous two references;

— Pace: Negotiation and Management of Defense Contracts [4]; this book presents a very extensive approach and can be considered as a guideline for contractors (whereas the previous documents tended rather to represent the client’s point of view). A considerable amount of practical experience is included. This book, unfortunately, seems to have escaped the attention of other authors and is seldom found as a reference.

— ESA: General Clauses and Conditions for ESA Contracts [5].

It should be noted here that there is a slight difference between USA and UK terminology. USA terminology, which is the most generally encountered one, is adopted in this text.

2.2 DIFFERENT TYPES OF CONTRACT

The two extreme types mentioned in Section 2.1 belong to two groups of contracts:
(1) Cost-Reimbursement Contracts
In cost-reimbursement contracts the client is required to reimburse all allowable, allocatable and reasonable costs that the contractor can be demonstrated to have made.

(2) Fixed-Price Contracts (also, particularly in the construction industry, called lump-sum contracts)
In this case, the contractor has the obligation to deliver a final product for a specified price, as contractually agreed.

In general, it is clear that in case of fixed-price contracts, the risks for the contractor are considerably higher; profit is more speculative. Overruns can only be paid if a change in the scope of deliveries or requirements can be demonstrated (which is not always evident).

Main differences within these groups are generally determined by the method of fee-determination. We shall demonstrate these differences, initially, considering cost aspects only. For the sake of uniformity, we shall demonstrate the differences graphically. As illustrative example, we assume that with a contract of 100 units, a fee of 10 percent will be paid. Specific terminology will be defined gradually. It should also be emphasised that in this chapter only those contract types will be presented that are described in referenced documents, and, as such, generally known. Where the word 'profit' appears in the following figures, 'contractor's profit' is of course meant.

2.2.1 Cost-reimbursement contracts

2.2.1.1 CPPF: Cost-Plus-Percentage-Fee Contract (see Figure 2.1)
This is definitely the most straightforward type of contract, from a contractor's point of view. All justified costs are paid and the fee is added as a fixed percentage.

The target cost is the estimated contractual cost to completion, whereas the target fee is the fee payable if the actual cost equals the target cost.

2.2.1.2 CPFF: Cost-Plus-Fixed-Fee Contract (see Figure 2.2)
In this case, costs are reimbursed, but the fee remains constant, whatever the actual costs.

2.2.1.3 CPIF: Cost-Plus-Incentive-Fee Contract (see Figure 2.3)
CPIF is similar to CPFF, but in this case the fee may vary up or down within set limits and in accordance with a formula tied to allowable actual costs.

We further identify the following elements:

Sharing Formula: The expression (normally in percentage terms) of the basis of the client's and contractor's cost-sharing arrangements;
RIE, Range of Incentive Effectiveness: In general, the fee has an upper (maximum fee) and a lower (minimum fee) limit. The band of costs over which the incentive provision is mainly operative is called the RIE.

It should be noted here that:

(1) The sharing formula can be nonlinear;
(2) The sharing formula for an overrun often differs from that for an underrun;
(3) Sometimes a neutral zone is introduced, which avoids discussions in the first overrun area (see Kahn [6] on this subject).
Figure 2.1 CPPF: Cost plus percentage fee (10% fee).

Figure 2.2 CPFF: Cost plus fixed fee (10% fixed fee).
2.2.2 Fixed-price contracts

2.2.2.1 FFP: Firm-Fixed-Price Contract

This is a one-price contract and the price is not subject to any adjustment unless there is a change in the scope of the work required under its terms.

Graphically, the profit in this case could be represented as in Figure 2.4 and can be negative.

2.2.2.2 FPI: Fixed-Price-Incentive Contract (see Figure 2.5)

In this type of contract, a target price is fixed, but the fee will be determined when actual costs are known. In this case, a ceiling price is determined, which is the maximum price accepted by the client for fee determination; for costs higher or equal to this ceiling price (= 119 in our example), the profit = 0. In general, also, a maximum fee is determined.

In order to obtain a fee = 0 at ceiling price, a so-called Point of Total Assumption (PTA) has to be calculated (i.e. where sharing stops).

The difference between this type of contract and a CPIF-contract is that, in this case, the upper limit is fixed (ceiling price); in the FPI case the contractor can suffer a considerable loss when his costs exceed the fixed ceiling prices. In the case of CPIF, the worst case for the contractor is no profit — his costs will be reimbursed anyway.

Note: We can represent some of the contract types mentioned by the following relation:

\[ P = BF + s \cdot (TC - AC) \]

where

- \( P \) = profit
- \( BF \) = basic fee
- \( s \) = sharing ratio
- \( TC \) = target cost
- \( AC \) = actual cost (as accepted by the client).
Figure 2.4 FFP: Firm fixed price contract (10% fee).

Figure 2.5 FPI: Fixed price incentive contract (10% target fee).
Then:
for \( s = 0 \), we have a Cost Plus Fixed Fee (CPFF) contract;
for \( s = 1 \), we have a Firm Fixed Price (FFP) contract;
for \( 0 < s < 1 \), we have a Cost Plus Incentive Fee (CPIF) contract.

2.2.3 Some variants

2.2.3.1 Adjustments for escalation

A contract provision foresees escalation (upward adjustment in price if there are allowable changes in materials or labour cost). This escalation is calculated separately with the aid of a predetermined escalation formula (commonly using officially published indices).

2.2.3.2 Other incentives

For simplicity, we have so far only considered cost incentives in our presentations. We shall often, however, consider other incentives, such as:

Performance Incentives: A positive or negative fee is paid upon obtaining a certain technical performance. Imagine a satellite payload with a target mass of 50 kg; a performance incentive on mass reduction could be included as shown in Figure 2.6.

Delivery Incentives: In cases where delivery time is important (e.g. payload for a satellite with a predetermined launch date), (stepwise) incentives are often included (see Figure 2.7).

It should be noted here that these incentives, certainly in the case of cost-reimbursement contracts, should preferably be linked with cost incentives (otherwise, the contractor could incur enormous costs in order to reach the maximum incentive fee). Consequently, in general, we shall find these used as multiple incentives, i.e. a combination of a cost incentive with performance and/or delivery incentives.

In this case, the total fee can be described as:

\[
P = BF + s(TC-AC) + DI + PI
\]

where:
\( P \) = profit
\( BF \) = basic (fixed) fee
\( s \) = sharing ratio
\( TC \) = target cost
\( AC \) = actual cost
\( DI \) = delivery incentive
\( PI \) = performance incentive

2.2.3.3 AF: Award Fees

At the beginning of the contract, an amount is determined for awards, the Award Pool. This award pool is divided into evaluation events, and (subjective) measurement systems are developed prior to the start of performance (e.g. rating system). At each event, the contractor can earn (part of) the attributed award.

In general, a (low) base fee is fixed, so, at the end of the contract, we shall have:
Figure 2.6 Performance incentive.

Figure 2.7 Delivery incentive.
\[ P = BF + AF \]

where:
- \( P \) = profit
- \( BF \) = basic (fixed) fee
- \( AF \) = award fee (earned, in steps, during contract award).

The most common form found in practice is a CPAF, Cost-Plus-Award-Fee contract. In principle, however, award fees can be added to any type of contract.

2.3 SUITABILITY OF CONTRACT TYPES

It should first of all be mentioned that reasons are often stated for not using a certain type of contract. A positive criterion is rarely expressed.

Clearly, clients and contractors have strongly conflicting interests:

1. Governments will in general prefer fixed price arrangements; see, for example, U.K. Incentive Contracting Guide, Introduction [3];
2. Contractors tend rather to favour cost-plus-reimbursement contracts; see, for example, Pace, pp 211-217 [4], except for CPAF contracts;
3. Incentive contracts can be an acceptable compromise; Kahn [6], for example, has demonstrated that, for the client too, in some cases, (long-term) cost-plus contracts may be preferable.

Only in one respect do most parties agree: award fees should be used only in exceptional cases, when performances cannot be quantified (see also Jenkins [7]).

A (partial) agreement can be found on the use of performance and/or delivery incentives combined with cost incentives; in other words, if incentives are to be used, most parties advise the use of multiple incentives.

For the various, specific types of contract, the general guidelines as given on p. 4 of the DOD/NASA Incentive Contracting Guide [1] are still the most frequently used ones:

**CPFF (Cost Plus Fixed Fee):**
Appropriate where a certain level of effort is required or where high technical and cost uncertainty exists;

**CPAF (Cost Plus Award Fee):**
Appropriate where conditions for use of a CPFF are present, but where improved performance is also required, and where performance cannot be measured objectively;

**CPIF (Cost Plus Incentive Fee):**
Appropriate where expectation of achieving an acceptable performance is good, but improvement over that level is desired and where technical and cost uncertainties are excessive for use of FPI;

**FPI (Fixed Price with Incentive):**
Appropriate where improved performance is desired and technical and cost uncertainties reasonably identifiable;

**FFP (Firm Fixed Price):**
Appropriate where performance has already been demonstrated and technical and cost uncertainty is low.
Note that CPPF (Cost Plus Percentage Fee) contracts are not covered (not allowed under DOD/NASA regulations) and that no objective keys are given to quantify these statements.

Peeters [8] elaborates this by relating specific contract types to typical programmes, as follows:

**FFP (Firm Fixed Price):**
- Production or construction under clear specification
- Short programme duration or profitable currency effects
- Training

**FPE (Fixed Price with Escalation):**
- Same categories, but longer programme duration

**FPI (Fixed Price with Incentive):**
- Development programmes using existing technology

**CPIF (Cost Plus Incentive Fee):**
- Prototype development
- Development of new machines

**CPFF (Cost Plus Fixed Fee):**
- Research and study programs

Furthermore, he points out that the different phases* of a programme can easily be administered with different contract types (which is common practice in ESA, for instance).

### 2.4 OVERVIEW

In attempting to give a schematic overview of the different types of contract, we have to take two major elements into account:

1. The risk factor;
2. The major reason why the new types of contract have been devised.

Whereas fixed price contracts constitute an important risk for the contractor, cost plus reimbursement contracts have a similar consequence for the client. It is evident that the extreme character of these two types of contract made it necessary to devise intermediate types, so that a compromise acceptable to both parties could be reached.

A progressive process can be identified, in which major drawbacks of a certain type of contract have been mitigated by the development of a new type. This process is presented schematically in Figure 2.8, which summarises this chapter.

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* In ESA terminology, projects are divided into distinct phases, which are considered as relatively independent: Phase A = system feasibility, Phase B = system design, Phase C = subsystem development, Phase D = system implementation and, afterwards, Phase E = exploitation. (This terminology deviates from that used by other organisations.)
Figure 2.8 Overview of contract types.

2.5 REFERENCES


CHAPTER 3
A LITERATURE SURVEY

3.1 INTRODUCTION

As a starting point for this study, an extensive literature survey was made (see Peeters [1]), using computerised databanks with retrieval systems. Some preliminary conclusions were:

(1) Most emphasis is placed on general aspects of contract types, considerable importance being attributed to the legal elements.

(2) A number of items are taken for granted and are not analytically evaluated.

(3) Information on the use of different types of contract in Europe is very scarce, and no reference is made to European expertise and overall results.

(4) We can discern a clear evolution with time, the drawbacks of existing types of contract being mitigated by the devising of new contract types (which, however, often entail falling into a new kind of trap!).

(5) There has been a distinct period of 'diversification' and, recently, an evolution towards 'simplification'.

Only the major elements of this literature study are summarised in this chapter, emphasis being laid on:

(a) technical administrative aspects of contract types;
(b) the situation in Europe.

Moreover, only appropriate recent publications have been added (up till early 1987).

Three major elements will be dealt with:

(a) A brief historical overview, which is essential to an understanding of the evolutionary pattern of contract types.
(b) A synthesis of important and relevant USA experience, which is the largest one existing in this area.
(c) An overview of European publications, which has not been attempted before.

A number of elements included in the original literature survey have not been extensively repeated here, e.g. econometrical and mathematical studies and the award fee concept. These two aspects have gradually become less interesting, owing to unsatisfactory results. Case studies, furthermore, are only given as references and in order to validate the models developed.
3.2 HISTORICAL BACKGROUND

3.2.1 Early evidence

Ever since mankind has been involved with contracts and initial cost estimates, there has clearly been a tendency to underestimate costs. The resulting overruns are very obvious in government contracts in general and in military contracts in particular. An early example can be found in Roman history:

'...The young magistrate (Herod, son of Atticus), observing that the town of Troas was indifferently supplied with water, obtained from the munificence of Hadrian 300 myriads of drachmas for the construction of a new aqueduct. But in the execution of the work the charge amounted to more than double the estimate, and the officers of the revenue began to murmur, till the generous Atticus silenced their complaints by requesting that he might be permitted to take upon himself the whole additional expense.' (Quoted by Gibbon [2])

Later on in history, two phenomena became more apparent: first of all, the officers of the revenue stopped murmuring and started to shout; secondly, the Atticuses became scarcer.

This small example might lead to the obvious conclusion that early incentives would belong to the category of cost incentives. In reality, however, the first documented contractual incentives were related rather to performances.

At the time of the Civil War, the American government (at least half of it) bought a new type of battleship (ironclad), the Monitor. The ship had to:

1. float;
2. attain a specified minimum speed;
3. win its first battle;

before the contractor would be paid. The two first objectives were met; the third objective caused a problem: the first battle (in 1863, with the Merrimac) resulted in a draw. The Merrimac had to return to Norfolk for important repairs, however, so the contract was finally paid. (See also Morris [3])

The best-documented and best-known example in the literature is without any doubt the procurement of a flying machine by the U.S. Army in 1908. The Wright Brothers had performed their memorable first flight at Kitty Hawk, North Carolina, on 17 December 1903. They patented their airplane and tried to sell it to the U.S. Government but, as has happened more than once in history, the military found no use for the new apparatus. In order to sell their machine, the Wright Brothers offered performances (minimum range and speed) and their negotiations finally resulted in the Signal Corps Specification no. 486, entitled Advertisement and Specification for a Heavier-Than-Air Flying Machine. The final contract foresaw delivery of a machine at a total cost of $ 25 000. Article 4 stipulated:

'The flying machine should be designed to have a speed of at least forty miles per hour in still air, but bidders must submit quotations in their proposals for cost depending upon the speed attained during the trial flight, according to the following scale:

- 40 miles per hour, 100%
- 39 miles per hour, 90%
- 38 miles per hour, 80%
- 37 miles per hour, 70%
36 miles per hour, 60%
less than 36 miles per hour, rejected
41 miles per hour, 110%
42 miles per hour, 120%
43 miles per hour, 130%
44 miles per hour, 140%.

In fact, this contract could now be considered as a FPI contract (with a firm target). The final qualifying flight covered a distance of ten miles and was flown at a speed of 42.86 mph. In accordance with the formula 25,000 x 1.20 or 30,000 dollars were paid (the formula made no provision for partial mph). In other words, an incentive of $5,000 dollars was earned. Note that this still represented a good deal for the Government, as the Wright Brothers initially intended to ask $100,000.99 for their airplane. Later, however, the Wright Brothers realised that they were in a monopolistic position and, as good businessmen, followed this strategy of market penetration (8 years later the Army already owned 12 airplanes). Data have been collected from Powell [4].

3.2.2 World War I and II procurements*

It is clear that incentives are mainly related to large development contracts and as such inherent to military contract booms during the recent large-scale wars. In earlier years, however, incentives on different sorts of contracts are found. During World War I, we find merely the so-called 'bonus for savings' contracts which were later the reason for several law suits and discussions. In several cases, when these incentives were applied, high profits were shown; this was regarded as very suspect and hindered further development of incentive contracting. In fact, under different prerogatives, the USA Government refused to pay several incentives. The following are some illustrative examples (exact figures unknown):

- A Fixed Unit Price production contract was made with several uniform-manufacturing companies, whereby a bonus-for-savings amounting to 20% of the savings on material was agreed (80:20 sharing). The Court afterwards denied the contractor this incentive, mainly because he could not establish definitely how much material had been saved by reason of the incentive provision**.

- In the case of a development contract for aerial photography devices, a 75:25 fixed price sharing arrangement was agreed; the target profit was 10%. As the actual cost proved to be less than half of the estimated cost, the contractor claimed profits 64% over target profits. In this case, the Court of Claims disallowed the incentive on the basis that:
  (a) There was no basis on which the saving could be properly measured.
  (b) The profits sued for were unreasonable and based on gross errors by the contractor in his estimate.***

*** Burke & James Inc. vs. U.S. 63 Ct of Claims 36, 1927.
In 1917, the Bethlehem Steel Corporation persuaded the Government to accept a 50:50 share CPIF contract (note that conditions are translated in actual incentive terminology); this contract was known as the half savings form of contract. This transaction involved a combination of thirteen separate contracts for parts of many ships, at an estimated price of $119,750,000. Total actual costs were $92,990,521, bringing a profit in excess of $26,000,000 (basic fee plus sharing). Initially the Court found that Bethlehem had taken absolutely no risk of loss under this type of arrangement and had taken advantage of the urgent circumstances.

The government contract negotiator stated in his testimony that the purpose of the bonus-for-saving provision was exactly to give the shipbuilders an incentive to use their ingenuity to make a larger profit. It was 1942 before this World War I case reached the Supreme Court, which ruled in favour of the shipbuilders.*

During the World War II period, so-called 'Target Price' contracts were introduced; as G.A. Lloyd, Director of Pricing and Purchases of the War Department described them:

'Some of the War-Department provisions for fixed fee contracts give the contractor incentive to reduce costs by allowing greater profits and profit margins if he reduces his price through efficiency. In cost-plus-fee agreements, and in other types of contracts with other Government agencies, similar incentives may be employed by the use of 'target' prices or other like devices. The general tenor of such contracts is to allow the contractor a larger fee if he succeeds in reducing costs or prices below a stated norm.' (Quoted by Nolan [5], p. 37).

Several types of 'target price' contracts were used, the results being rather disappointing. In general it was felt that targets were put too high. Incentive contracts were used for production procurements of missiles, aircraft and propulsion systems, but only to a very limited extent.

We should not forget that, as a consequence of rapid decisions taken under urgent war circumstances, some innovative incentives were probably fixed too hastily. This could explain the negative experience with these early incentive contracts.

As a consequence, CPFF (Cost Plus Fixed Fee) contracts gained in popularity during the period 1950 - 1960. The basic idea behind this decision was the feeling that these CPFF contracts contained a built-in incentive. Experience, however, showed that this incentive had only a very limited effect. As we shall point out in the next section, this CPFF incentive effect was not recognized by the McNamara administration at all.

3.2.3 The struggle against overruns during the 1960s

Owing to an increased degree of technological complexity and to the need for rapid development occasioned by the war, a considerable number of cost-plus contracts were being issued. Only after some experience had been gained and data collected, did it become obvious that these contracts had led to enormous overruns, in comparison with estimated costs.

In the fifties, and particularly during the Korean War, overruns by factors of 200 to 800% were noted. In the winter of 1958, a working group was established at Harvard Business School to undertake a systematic study on the area of advanced weapons acquisitions. The results of this working group's work had an extremely strong influence on procurement policies in general and incentive contracting in particular. The resulting books:


can be regarded as very important milestones in the history of incentive contracting.

In this study, 12 major weapon systems (from the post-World-War-II period) were carefully analysed. Actual development costs were found (as an average) to be not less than 220% higher than originally estimated. In one case, an overrun of 600% was reported; there was only one instance of an underrun. On top of this, an average development time factor of 1.36 was found (i.e. the ratio actual time / original time estimate), or, in other words, on the average the actual times exceeded estimated times by 36%.

In their study, Peck and Scherer describe a publication by Marshall and Meckling ([6],p.435), covering 22 U.S. Air Force development projects (from the 1950s). These authors found a strong correlation between cost overruns and the level of technological advance. For small technological advance (e.g. cargo aircraft) they reported an average cost overrun of 40%; for medium advance (fighters) an average cost overrun of 70% and for high technology advance (missiles and special fighters) not less than 240% as an average (with a peak of 1270% of the original estimate). For advanced commercial development programmes, Peck and Scherer ([6],pp.428-432) found an average cost overrun of 70% with an average time overrun of 1.40 (even higher than the 1.36 of the weapons sample). The authors quoted several other sources and indications and formulated their conclusion as follows:

'It is reasonable to conclude from this evidence that, on the average, the organisation charged with conducting U.S. weapons development programs have been fairly successful in meeting quality predictions, but not in meeting cost and time predictions. This conclusion is no more than common knowledge among government personnel and weapons industry members.' (Peck and Scherer [6], p.430)

Although the authors stated in mitigation that this was common knowledge, their report had a considerable impact on U.S. procurement policy.

Under President John F. Kennedy, the Secretary of Defense, Robert S. McNamara, was given strong instructions to effect economics without compromising the U.S. defence position. McNamara realised that this could only be effected by means of new management techniques. In a memorandum to the President, McNamara stated [8]:

'The increasingly complex weapons systems resulting from the technological revolution of the 1950s has led to a great expansion in the use of cost-plus-fixed-fee (CPFF) contracts. However, both Department and industry officials agree that CPFF contracts not only fail to provide incentives for economy, but actually deaden management efficiency by removing the need for either the Department or the contractor to estimate costs accurately, and to plan and control programs tightly.'

It is evident that these statements were largely based upon the conclusions reached by Peck and Scherer [6], published one year earlier.

In principle, two main objectives were established by McNamara:

(a) To shift from Cost-Plus-Percentage-Fee (CPPF) and Cost-Plus-Fixed-Fee (CPFF) to incentive and fixed-price contracts;

(b) To shift defence procurement from noncompetitive to competitive markets.

As a consequence, the Armed Services Procurement Regulations (ASPR) were amended, placing much greater emphasis on the use of incentive contracts and restricting the area for
application for CPFF contracts; the regulations stated:

This type of contract normally should not be used in the development of major weapons and equipment, once preliminary exploration and studies have indicated a high degree of probability that the development is feasible and the Government generally has determined its performance objective and schedule of completion'. [ASPR 3-405.5A(c)].

On several occasions, McNamara stated that for each dollar shifted to firm fixed price and incentive contracts, a reduction of at least 10% in final costs could be effected. (See, for example, Statement before the House Armed Services Committee on the Fiscal Years 1966-1970, February 18, 1965, p. 187).

Studies performed afterwards all conclude that the announced 10% cost saving was much exaggerated and never reached; only savings in the order of three to four percent could be proven after post-evaluation (see Hiller and Tollisson [9], and Fisher [10]). All the authors agree, however, that the measures taken have had a considerable impact on attitudes; the whole process has made Government and defence contractors more cost-conscious than before. The Government has assumed the rôle of cost-conscious buyer rather than benevolent sponsor.

The National Aeronautics and Space Administration (NASA) had followed a more cautious approach towards the conversion to incentives. Once the results started to reveal the benefits of this more conscientious approach, however, a major programme was established to shift to incentive contracts (e.g. in the Gemini programme CPFF contracts were converted into CPIF contracts). In view of its special mission, more importance is attached to performance/award contracts. As stated by NASA - P.R. (Procurement Regulations):

'It is NASA's policy to make judicious and effective use of incentive contracts of both the cost and performance type. Particular care and judgement are required in choosing procurements appropriate for incentive contracts, and in framing and negotiating the specific incentive terms.' [NASA P.R. statement 3.450 (a)]

As reported in further articles, it is clear that this policy has been an important factor in bringing about the success of such large programmes as Apollo (CPIF, see Philips [11]); Titan III (CPIF, see Purdy [12]) and Gemini (PIIM, see Schneider [13]). It is worthwhile to note, however, that this success is seldom exactly quantified. Published figures, compared with figures evaluated later, show substantial differences...

As NASA's P.R. and the ASPR of the Department of Defense are controlled by the same procurement law and generally deal with the same segment of industry, this has led to a joint DOD/NASA Incentive Contracting Guide, published in 1969 [14]. This also illustrates the more cautious attitude on NASA's part (in 1962 the two guides were still published separately).

Another way to show the differences is by plotting the contracts awarded, in financial terms, in relation to the type of contracts. Data found in several publications have been compiled; the result is given in Figure 3.1 (for DOD contracts). We notice a relatively high percentage of fixed price contracts after World War II. This percentage was declining slightly, but rose again after McNamara's intervention in 1962. The drop in CPFF contracts after 1962 is also remarkable (similar reason).

Rule and Cravens [15] and Thomas et al. [16] illustrate NASA's efforts at introducing award fee contracts, especially CPAF contracts. In fact, the idea was already brought forward in 1961 at the Joint Industry/Defense Department Symposium. These ideas were adopted by NASA, which found this type of contract more appropriate for development work than CPIF contracts. The first NASA CPAF contract was initiated in 1962. A very important CPAF contract was
Figure 3.1 Proportion of DOD dollars by contract type, per fiscal year.

issued in 1964 for the construction of the John F. Kennedy Space Center in Florida. Experiences gained resulted in NASA's Cost Plus Award Fee Contracting Guide [17].

In general, owing to their particular field of activities (more development contracts), NASA uses more intermediate types of contracts. Incentive contracts represented 72-75 percent of total awards annually in the period 1980-1984 (quoted in Defense Daily, January 4th, 1985, p. 21).

The evolution over the last decade can be best described as a process of simplification. Some contract types were, indeed, getting overcomplicated. Complex mathematical relationships were developed which needed the use of computers to determine the incentive fee. This, of course, hindered an efficient feedback during project execution and an important aspect of these intermediate contract types, incentives as motivators, was partially lost. Kennedy [18] summarises these effects in his latest work and pleads for simpler, straightforward contract constructions.

In the same sense, a greater hesitancy to use award fees has recently become noticeable. The subjective element involved makes management of these fees again rather complex.

A very recent development is the DOD decision to implement contract incentives for modernisation. The programme is called IMIP (Industrial Modernisation Incentive Program) and proposes to share industrial modernisation cost savings with contractors in return for the introduction of cost-saving manufacturing technology. The rationale behind this proposal is clearly to motivate contractors to reduce costs through capital investments and, at the same time, to modernise defense factories. The effect will be augmented as, at the same time, contractors' productivity and manufacturing performance are introduced as a major element in source selection (DOD directive 4104.62, 8th May, 1984). This programme is dealt with in
more detail in Fox [19], Connolly [20] and Stansberry [21].

As the literature contains no adequate overview of the use of contract types in Europe, this topic will be dealt with below (Section 3.4).

In general, since 1969, ESA/ESRO has adopted most of the established principles used by NASA and has become a defender of the use of different contract types. Only very slowly, do we see any attempt to introduce these techniques in other areas in Europe.

3.3 AMERICAN STUDIES ANALYSING THE OUTCOME OF DIFFERENT TYPES OF CONTRACT

3.3.1 General

It is evident that every author formulates (implicitly or explicitly) his opinion on the effectiveness of a specific contract type. In this chapter, however, we wish to group studies which try to draw lessons from past experience. Two categories can be distinguished:

(a) Quantitative approaches: using statistical techniques (regression analysis mainly), the authors try to find correlations and corresponding conclusions.

(b) Qualitative approaches: authors try to achieve the same objective by means of a form of questionnaire or working group. In this case, however, the conclusions drawn tend to be based on comments.

It should be clearly understood that, initially, we try to analyse the results from (relatively) large samples. Individual experiences and case studies are briefly indicated in a separate paragraph.

3.3.2 Quantitative approaches

In the historical overview, we have already mentioned some studies which merely registered overruns in programmes (cost and time); see, for example, Peck and Scherer [6].

Holman [22] has given some more recent examples from the NASA situation: the total duration of the Mercury Project is reported to have been no less than 2.25 times the originally scheduled duration, with a cost overrun of approximately 120%. Later projects gave better results, e.g. the Apollo project had a cost overrun of 25%, which is partially due to the fact that the rate of inflation was higher (as a result of the Vietnam war) than scheduled. In fact, if corrections are made for inflation, the real cost overrun factor would be in the order of 6%, which is rather moderate for such an innovative project.

It would be overoptimistic to relate this decrease in overrun to the introduction of incentive programmes. The overall economical situation (Vietnam, oil crisis) made governments act as more careful buyers, and led to the introduction of more effective project-control tools (cost control, network scheduling). The use of these tools provided the means for giving early warnings and facilitated corrective actions.

Early studies, analysing the real effectivity of incentive clauses can be found in the late 60s. Belden initially studied 834 production and development contracts and expanded this analysis later, together with Parker, to 2683 Army, Navy and Air Force Contracts. at the end of their study, some of Parker and Belden's [23] conclusions were:

(1) No meaningful relationship exists between overrun/underrun and contract changes.
(2) Significant differences in average overrun/underrun exist for type of contract and type of work; e.g. CPIF contracts show substantially higher overruns than FPI contracts.
(3) Contracts with larger contractor sharing rates tend to overrun. This conclusion is rather surprising. The authors related this conclusion to the fact that incentive provisions are probably inaccurately defined (e.g. definition of target costs).
(4) Contractors tend to earn performance incentives, regardless of contract cost outcome. This supports the opinion that contractors working in this field of activities were more motivated towards performance than cost.
(5) Higher contractor's share rates have not generally resulted in higher average profits.
(6) Production contracts containing cost incentive provisions generally average larger outgoing profit rates than R&D contracts. This last conclusion can be directly related to technical uncertainty.

Fisher [24] studied 1007 Air Force contracts and also found a significant difference in the relationship overrun/underrun by type of contract. FPI contracts resulted in an average underrun, unlike CPIF and CPFF contracts. There was no evidence to suggest that this difference was related to the sharing ratio or to the contract size. There were, however, significant differences per contractor: some contractors show (constant) cost overruns, others (regular) underruns. This might lead to the conclusion that the managerial capabilities of a company are more important than formal contract incentives. A considerable danger noted by Fisher was that contractors tended to adapt their target price to the type of contract (thus tending to neutralise the effect).

In another study, Fisher [10] has gone into this matter in more detail. Since underruns could not be (statistically) attributed to incentive provisions, the most likely explanation was that target costs proposed by the contractor were significantly larger than anticipated actual costs. In other words, Fisher feels that contractors have the tendency to inflate their target costs artificially (in order to obtain a part of the underruns afterwards).

It should be noted here that this conclusion is not always valid and will strongly depend upon the contractor's attitude. On the other hand, it is doubtful whether this inflating effect can be achieved in the face of competition.

Fisher feels that only a closer control on these target costs can improve the effectivity of incentive contracting. More intense competition is, in his opinion, the most effective way to obtain credible target costs. In cases where such competition is not possible, independent cost estimation should further be developed as a useful tool.*

Cross [25] performed a statistical analysis which was mainly directed towards answering the question whether McNamara's statement (i.e. that a 10% saving could be effected by shifting from CPFF to CPIF) was borne out by experience. In order to do this, he studied data from groups of contracts before and after the statement, covering some 3000 CPFF and CPIF contracts. His conclusion is that, at the most, a net saving of some 4% could be shown, with a decreasing tendency over time, after introduction. Cross also found evidence that target prices were manipulated. (It is our opinion that too many factors influence these savings, which makes it impossible to relate them to a single factor.)

He remains very sceptical about the usefulness of the cost incentive device in contracting, certainly as long as incentives are linked purely to cost aspects. In fact, he pleads for the

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* It might be worthwhile to note that a so-called Truth-in-Negotiations Act (PL 87-653) gives the U.S. Government the chance to check the reliability and accuracy of cost information furnished by contractors.
introduction of performance parameters.

The same McNamara statement is statistically evaluated by Hiller and Tollison [9], and they also reach the conclusion that no proof is found that the 10% saving has been obtained. In general, the authors dispute the statement that cost-plus contracts are more costly for the government. Their final advice is that the government would be better off rewarding firms simply on the basis of output (as the market does) without directly trying to influence the internal operations of the firm (e.g. by introducing internal incentives).

Although the trend of their observations is valid (control belongs to the firms), it would seem that the authors are missing an essential point, namely that incentives are indeed an attempt to reward positive outputs.

Trimble [26] studied the profitability of DOD/NASA contractors involved in incentive contracts. The results, in terms of efficiency and productivity, were compared over a period of time with those of a group of similar firms having purely commercial business. The analysis showed that the incentive environment failed to induce DOD and NASA contractors to increase efficiency and productivity in the use of capital and labour resources.

In his study, Dixon [27] develops a regression relationship, testing several parameters and their significance level. He studied the overruns of 177 Navy Contracts (aircraft and missiles) and obtained the following formula:

\[ D = -42.4 + 0.128L - 1.68T + 0.397C - 0.297N + 0.823Y - 0.00004V \]

where

- \( D \) = deviation from standard cost (in percentage)
- \( L \) = length of the contract (duration)
- \( T \) = target profit (percentage)
- \( C \) = ceiling price (as a percentage of the target price)
- \( N \) = number of contracts per company
- \( Y \) = year of signing the contract (with 1965 = 1)
- \( V \) = value of the contract (dollars)

This relationship shows which factors contributed to the overrun (and to what extent). (Note that a number of factors are relatively dubious in consistency. It is doubtful whether the relation between deviations and these factors has any realistic significance beyond the statistical one...)

Various factors that were statistically insignificant were:

- the sharing ratio;
- the contractor (note: this is in contradiction with Fisher [24]);
- the type of items.

In a study grouping findings of incentive research projects, Demong [28] drew the following conclusions:

- The motives of contractors are very complex, but they can be influenced by incentives.
- Statistical evidence can be found to show that incentives reduce cost overruns (although less than initially expected).
- There is a considerable relationship between cost overruns and delays; scheduling incentives can help in this respect.
- Performance incentives are indirectly useful, in that they avoid the negative reactions that result from purely financial incentives.
- Award fees have proved to be effective motivators. The administrative costs induced by
this type of contracts, however, cannot be neglected.

The statistical data used in the above-mentioned studies have mainly been collected from military and NASA procurements. Only few references are made to other areas (as is generally also the case for contract studies). One of the few studies analysing industrial data is reported by John and Saunders [29]. They studied the effect of incentive contracts on the procurement of nuclear and non-nuclear power plants. An example is given for the Shoreham 1 nuclear plant (Long Island), which finally cost five times the amount first estimated. The authors show, on the basis of statistical data, that overruns of this type are drastically reduced by using incentive contracts. They also found that contractors with specialised technology would be more inclined to bid under fixed price and incentive conditions.

Stukhart [30] deals with some results in the (traditional) field of construction activities. A 1983 survey showed that, surprisingly, 12% of the contracts in the private sector of the construction industry in the USA were of an incentive-based type. Results were very satisfactory, but extension into public-type construction are limited by regulations (only FFP accepted).

3.3.3 Qualitative approaches

Some studies have been performed on the basis of either questionnaires, or interviews or both. We call these studies qualitative, since most of the conclusions are drawn from verbal statements, not necessarily supported by data or figures. It is to be noted that the information presented in these studies is different from that in the previous, quantitative, group. It represents rather the underlying feelings of the participants.

In the early application period of incentive contracting, Steiner [31] reports the results of UCLA-conferences with project managers in the aerospace industry (1968). We note a certain resistance to change and evidence of the industry’s cautious attitude. The overall opinion was that an incentive contract should only be used as long as technical uncertainties were not too great (traditional engineering). As, in development contracts, a large number of essential technical events are not known, working under incentive provisions was regarded as too risky.

A later study by Hunt [32] concentrates on award fee contracts. Some of his conclusions are:

- Award fee contracts induce a large administrative effort.
- Dialogue and feedback (with government) is generally felt as being very good by the contractors.
- Contractors feel uncomfortable with the subjective aspects of fee determination.
- Award fee contracts are seldom used in subcontracting, even when the prime contract falls under award provisions.
- The contractor feels himself vulnerable in negotiations (which are bound to occur).
- All contractors have to admit the motivational effects of award fees, even to the extent that they may create a very tense situation.

Hunt concludes that a key factor in making a success of award fee contracting is the government’s programme manager. The question here is whether this person has sufficient (objective) ability to make wise use of the control given to him by award fee structures.

As the result of a student research project in 1981, reported by Solloway [33], it was once more apparent that contractors still feel reluctant to accept incentive clauses. In answer to the question:

"What is the most preferable contract type in the view of both the government and the contractor?"
approximately 75% of the contractors interviewed still opted (in order of importance) for CPFF and/or FFP contracts (it is very doubtful whether they took the government’s point of view into account!).

Recently, an extensive study on incentive contract influences was published by Kennedy [18]; both questionnaires and interviews were used. Questionnaires were sent to NCMA members (National Contracts Management Association, which is a professional organisation for contracts officers). The following conclusions were drawn:

1. The contract type is not the determinant variable in the contractor's decision process; the firm's management style is not adapted to a particular type of contract.
2. Most incentive contracts end up near target.
3. The target costs of incentive contracts are higher than those of alternative CPFF contracts.
4. The most significant factor in determining the target cost is where the company expects to end up. (In relation with conclusion (3) above, this means that contractors feel that the risk of incentive contracts is high and, consequently, take this risk into account when calculating the target cost).
5. In many cases, the government eliminates much of the opportunity for gaining by the incentives, by introducing many changes during the course of the programmes.
6. The cost of administering incentive contracts is often excessive.
7. Contracts are often designed by the contractors to absorb anticipated overruns. (It is worth noting that the question of whether this was in fact true was of course avoided in interviews and only evoked a meaningful answer when those completing the questionnaires were strictly anonymous.)
8. Incentive contracts are seldom tailored to the situation; too many classic rules of thumb are used.
9. Penalties are probably better motivators than rewards.
10. Only simple incentives work.
11. The most important element in incentives are product performance goals.
12. Incentives need to be visible to those inside the organisation in order to work properly.
13. In the case of high uncertainty, CPIF contracts are preferable to CPFF contracts.
14. Cost-plus contracts usually lead to inefficient producers (and lead to a careless attitude towards costs). CPIF provisions cannot remedy this effect; only fixed price contracts result unambiguously in a more cost-conscious attitude.

3.3.4 Case studies in the USA

In view of the extensive period over which different contract types have been experimented with in the USA, it is not surprising that a considerable number of case studies have been published over the years.

It is very difficult to derive lessons from these case studies. In general, the most important conclusion (lessons learned) is not explicitly available. The authors, who are usually the programme managers, tend to delete the elements which went wrong. Unfortunately, it is precisely these elements that might have constituted the most interesting information.

For the sake of completeness, the case studies consulted are listed in Table 3.1. The column headed ‘Success’ is, of course, highly arbitrary. First of all, one could question the absolute relationship between the overall programme and the contract type. It is evident that the contract type is a major, but not the only factor. Furthermore, one has to rely on the author's subjective opinion on whether the programme was successful or not. In looking at this column, one should
beware of the misleading conclusion that most programmes were successful. The simple truth is, however, that very few programme managers take pleasure in documenting (their?) failures. The table is therefore added for reference only. Note also that some articles discuss incentive provisions without addressing the subject of the main contract type used.

### 3.4 SITUATION IN EUROPE

#### 3.4.1 General

First of all, there is a large difference to be noted between the situation in the UK on the one hand and that in the rest of Europe on the other.

The UK (military) administration has relatively closely followed developments in this field of USA experience. We should also not forget that in most military conflicts of the last century, a close collaboration has existed between these two (allied) countries. If we consider, as an example, World War II; a close co-ordination in the area of military acquisition was a necessity. All early evidence can be related to this effect. For simplicity, we group these unification tendencies under the heading: the UK school.

Once successful results, mainly from NASA projects, became evident, ESA adopted a number of these contract types and has used them extensively over the last two decades. Later on, we also find some sequels in related sectors (space industry and national centres). We group these into: the ESA school.

A third, relatively recent, wave exists in Germany. There, developments have taken place mainly in the aircraft industry. As there is a clear link between these articles, we refer to them as: the German school.

Also of recent date are the trends on incentive provisions in France. We see a strong connection with aerospace activities in this case. We call this the French school.

If, lastly, we group the Dutch articles in one chapter as the Dutch school, we have covered European publications.
Case studies will, again, not be described extensively, but only tabulated for further reference.

3.4.2 The UK School

Within the framework of the rearmament programme, an agreement was negotiated in 1936 between the Air Ministry and SBAC (Society of British Aircraft Producers), introducing the 'basic cost' method (also called the First McLintock Agreement). In 1939 the agreement was reworked, prescribing the cost incentive arrangements and now using the term 'target cost'. (See Blyth [44]).

Existing methods were compiled by the Ministry of Technology, and issued as a training guide in 1969 [45]. This guide shows strong resemblance to the DOD/NASA Incentive Guide of the same year. Activities in this field are now in hands of The Procurement Office (Ministry of Defence), which published an updated version of the Incentive Contracting Guide in 1979 [46]. A number of field experiences with these procedures were recently reported by Dixon [47].

Related aspects of these contract types in the legal and management fields were dealt with by Gaisor [48] and Walker [49], respectively.

Basically, preference is given to fixed price arrangements; incentive contracts should be used whenever risks are too great to permit fixed prices, but not so great as to justify the use of cost-plus contracts.

Particularly in the area of military aircraft, great emphasis is laid in the UK on reliability incentives. Sledge [50] and O'Connor [51] report on this issue extensively. Maintenance costs are reported to account for 47% of the UK Air Force budget, which explains the high incentives paid upon obtaining higher MTBFs (Mean Time Between Failures).

Another, similar element which is promoted in UK is the so-called RIW concept (Reliability Improvement Warranty); see also O'Connor ([51], p. 134), who explains some warranty aspects. RIW basically implies that the contractor has to bear all the expenses of repair and maintenance (improvement) during the warranty period (3-5 years). This will, of course, motivate him to improve the maintainability of his product.

Newman [52] describes how a large company such as Westland got into huge financial problems with large helicopter contracts, mainly as a result of underestimating (incentive) contract conditions.

Harrison [53] refers to the use of incentives in UK civil engineering contracts, where, according to the author, the following standard formula is often used:

\[
\text{Contracts fee} = 0.045 \, TC + \frac{1}{3} (TC - AC),
\]

where \( TC = \) target cost, \( AC = \) actual cost and the minimum fee is 2%.

A recent trend in UK military procurements is the intention to cut the total value of cost-plus contracts to well under 10% of the total procurement spending (Brown [54]). The Ministry of Defence now considers cost-plus contracts as the prime villain in driving up costs, and intends to replace them by fixed price or maximum-price plus incentive fee (FPI) contracts.

3.4.3 The ESA School

ESA (European Space Agency) was established in May 1975. European space co-operation, however, has been in existence for about 20 years (after an introductory period).
It is evident that, certainly in the beginning, many of NASA's management techniques were adopted. Already in 1969, however, Van Reeth [55] described the advantages (and disadvantages) of incentive contracting and illustrated a case-study, HEOS-1. HEOS-1 was a scientific satellite, studying the interplanetary field and solar particles (solar wind). The CPIF contract was finalised satisfactorily and the satellite was launched as foreseen. The incentive contract had a multiple incentive fee, with:

- 43% cost incentive,
- 17% scheduling incentive, and
- 40% product performance incentive according to:

\[ F_i = (0.43 \, C_f + 0.17 \, S_f + 0.40 \, P_f) \, F_n, \]

where

- \( F_i \) = incentive fee
- \( F_n \) = nominal fee
- \( C_f \) = cost factor (varying from 0 to 2)
- \( S_f \) = schedule factor (varying from 0 to 2)
- \( P_f \) = performance factor (varying from 0 to 2)

As for the cost part, the contractor obtained a 20% sharing in the case of underrun and had to contribute a 10% sharing in the case of overrun.

For the performance part, two parameters were measured on the ground; two others during in-orbit operations.

In a later article, Van Reeth [56] defended a further use of incentive contracts. He postulated that final costs and technical performances had to be accurate at approximately 20-30% in order to determine a successful incentive clause.

Another well-documented case study is that of the satellite ESRO IV (launched in 1972). This scientific satellite was developed to study the ionosphere and solar particles.

A general overview of the case study is given by Lafay and Laurentie [54]. A detailed description of the managerial experience is given by the project manager, Lafay [58], while the incentive scheme is presented in detail by Vandeput [59].

In the case of ESRO IV, too, a multiple incentive scheme was established. In this case, however, more interrelations were established between the respective elements. The obvious objective was to compel the contractor to make an optimum choice for the client between cost, performance and delivery.

The incentive fee on performance and schedule (\( F_i \)) was determined as:

\[ F_i = (0.75 + 0.25 \, S_f) \, P_f \, F_n \]

where

- \( P_f \) = performance factor (varying from 0 to 2),
- \( F_n \) = nominal fee,
- \( S_f \) = schedule factor (varying from 0 to 2).

The performance factor was determined by:

1. measurements on ground (i.a. solar cell performances);
2. in-orbit performance (boom deployment, power supply, thermal control etc.).

The scheduling factor was presented by a degressive step function (dependent on target
delivery date).

The cost incentive involved a 40% bonus for actual cost smaller than target cost, but this bonus was to be multiplied by Pf (interrelating performance with cost savings). For the case where the actual cost was larger than the target cost, on the other hand, a 10% penalty on the difference was foreseen, although this, too, was to be corrected by multiplying by Pf.

Thus:

\[
\text{a bonus fee} = 0.4 \times (\text{TC} - \text{AC}) \times \text{Pf} \text{ for AC < TC}
\]
\[
\text{a penalty fee} = 0.1 \times [\text{AC} - (\text{TC} + 50000)] \times \text{Pf} \text{ for AC > TC + 50000}
\]

where

\(\text{Pf} = \text{performance factor}\)
\(\text{TC} = \text{target cost}\)
\(\text{AC} = \text{actual cost}\)

50 000 = range of neutral zone [in accounting units (AU)]

The project was considered to be extremely successful:

- the satellite was delivered 30 days before the target date;
- the final cost overrun was less than 5% of the initial target cost;
- the satellite worked perfectly for 450 days (180 days being considered as target design performance).

The Orbital Test Satellite (OTS) has also been reported as a case-study. Stockwell [60] described the procurement programme of this experimental telecommunication satellite. Once more, a multiple incentive scheme was adopted, in this specific case heavily oriented towards performances. Additional award fees were granted upon successful presentation of reviews. The performance incentive was based upon the flux delivered at ground level (in-orbit performance). A (very steep) scheduling incentive was given in order to motivate the contractor to deliver the satellite within the time schedule. Cost sharing was, in this case too, linked to the performance and amounted to 20-40% bonus in the case of underrun (range in function of performance); a 5-10% penalty in the case of overrun.

The award fee system employed during the procurement of Spacelab has been the subject of many discussions. The elements have been described by Stöwer [61] and Pfeiffer [62]. Fourteen percent of the basic price agreement was assigned for the award fee. Of this amount, 75% could be earned during project development and 25% was made dependent upon final performance.

Here, the lack of objectivity (perhaps reinforced by national interests) resulted in a failure of this system and led to conversion to a more classical incentive structure.

Herten and Peeters [63] deal with this ESA experience in a wider context, describing it as a more generally applicable project management tool. Problems of implementation in a multinational environment are discussed.

Kahn [64] describes ESA's experience with cost incentives in development contracts. He compares the applicable contract types and their financial consequences. Kahn strongly defends the introduction of a neutral zone and claims that each particular formula has to take into account the commercial risks and the state of technical definition. The influence of escalation and exchange rates is discussed. An important statement made is that a cost-sharing incentive without some balancing factor might tempt a contractor to take excessive technical risks in order to achieve a positive cost bonus. In other words, it is advisable to balance costs and technical performances in order to obtain an optimum product.

In another recent publication, Kahn [65] reviews recent trends in contract types for European
satellites. In general, he feels that contracts for scientific and pre-operational application satellites are usually placed under cost-reimbursement conditions. Follow-on application satellites are merely contracted for on a fixed price base. Incentives earned under ESA contracts usually tend to be higher than a factor 1. It is generally agreed in ESA that this is a reflection of the good performances in European space industry. He also concludes that award schemes have found little favour with either ESA or its subcontractors.

Incentive contracts are, mainly as CPIF types, covered by the General Clauses and Conditions for ESA Contracts [66] and several (internal) administrative procedures. In a recent publication on Twenty Years of Co-operation in Space [67], it is emphasised once more that ESA tries to combine performance and cost incentives in order to avoid distortion of balance between final costs and performance. As a guideline, performance should be evidenced in ground tests, in performance in orbit and in operational life.

Thoma [68] re-evaluates incentives as a project management tool. For this tool to be successful, he feels that the following main characteristics have to be met:

- Simplicity;
- Early agreement;
- Sufficiently large;
- No dispersion over many criteria;
- Involvement of company’s project team.

3.4.4 The French School

A number of French articles are closely related to the ESA methodologies. As derivatives of this ESA experience we can refer to the articles by Rouze [69] and Vanhems [70]. Although they recognize certain advantages, they underline the prerequisites of good co-operation and flexibility between client and contractor. An unbiased use of cost incentives may, according to Rouze [69], also limit study costs and inventive improvements (in this context he represents Aerospatiale, i.e. industry’s point of view).

Couillard [71] describes the incentive scheme used for the satellite SPOT (CNES). The fee is directly proportional to in-orbit performance and is evaluated and determined on a monthly basis. The contractor, consequently, had a strong inducement to achieve a maximum lifetime.

Although the primary objective is the study of cost reimbursement contracts, a working group of the International Chamber of Commerce (Paris) has been performing an extensive study on contract types, regulations and standards for public procurement. Major contract regulations have been collated and are systematically discussed. This study covers governmental contract regulations in France, Belgium, Germany, USA, UK, Canada, Sweden, The Netherlands (i.a. framework contracts of Rijkswaterstaat) and several others. Besides these governmental regulations, the procurement standards of international organisations are also described, such as those of ESA, European Community contracts (EURATOM, CERN), OECD and World Bank contracts. Typical examples and case studies are presented. The results of the working group have been compiled by Schneider [72] and published in an extensive final report. In view of its comparative and unique character, this publication is to be considered as an important recent asset for (European) practitioners in this field.

3.4.5 The German School

The origin of this school lies in the dissertation published by Hansen [73]. She made a thorough study of the USA aerospace industry and published her results (in German),
introducing the different aspects of several contract types. Köppl [74] adopted some of these ideas and introduced them in the Tornado (multinational) project.

Madauss [75] and Rusberg [76] re-evaluate the lay-out of incentive contract types and discuss the advantages/disadvantages. They both feel that well-balanced incentives can be a very powerful project management tool.

A typical characteristic of this school is that ideas seem mainly to represent the contractors’ (e.g. MBB and Dornier) point of view, in contrast to what has happened in the USA.

Wolff [77] considers development contracts as a unique and recent form of contract, owing to their specific elements. In his opinion, control over the magic triangle (performance, schedule and cost) has no equivalent in any other contractual relation. According to Wolff, clarity of definition and accuracy of estimates must be the two major elements on which to base a decision as to the type of contract to be used. As the novelty of the performance is, in general, the most essential element, a cost reimbursement base is to be preferred.

The author (although clearly defending industry’s point of view) obviously respects and understands the desire of the client to add cost sharing and other incentive arrangements in order to protect his interests.

Wiibbenhorst [78] emphasises the strong relationship between the project stage and the contract type. According to him, the type of contract can only be chosen when the following three criteria have been evaluated:

- Degree of uncertainty;
- Efficiency required;
- Availability of means of control.

Herten [79] has prepared a dissertation, mainly in the area of multinational contracting and associated project management. He warns of the increasing problems in relationship with the number of partners, illustrating this with examples such as Airbus and Tornado.

3.4.6 The Dutch School

As long ago as 1970, Linssen [80] tried to explain the motives for using different types of contract in projects in the Netherlands. He mainly bases his article on the management aspects, reviewing the historical development of traditional management techniques. One of the defects in Europe lay, according to him, in the so-called managerial gap. In this connection, two elements are emphasised:

(a) Resistance, in Europe, to the adoption of new management techniques (essential to the coordination of modern large-scale projects);
(b) Lack of flexibility to adapt to changing circumstances, e.g. when implementation deviates from the target (bureaucracy).

He illustrated an essential new management tool, i.e. incentive contracts, and pleads for their introduction.

Goemans and Smits [81] mention the use of (delivery) incentives in the Oosterschelde-werken, a multi-million-dollar project in The Netherlands.

After a survey of different public directorates in Holland, Peeters [82], however, has to conclude that, notwithstanding substantial overruns, the existence of several types of contract is well known, but their implementation has still not begun. Consequently, the (gradual) introduction of simple incentives (delivery, performance) is strongly recommended.

It should be mentioned that, in the recent updating of the Army procurement guidelines in
The Netherlands, these recommendations have been taken into consideration.

### 3.4.7 Relevant Case Studies in Europe

As the European projects covered by the case studies published are rather well known, more objectivity could be introduced into Table 3.2. It remains a fact, however, that major failures have rarely been documented. We do, nevertheless, have a number of case studies which can be judged with a certain objectivity and can therefore be used later, in order to validate the models developed.

#### TABLE 3.2 Published case studies of relevant European projects

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>AREA</th>
<th>CONTRACT TYPE</th>
<th>AUTHOR</th>
<th>DATE</th>
<th>SUCCESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEOS 1</td>
<td>ESA SATELLITE</td>
<td>MULTIPLE INCENTIVE</td>
<td>VAN REETH [55]</td>
<td>1969</td>
<td>YES</td>
</tr>
<tr>
<td>ESRG-IV</td>
<td>ESA SATELLITE</td>
<td>MULTIPLE INCENTIVE</td>
<td>LAFAY AND LAURENTIE [57]</td>
<td>1974</td>
<td>YES</td>
</tr>
<tr>
<td>OTS</td>
<td>ESA SATELLITE</td>
<td>MULTIPLE INCENTIVE</td>
<td>STOCKWELL [60]</td>
<td>1979</td>
<td>YES</td>
</tr>
<tr>
<td>SPACELAB</td>
<td>ESA PAYLOAD</td>
<td>PERFORMANCE INCENTIVE</td>
<td>COUILLARD [71]</td>
<td>1982</td>
<td>YES</td>
</tr>
<tr>
<td>SPOT</td>
<td>CNES SATELLITE</td>
<td>PERFORMANCE INCENTIVE</td>
<td>SLEDGE [50]</td>
<td>1981</td>
<td>NO</td>
</tr>
<tr>
<td>TORNADO</td>
<td>NATO AIRPLANE</td>
<td>PERFORMANCE INCENTIVE</td>
<td>NEWMAN [51]</td>
<td>1982</td>
<td>NO</td>
</tr>
<tr>
<td>WESTLAND</td>
<td>HELICOPTERS</td>
<td>FIXED PRICE INCENTIVE</td>
<td>FEAZEL [43]</td>
<td>1984</td>
<td>NO</td>
</tr>
</tbody>
</table>

### 3.5 SUMMARY

Once more, we shall try to summarise the foregoing considerations in a single table (Table 3.3), which lists the various events in a strictly chronological order. The ‘periods’ are only indicative and should not be considered as in any way fixed. The main aim of grouping events in this way is simply to obtain some significant milestones for future references.

It is impossible to include all the publications found in the literature in this table. A number of articles describe (past) case studies, others contain isolated proposals. Some articles have obviously had an important influence on the evolution of contract types.

An attempt is made, in Figure 3.2, to give an overview of such important ‘milestone’ publications. We have taken Figure 2.8 from Chapter 2 and have used this as a background on which to ‘project’ such milestone publications.

Consequently, Table 3.3 and Figure 3.2 give us two evaluations of the tendencies, both timewise (in relation to key events) as well as from a contract-technical point of view.

In Europe, it is mainly the aerospace sector that has played an important part in furnishing increasing experience with new types of contract.

All major techniques used in Europe have been adopted from the USA experience. Incentives, in continental Europe, have been initiated by ESA and, owing to ESA’s European involvement, have gained more popularity in the respective European countries. We can also observe an initial implementation of these techniques in other sectors in Europe.
Figure 3.2 Overview of major influencing opinions.

TABLE 3.3 Historical milestones in incentive contracting

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>TYPE</th>
<th>CONSEQUENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE WORLD WAR I</td>
<td>PERFORMANCE INCENTIVES</td>
<td>ONLY EXPERIMENTAL</td>
</tr>
<tr>
<td>WORLD WAR I</td>
<td>BONUS FOR SAVINGS CONTRACTS</td>
<td>RESULTS STRONGLY DISPUTED / LAW SUITS</td>
</tr>
<tr>
<td>WORLD WAR II</td>
<td>TARGET PRICE CONTRACTS</td>
<td>RESULTS DISAPPOINTING</td>
</tr>
<tr>
<td>POST WORLD WAR II</td>
<td>BACK TO COST-PLUS-FIXED-FEE</td>
<td>OVERRUNS</td>
</tr>
<tr>
<td>1962 (MCNAMARA)</td>
<td>COST-PLUS-INCENTIVE-FEE</td>
<td>DEFINITIVE BREAKTHROUGH IN MILITARY PROCUREMENT</td>
</tr>
<tr>
<td>FROM 1969 ONWARDS</td>
<td>NASA INCENTIVE GUIDE</td>
<td>WIDER APPLICATION OF INCENTIVES IN SPACE PROGRAMMES (IN EUROPE AS WELL), BUT OVERCOMPLEXITY</td>
</tr>
<tr>
<td>FROM 1980 ONWARDS</td>
<td>SIMPLER, INTERRELATED MULTIPLE INCENTIVES, LESS AWARD FEES</td>
<td>(SYSTEMATIC) RE-EVALUATION OF PREVIOUS EXPERIENCE, SIMPLIFICATION</td>
</tr>
</tbody>
</table>
3.6 REFERENCES


CHAPTER 4
PILOT ENVIRONMENT

4.1 INTRODUCTION

Because of the increasingly large financial investment involved, development contracts play a very important part in the present-day industrial environment. We can differentiate between two types of development contracts:

(a) Prototype development

Before any item can go into (serial) production, a prototype has to be developed. In industry, this activity is the typical task for R & D (Research and Development departments). For complex products (e.g. aircraft), the financial resources needed and the associated risk can, in certain cases, not be carried by individual or even grouped industrial companies. In these cases, and especially when public interests are involved, the (prototype) development costs are taken over by government or delegated bodies (e.g. NASA, DFVLR, CNES, NIVR etc.). In this case, taxpayers' money is used (sometimes with participation of interested industry) to develop projects of public interest. Even with this type of structure, smaller countries would not be able to finance huge development projects such as nuclear power stations and spacecraft. In this case, countries join together in supranational agencies as Euratom and ESA. They contribute, in general, on a pro rata basis.

(b) One-shot developments

In this case, the development of a single item is the ultimate purpose, with no intention to proceed to a (subsequent) production phase. A typical example here consists of scientific projects in the field of energy research, space research etc. Industrial companies can devote only a minor part of their funds to basic research. For example, large American companies spend no more than 3% of their overall R & D budget on it. Higher percentages would influence the costs of their products too much (via overheads) and therefore endanger productivity. For similar reasons, only very large companies can allocate substantial funds to research. In The Netherlands, two-thirds of (industrial) R & D expenditure is borne by the five largest companies* (data from In't Veld [1], nr 119, pp. 1-3).

Industrial research is mainly of an applied nature, the ultimate aim being either an improvement of an existing product (or production method), or the development of a new

* In alphabetical order: AKZO, DSM, Philips, Shell and Unilever.
From these considerations, it is clear that major development contracts are most likely to be encountered in the governmental and supranational sector. This sector, however, is a different kind of buyer, because of its non-profit-making aims. For this reason, a knowledge of its characteristics is most important to anyone wishing to understand the rationale behind certain typical elements.

In particular, the space sector is one in which these large development contracts are typically encountered. Investments are very considerable and commercial exploitation is as yet very speculative. In Europe, it is actually one of the few sectors where the supranational structure is working with remarkable success. We will therefore use this sector as a pilot environment. Some other European supranational agencies, such as CERN and Euratom, also have a successful record, but represent a less typical environment because, when the development contracts were placed, intermediate types of contract were very experimental and not yet in common use.

### 4.2 DEVELOPMENT CONTRACTS

The development of products, certainly those in hi-tech industry, is subject to increasing costs. Whereas the cost of developing cellophane was in the order of $40 000, the amount of money involved in the development of an integrated circuit ('chip') is something like $250 000 000 (In 't Veld [1], 119, p 3). Examples of a few developments in the field of aeronautical engineering are given in Table 4.1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Year</th>
<th>Development cost at that time without correction for inflation ($ \times 10^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. AIRCRAFT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F 27 (Friendship)</td>
<td>1955</td>
<td>f 27</td>
</tr>
<tr>
<td>F 28 (Fellowship)</td>
<td>1968</td>
<td>f 130</td>
</tr>
<tr>
<td>F 50</td>
<td>1985</td>
<td>f 600</td>
</tr>
<tr>
<td>F 100</td>
<td>1986</td>
<td>f 850</td>
</tr>
<tr>
<td><strong>B. SPACECRAFT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>1960</td>
<td>$ 380</td>
</tr>
<tr>
<td>Ariane 1</td>
<td>1979</td>
<td>$ 800</td>
</tr>
<tr>
<td>Gemini</td>
<td>1964</td>
<td>$ 1 250</td>
</tr>
<tr>
<td>Shuttle</td>
<td>1980</td>
<td>$ 8 000</td>
</tr>
<tr>
<td>Apollo</td>
<td>1969</td>
<td>$17 600</td>
</tr>
</tbody>
</table>

The parameters of a development project are given in Figure 4.1. In general, the development phase is preceded by a feasibility phase, in which the technical and financial feasibility is determined before the project is started. Here, again, the difference between such projects and industrial developments is very important. Both industry and governmental institutions have budgetary limitations, but the ranking of importance, within such budgetary constraints, is made differently. Whereas industry will first consider the overall profitability of the projects, governmental institutions will consider other aspects. Here, in principle, a ranking will be made.
as a function of public or scientific interest, and the development of projects is started as long as they fit the budgetary availabilities. Profitability is, in this case, considered to be a less important element in the decision process.

4.3 CHARACTERISTICS OF GOVERNMENTAL/SUPRANATIONAL SECTORS

We have already noted the specific differences in the decision-making process between government and industry. The major factor which dictates all differences is the absence of the profit motive. Profit(ability) is a major criterion in determining the allocation of resources; the lack of this yardstick complicates the process considerably. Hinrichs ([2], p. 9) expresses this as follows:

'Ever since the Garden of Eden, man has been concerned with allocation problems, the problems created by scarce means and unlimited ends. Then it was allocating four fig leaves between two people; now it is spending billions of dollars to pacify millions of people. In theory the problem is simple; it is difficult only in practice.'

Characteristics of governmental structured agencies are described by Anthony and Herzlinger ([3], p. 34) as:

(A) Lack of profit measure for allocation of resources.
(B) Tendency to be service organisations.
(C) Constraints on goals and strategies.
(D) Source of financial support.
(E) Dominance of professionals.
(F) Differences in governance.
(G) Differences in top management.
(H) Importance of political influences.
(I) A tradition of inadequate management controls.

The major consequences of these characteristics are as follows.
(A) Lack of profit measure for allocation of resources

The amount of profit can give an objective measurement of productivity*. Without this profit measure, outputs cannot be measured in quantitative terms. This, in turn, makes control of productivity extremely difficult. The consequences of this are more important than one might at first sight expect and result in:

(a) Lack of a single decision criterion; there is often no unambiguous objective that can be used in analysing proposed alternative courses of action.
(b) Difficulty of relating costs and benefits; there is no way of estimating the benefits of a given increment in spending. On the other hand, moreover, there are no arguments with which to defend this increment, e.g. in cases of (public) criticism.
(c) Difficulty of measuring performance; performance with respect to the important goals is difficult to measure and is, therefore, also very vulnerable to criticism.
(d) Centralisation of decisions; delegation to lower level managers is not possible to the extent that is feasible in industry. Performance cannot be identified and measured, so the risk of delegating this responsibility is seldom taken.
(e) Comparison of units; in cases of budgetary restrictions, how are priorities given?

The lack of the profit yardstick makes the (economical) management of such organisations more difficult. This does not mean at all that these organisations cannot act as cost-conscious buyers; it only highlights an additional problem. Even the most economic procurement policy cannot be demonstrated so easily as in cases where profit can be calculated.

(B) Tendency to be service organisations

From a control point of view, services are a priori more difficult to determine. Furthermore, goods can be stored, services cannot. As a consequence, governmental organisations tend to have excessively high staff complements, in order to be able to respond to (infrequent) peak loads. A typical example here is the army.

(C) Constraints on goals and strategies

Most services to be provided are strictly directed by an outside authority rather than as decided by their own management. Most service organisations must conform to the wishes of fund providers. Conflicts in motives often result in very high (hidden) costs.

(D) Source of financial support

In industry, a relation exists between budgets and revenues; thus the market strongly influences the limits within which the management of a profit-oriented company can operate. This is less the case in governmental structures; the budgets are dictated by taxes, which are completely independent of the outcome of the services rendered. On occasions, the relationship may even be negative: in periods marked by a low level of welfare benefit, the level of taxation may fall, but the need for an increase in (social and medical) services may strongly increase.

* Terminology used in accordance with In 't Veld [4], p. 241.
(E) Dominance of professionals

Specialists (scientists, research workers, military commanders etc.) often have motivations that are completely inconsistent with good resource utilisation. Their professional education, moreover, does not usually include education in management (one often hears the remark that if you promote a good specialist, you may lose twice: you lose a good specialist and you gain a bad manager!). Managerial skills are disregarded in promotions and the importance of having good managers is often underestimated.

As an illustration, even the well-known economist, Prof. J.K. Galbraith, stated [5]:

'Harvard Business School is a good school. We should be grateful to it for training people who will shoulder the dull, tedious administrative jobs in organisations.'

Such a poor opinion of managerial training is highly surprising.

(F) Differences in governance

In industry, the ultimate authority and control is well-defined and known (shareholders, board, directors). In non-profit (governmental) organisations, the corresponding line of responsibility is very vague. This, again, hinders effective control. External influences may, moreover, come from such a large number of sources that confusion is more likely to result than clear guidelines.

(G) Differences in top management

It is well known that President Truman's desk bore the sign: The Buck Stops Here (meaning that he could not shift decisions any further). Unfortunately, most nonindustrial organisations have a multi-headed top management (bucks heading off in all directions). In industry, however, even multi-headed management has a collective responsibility. Moreover, when functional responsibilities are not clearly defined, this likewise leads to more confusion.

(H) Importance of political influences

In general, the prime objective of elected officials is ...to be re-elected. Not infrequently, the means of accomplishing this re-election tend to conflict in no small measure with the interests of the organisation these officials (are supposed to) represent. Another important element is that top management tends to change as a result of changes in administration or shifts in the political climate. This rapid turn-over often results in short-term plans and programmes that produce quickly visible results, rather than longer range programmes. This effect is presumably less marked in the case of administrations whose civil servants do not lose their jobs when a new party comes to power (e.g. UK).

(I) A tradition of inadequate management controls

Bennet ([6], p. 433) points out that well-established accounting methods, even those with proven results, have not been introduced in governmental organisations. The bureaucratic system has developed a tremendous resistance to change, which is very hard to overcome.
4.4 EUROPEAN SPACE AGENCY

4.4.1 Historical background
(see also Battrick [7])

On 4 October 1957, the Soviet Union launched Sputnik 1, the first man-made object to orbit the Earth. European scientists realised that this first, modest, step in space would finally result in an enormous field of research. They also realised, however, that the financial means, industrial potential and organisation needed to explore this field would be considerable. Their fear was that only the Soviet Union and the United States had (at that time) the necessary resources to initiate activities in space. This would mean that these two nations would have the monopoly, and that Europe would remain an onlooker, getting the leftovers of scientific results and data.

These scientists therefore suggested a structure on the same lines as CERN (created in 1950). After preliminary committees had convened in the early 1960s, ESRO, the European Space Research Organisation came into existence in 1964. The main objective was to build satellites and co-ordinate the experiments; launchers would be purchased outside. As a first step, ESRO established the necessary departments and installations, which became operational in 1966. In 1968, with the aid of American launchers, three European scientific satellites were placed in orbit (Heos-1, ESRO-I and ESRO-II). From 1972, the scope of the ESRO convention was extended to cover application programmes. As such, aeronautical navigation, meteorology and telecommunication programmes were initiated.

The continuing science programme included the launch of such successful satellites as Heos-2, TD-1 and ESRO-IV (in 1972) and Cos-B (in 1975).

In parallel, an organisation had been set up in 1964 to co-ordinate the construction of a joint European launcher: ELDO (European Launcher Development Organisation). The ELDO programme considered the development of a three-stage launcher, Europa I, with Britain’s Blue Streak as its first stage, France’s Coralie as its second stage and Germany’s Astris as its third. In 1966, it was decided to develop an upgraded four-stage version, Europa II, and in 1970 a Europa III launcher was selected for further development.

In practice, however, the technical and financial assumptions proved inadequate. The Europa I launcher suffered from a considerable number of interface problems and launches were only partially successful. When the first test launch of Europa II was also unsuccessful, the enthusiasm of several member states decreased rapidly and the development of Europa III was stopped.

If we also mention the formation, in 1963, of another organisation, CETS (European Conference on Satellite Communications), it becomes evident that a considerable amount of effort and resources was being deployed rather ineffectively. It was not until 20 December 1972, however, that the decision was finally taken to establish a single European Space Agency.

4.4.2 Organisation and achievements

ESA is governed by a Council, which is the sovereign political and legislative body. This Council is composed of representatives of the Member States and appoints a Director General who, with his international staff, constitutes the executive.

ESA is basically a non-profit organisation. The conflict with profit-yielding activities is avoided by creating new entities, once specific elements have shown commercial potential, e.g.:
— Inmarsat (managing maritime communications);
— Eutelsat (managing telephone communications and TV broadcasting);
— Arianespace (managing and selling satellite launchers);
— Eumetsat (managing meteorological satellite services).

A number of programmes conducted by ESA have been very successful. Probably one of the biggest successes has been the development of a European launcher, Ariane. (It was Ariadne’s thread which enabled Theseus to find his way out of the labyrinth...). This launcher proved to be a financially viable alternative to the American launch vehicles. Furthermore, a number of satellite programmes were successfully executed:

— European Communications System Satellites (ECS);
— Maritime European Communication Satellites (Marecs);
— Scientific Satellites (IUE, ISEE, Exosat, Giotto);
— Meteorological Satellites (Meteosat);
— Shuttle-related activities (Spacelab, IPS).

These events and successes have given a renewed confidence in Europe to invest in space activities. A very important milestone was reached in January 1985, when the ESA Council meeting at ministerial level in Rome adopted a number of resolutions that opened new horizons for ESA activities. The main decisions taken were:

— That ESA should participate in U.S. Space Station Programme (Columbus);
— That a more powerful generation of Ariane launchers should be developed (Ariane V);
— That the funding of scientific, application and microgravity programmes should be increased;
— That ESA should maintain an interest in the development of Hermès, the French (later, perhaps, European) manned space vehicle.

The budgetary evolution of ESA’s activities (including those of the pre-existing organisations, ELDO and ESRO) is given Figure 4.2. These budgets show (with a delayed effect):

1. The initial enthusiasm (1962-1967);
2. The doubts and criticism (1968-1974);
3. The new impulse after ESA had been established (1975-1978);
4. A period of stagnation (1978-1984);
5. A new impulse, after ESA’s scope had been extended (1985-?).

A new period of stabilisation may be expected in 1990-1995, at a level of (approximately) 1700 MAU/year (1 AU = 1 Accounting Unit = 1 ECU = 0.9 US dollar (1986)).

In order to understand how these budgets are spent, we should go back to ESA’s convention [8], in which the following principles were laid down:

1. For the execution of the Agency’s programmes, maximum use should be made of industry (as opposed to building-up ESA in-house capabilities).
2. Available resources should be used in a cost-effective manner; in particular, utilisation of industry should be based on free bidding.
3. An appropriate procurement policy should be defined and approved before procurement action is undertaken.
4. Development and procurement policy should, in principle, be to make maximum use of Member States’ industries.
Figure 4.2 ESA budgets (in 1986 constant million accounting units).

(5) In particular, launchers developed by the Agency should in principle be used in support of European programmes.

(6) An equitable geographical distribution of contracts to Member States' industries should be ensured.

(7) A balanced development of a competent European space industry should be aimed at by utilising, structuring and rationalising existing industrial capabilities.

(8) To this end, industrial potential and industrial structures should be under review by the Agency, in order to monitor and, if necessary, adapt the Agency's industrial policy.

(9) Measures should be taken to improve the world-wide competitiveness of the European space industry.

(10) Possible conflicts originating from the simultaneous implementation of two or more of the above principles should be solved in a pragmatic way.

A number of clashes are evident. Some examples:

- (2) (cost efficiency) is often incompatible with (1) (building-up in-house capabilities), (4) (buy European) and (6) (geographical distribution).
- (2) (free bidding) clashes with (4) (buy European), (5) (exclude non-European launchers) and (6) (geographical distribution).
- External (geographical and political) influences have led to the fact that a large number of contracts are negotiated directly, without free competition (see also Thoma [9]).

These examples illustrate the effects of constraints and influences, as described in Section 4.3.
4.4.3 European space market

So far, we have more or less concentrated on ESA. The overall European space market, however, has three segments:

1. ESA market;
2. National programmes market;
3. Commercial market.

Most European countries, in fact, have their own national programmes (which they finance themselves). The first two market segments have many similar elements; the third segment is more related to the classical market structure with open competition and related rules.

Table 4.2 clearly shows the shift from a development to a commercial phase that has manifested itself in recent years.

<table>
<thead>
<tr>
<th>Year</th>
<th>ESA (%)</th>
<th>National (%)</th>
<th>Commercial (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>70</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>1983</td>
<td>43</td>
<td>29</td>
<td>28</td>
</tr>
<tr>
<td>1988*</td>
<td>49</td>
<td>17</td>
<td>34</td>
</tr>
</tbody>
</table>

* Estimate

This shift illustrates the 'spin-off' of ESA development and pioneering work. An independent study [10] shows that the indirect effects of ESA contracts have brought advantages to the European space companies at an average ratio of 2.5 (measured as the ratio of total output of space division to amount of ESA contracts).

On the basis of internal and external publications (e.g. [11]), the total commercial world space market for the coming years is estimated at 4500 MAU yearly. It is estimated that Europe can obtain some 1000 MAU of this commercial market. If we take into account the fact that parts of the national and ESA budgets are spent on their own costs (personnel, administration etc.), this gives Europe a potential space market (governmental and commercial) of some 3000 MAU per year (from 1988 onwards), distributed as shown in Table 4.3.

<table>
<thead>
<tr>
<th>Market sector</th>
<th>Annual value</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA</td>
<td>1450</td>
<td>49</td>
</tr>
<tr>
<td>National</td>
<td>520</td>
<td>17</td>
</tr>
<tr>
<td>Commercial</td>
<td>1000</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>2970</td>
<td>100</td>
</tr>
</tbody>
</table>
It can only be hoped that European (space) industry has foreseen this evolution and will have taken the necessary steps (investment, recruitment, training, ...) to make itself competitive in this market.

As another illustration of the importance of this market, the number of people involved in space activities is set out in Table 4.4 (see also [12]).

**TABLE 4.4 Employment in European space activities (1983)**

<table>
<thead>
<tr>
<th>Sector</th>
<th>employees</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space companies</td>
<td>16 000</td>
<td>51</td>
</tr>
<tr>
<td>Related (consultancies)</td>
<td>6 000</td>
<td>20</td>
</tr>
<tr>
<td>Institutions (ESA &amp; national)</td>
<td>5 000</td>
<td>17</td>
</tr>
<tr>
<td>Universities and laboratories</td>
<td>4 000</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31 000</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Forecasts considered a 5% yearly staff increase; it is therefore evident that qualified space engineers and technicians are becoming a scarce commodity in Europe. (Note that these are 1983 data, derived from the latest available survey. It is anticipated that, in view of the present upsurge in large European space projects, the actual increase in staff numbers will be even greater.)

### 4.5 SUMMARY

In view of their specific character, we shall lay emphasis on development contracts in the governmental and supranational sector. However, it is not impossible that results of this analysis may be applicable to other types of contract or other environments. Two aspects should be considered:

- For other contracts (production, of-the-shelf procurement etc.), the product can be clearly specified and less need will be felt to deviate from the traditional types of contract.
- For other sectors, there will be various different constraints and situations, so transfer of the techniques described here to other sectors should be done with extreme care, after it has been checked that the assumptions made are still valid.

A typical example of such a sector is ESA, the European Space Agency. In view of the availability of data, we shall use this agency as a pilot environment.

A general model will be made for development contracts in the governmental/supranational structure, and each model will be illustrated with the aid of ESA data.
4.6 REFERENCES


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CHAPTER 5
SYSTEMS APPROACH TO INCENTIVES

5.1 GENERAL

One main conclusion drawn from the extensive literature survey was that the decision concerning the type of contract to be employed in a particular case is usually made in a very heuristic way. When this point was discussed with authors and initiators, they admitted that the incentive schemes, for example, were determined more or less on a trial-and-error basis. The two negotiating parties, the client and the contractor, have a feeling about what they find acceptable and use this, relatively subjective, concept as a starting point. This, most of the time, will result in a compromise, dictated by the strongest party, but not necessarily reflecting reality.

The first consequence of this pragmatic approach is that lessons drawn are mainly based upon past subjective experience, without any questioning of the underlying rationale of the choice made. A secondary consequence is that certain aspects are taken for granted and that essential elements, once overlooked, will not reappear in future negotiations.

Not only has the need for more objective criteria been felt and expressed by several parties, most people also realise that their use will make negotiations easier. Indeed, an objective evaluation, based upon an unambiguous, scientific approach, will certainly be acceptable to both parties as a valid starting point. Final refinements will, of course, always remain a point of negotiation, but both opponents can at least use the same language and information.

In order to achieve such a set of objective criteria, a systems approach will be adopted in this study. For each important element that influences the final decision, a general model will be developed on the basis of systematic considerations. As an illustration of this model, data from the pilot environment (ESA) will be used.

First of all, however, we have to introduce some general elements of this 'systems approach'.

5.2 SYSTEMS THEORY

In order to avoid any confusion, we shall first define some of the relevant terminology; in this connection, the definitions laid down by in 't Veld [1] will be followed.

A system is, depending upon the objectives as defined by the analyst, a set of clearly distinguished elements within the total reality. These elements certainly have relations amongst themselves and may have relations with other elements of the total reality, where:

- **elements** are the smallest entities that the analyst wishes to consider in his analysis;
- **relations** are descriptions of the coherence between these elements.

Reality consists of an enormous number of elements and relations. Consequently, we tend
to develop a concept or simplified construction so as to be able to manipulate, exercise and imitate, until the complicated reality becomes clear, understood and, preferably, controllable. These strategic aids, serving to order and analyse the chaos of information collected, are called models.

De Leeuw [2] distinguishes four branches within system theory:

1. **A philosophical branch**, which sees systems theory as a new philosophical view of the cosmos;
2. **An organismic branch**, regarding it as a general and empirical theory about systems of various kinds (emphasis on biological aspects);
3. **An axiomatic branch**, where systems theory is seen as an abstract non-empirical set of concepts and models which may be filled up with empirical content by specific mapping procedures (with emphasis on models and control mechanisms);
4. **A methodical branch**, which considers systems theory as an aid to problem solving — this is closely related to operational research.

In our specific case, we shall aim for a modelling tool that closely involves the control aspects. Consequently, we shall refer mainly to the axiomatic branch of systems theory. De Leeuw [3] has developed the control paradigm concept within this axiomatic branch. This concept proves to be very useful for our purpose. Kramer [4] has also used this control paradigm as an aid in solving problems for which no clear-cut traditional solution is available. The control paradigm consists of a set of abstract control systems and methodological considerations concerning the modelling of concrete systems by means of one (or more) of these abstract control systems (De Leeuw [3], p. 196). This principle is illustrated in Figure 5.1.

![Control System Diagram](image)

*Figure 5.1 The control system*
The requirements for efficient control have been described *in extenso* by De Leeuw [3] and Kramer [4] and can be summarised as follows:

1. The controller should have some index of performance by which to evaluate system behaviour;
2. The controller should have a model of the system to be controlled;
3. The controller should get information about the input, the output and the state of the system;
4. The controller should have at its disposal sufficient alternative measures of control (this is also known as Ashby’s Law of the Requisite Variety).

We can now evaluate how these general principles will be applicable to our contract choice problem, though one must not lose sight of the fact that any appropriate control tool has to be tailored to the task in hand.

### 5.3 PRACTICAL IMPLEMENTATION

#### 5.3.1 Compliance with general prerequisites for effective control

The purpose of a client is that he wishes to receive (clearly specified) goods or services within a certain delivery time and for an agreed price. So, the main inputs which are given by the client are:

- a clear specification, with quantified requirements;
- a delivery date he wishes to be met;
- a price he agrees to pay.

In order to ensure proper execution of the contract, a number of control instruments will be described in the contract. For example, the client will stipulate that, under certain well-defined circumstances, he has the right to terminate the contract or to withhold payments. Most of these instruments are relatively drastic and will only be implemented in extreme cases.

In general, the client’s interest is primarily to get the product (not to cancel the order). The major control mechanism will therefore be designed to meet this objective.

Direct control (i.e. inspectors on contractor’s premises) is very expensive, however, and will, in general, only be implemented for critical reviews (e.g. witnessing tests, design reviews). Therefore, one part of choosing the right type of contract is an attempt on the part of the client to put the control mechanism where it really belongs, i.e. with the contractor.

The quicker a deviation from one of the three targets (performance, delivery time and cost) is detected in the control loop, the quicker corrective action can be taken and, in consequence, the less corrective effort will be required.

Information within organisations already suffers from a certain lead time. We can illustrate this by the following example (see in ’t Veld [6], p. 11). The president of the Douglas Aircraft Company announced very optimistic prospects for the company at the annual shareholders’ meeting. At that very moment, the company was in fact already bankrupt, although this was only discovered 6 months later, when the figures were properly processed (which was the normal processing time in the company).

Although introduction of data processing equipment has greatly reduced this time lag, there is still a considerable time difference between the measurement of a deviation and its correction (mainly as a consequence of organisational procedures).

The situation is much worse for the client. Information is filtered before it reaches him. The
contractor, generally, considers bad news as temporary and hopes to rectify this within the shortest delay. Even with the strictest direct control (auditors, inspectors etc.), it takes months before the client can detect important deviations (e.g. in delivery date). Generally speaking, the client will only be informed once the situation is hopeless. For the client, therefore, it is more useful to build in control mechanisms that are effectively transparent for the contractor. If the contractor is to be penalised for deviations afterwards, and if he can quantify this penalty, he will try to correct a deviation as quickly as possible, in his own interest.

The right type of contract is the most important element in this context. Let us take the two main contract types as an illustrative example.

Once important deviations from target costs (or trends) are detected by the contractor's internal cost reporting system, he will either notice them (if he is working under cost-reimbursement conditions) or try to correct them (if he is working under fixed price conditions). This clearly illustrates the internal control function of the contract type.

Following Kramer ([4], pp. 92-96), we describe this system as meta-control. The main control function will be set by the contractor, while the client acts only as a meta-controller (see Figure 5.2).

![Figure 5.2 Meta-control within the contractor/client framework.](image)

The (internal) control functions exercised by the contractor will, in general, be dictated by the desire to achieve higher productivity. He will continuously measure his efficiency and effectiveness (see Figure 5.3). In general, he will try to deliver an acceptable product (meeting the requirements) within an acceptable time frame (meeting the delivery time) with minimum effort.

It is essential for the client to take these (contractor's) objectives into account. If the client develops his own control mechanisms, they can only be effective if they amplify the contractor's internal control mechanisms or, at any rate, do not neutralise them. Figure 5.3 is in fact the simplified model of the system to be controlled, which the meta-controller should always bear in mind (prerequisite 2 for effective control).

The meta-controller, however, has very limited knowledge of the state of the system (certainly none of its current state) and will therefore never be able to keep effective control of, say, the efforts made. In general, even, he has no notion of the norms set (these can be strongly influenced by the capacity situation within the company). The client (the meta-controller) should therefore never try to take over the controller's role, since it is one in which he can under no circumstances be effective.
The client will be a much more effective (meta-)controller if he introduces a number of control mechanisms for which:

(a) he can set quantitative standards;
(b) he knows the way in which they influence the system;
(c) he can get objective information;
(d) he can provide alternative mechanisms,

and which, in other words, will enable him to exercise effective control.

Note that the lack of quantitative standards and objective information already theoretically explains why award fees can never be effective as control instruments.

5.3.2 Design of appropriate meta-control instruments

We have already noticed that the type of contract, on its own, will strongly influence the system's behaviour.

Ideally, the client wishes to obtain a good product, preferably performing better than specified, within the shortest possible delivery time and at the lowest price. These wishes will, however, conflict with what the contractor understands by a good product. The two parties can find a consensus and avoid conflicts on the separate elements as follows:

(a) Performance: The contractor will not a priori object to higher performances (which will improve his reputation), as long as the additional effort required to reach this higher performance receives adequate compensation.

(b) Delivery time: If the contractual delivery time is realistic, this will result in a minimal cost to the contractor. He will only be inclined to shorten this delivery time if the additional effort required is paid for.

(c) Costs: Cost overruns will be strongly felt in fixed price contracts and are the main subject of the contractor’s internal control system. A strong motivation will have to be given to the contractor, however, to induce him to reduce costs under cost reimbursement conditions.

(d) Combination of these elements: The contractor will always consider his overall productivity, and will therefore tend to save on one aspect (e.g. quality) if another element tends to deviate (e.g. costs). The client can only avoid this by interrelating the above-mentioned elements.
Overall, if the client wishes to motivate the contractor to achieve higher performance and better delivery schedule under fixed price contracts, he will have to introduce — depending on his objectives — either performance incentives or delivery incentives or both. At the same time he can avoid having to compensate for (internal) cost overruns in these areas.

In the case of cost reimbursement elements, the situation is even more complex. In this case, the client will have to control costs by introducing some form of cost incentive, but will have to compensate for the possible negative effects on performance and delivery by offering performance and delivery incentives.

5.3.3 Additional requirement: simplicity.

Several authors have warned, either on the basis of experience or as a result of detailed studies, that most incentive schedules are too complex. Kennedy [7] concluded:

'Complex incentives are difficult to negotiate and impossible to administer.'

Jones [8] also found that:

'Arrangements were too complex, and the incentive formulas were too complicated.'

Hunt [9] advises:

'Clarity and simplicity are the keys to effective incentives.'

Some schedules even required such extensive computations, that results were only available after a considerable delay.

Besides the obvious administrative burdens involved, neither the client nor the contractor has rapid insight into the effects of reorientation. More or less complex simulations hindered discussions during negotiations.

Both parties have the feeling that the result can only be determined after completion of the programme, and therefore deny themselves effective control or feedback possibilities. Under these circumstances, incentives lose their power as an effective project management tool. As a rule of thumb, one may state that if a (nomo)graph or quick (hand)calculation does not make it possible to obtain a rapid evaluation of the incentive, the incentive is an ineffective motivator.

As a reaction against such complex schedules, a KISS-tendency has been referred to (KISS = Keep It Simple and Stupid). We will, therefore, add the following (5th) prerequisite of an effective controller:

(e) The control instrument must be logical, must reflect reality and must have a high degree of transparency and visibility.

5.4 CONCLUSION

Within the axiomatic branch of systems theory, we have found a very useful model which gives us a better understanding of the processes of contracting: the (meta-)control paradigm. The prerequisites for effective control teach us that the client cannot take over the ultimate controller function; he will only be able to impose an effective form of meta-control.

Three specific motivational control instruments are available:

— cost incentives;
— delivery incentives;
— performance incentives.
In order to be effective, these incentives will have to respond to the four (traditional) prerequisites. We have, however, introduced in our case a fifth prerequisite: simplicity. We shall therefore try to fix the criteria that each of these (separate) elements have to meet.

In the following chapters, we shall develop a general model for each aspect, which will be illustrated with the help of data taken from the ESA pilot environment.

Although it is ultimately the purpose to obtain a quantitative model, this will not always be possible. As explained by in 't Veld [10], a number of consecutive steps have to be taken, one of them being that before quantification, a qualitative model has to be constructed anyway.

5.5 REFERENCES

CHAPTER 6
COST INCENTIVES

6.1 GENERAL

The principle idea behind a cost incentive is ‘sharing’. The contractor will have to share a part of the cost overruns, but will get a share of the savings in case of underruns. The most significant parameter in this context, therefore, is the ‘sharing ratio’. This ratio determines what percentage will be shared between the two partners, the contractor and the client; e.g. in the case of cost overruns, a 70/30 sharing ratio would mean that only 70% of the contractor’s overrun expenses will be paid by the client.

A number of authors have tried to link this sharing ratio to ‘risk analysis’. Feeney et al. [1] and later Newman [2] experimented with bidding games. They both concluded that participants (bidders) showed a great reluctance to accept high sharing ratios. They both admit, however, that their approach is very ‘clinical’. Influences of real life situation and client’s impact could not be taken into account; in fact they only measured a theoretical contractor’s preference.

Murphy [3] and Worm [4] developed normative models which can, in theory, predict the optimum sharing ratio. As a prerequisite, however, the analyst needs to know a considerable number of factors as:

— accurate estimate of the real costs;
— distribution (shape) of probable costs;
— standard deviation of that distribution.

Although these models definitely give a better insight into the mechanisms and background of the sharing principle, it is slightly optimistic to assume that such information would be readily available. Certainly, in our case of development contracts, the necessary inputs for these models are not available at all.

Lieber [5] develops a model based upon learning curves. This model is not a priori applicable to development contracts, owing to the implementation of learning (production) factors and experience.

Miller [6] introduces a pragmatic approach, whereby the tenderers would be asked to quote under different sharing assumptions. Using a cross-section analysis, he calculates the most appropriate sharing ratio (from the client’s point of view). The considerable danger of this method is that it can easily be manipulated (e.g. by contractors who have read his paper). Furthermore, the analysis cannot be performed for direct negotiations involving one (or two) tenderers.

A number of authors, e.g. Kahn [7], have shown qualitatively that the sharing ratio has to be sufficiently high to motivate the contractor. This is clearly illustrated by Clough [8], who reports on the high (up to 50/50) sharing ratios for cost over- and underruns successfully
employed for the Shuttle development contracts.

Other authors have clearly demonstrated the importance of the overhead factor, which can be considered as the most realistic approach to our problem.

6.2 INFLUENCE OF OVERHEADS

Talley and Curry [9] give a figure of 35.9% for the overhead part of weapons systems. (Even this 35.9% they call an estimate. The accuracy of this estimate, i.e. approximately 0.3%, is highly doubtful.) They then develop some formulas to incentivise this overhead, using an overhead pool. In this work, they do mention the relation between overheads and incentives. Their proposal, however, is relatively complex.

Backe [10] also expresses the opinion that there should be a relation between overheads and incentives. We shall illustrate this statement with the help of some consecutive balance sheets. In order to put some realistic elements into the cost structure, we have followed the typical cost data for the aerospace industry, as given by Hoss [11]. If we take an (imaginary) company with such a cost structure, which obtains a short-duration contract (less than 1 year) representing 10% of its turnover, we obtain a theoretical balance sheet such as that in Table 6.1.

<table>
<thead>
<tr>
<th>TABLE 6.1 Theoretical balance sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour related costs</td>
</tr>
<tr>
<td>Material related costs</td>
</tr>
<tr>
<td>Overheads (50%)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
</tr>
<tr>
<td>Fee (10%)</td>
</tr>
<tr>
<td>Grand total</td>
</tr>
</tbody>
</table>

Overall yearly profit = \( \frac{148.5}{1633.5} = 9.09\% = \frac{135}{1485} \) (so, equal with or without new contract)

Imagine the situation where the contractor has:
- a 10% overrun on the new contract;
- a contract with a 90/10 sharing for overruns (i.e. in our case, no fee is added to his costs).

We then obtain, highly simplified, the situation given in Table 6.2. Obviously, the situation described in the two tables is a gross oversimplification of reality. The fact remains, however, that for relatively small overruns, no extra overhead costs will occur. This means, in other words, that the overheads which the contractor was able to justify at the beginning of the contract (e.g. on the basis of a cost audit) will not be significantly influenced by small changes and overruns.
TABLE 6.2 Balance sheet in case of overruns

<table>
<thead>
<tr>
<th>Labour related costs</th>
<th>Original cost elements</th>
<th>New contract</th>
<th>Overruns paid by client</th>
<th>End-of-year theoretical balance sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600</td>
<td>60</td>
<td>6</td>
<td>666</td>
</tr>
<tr>
<td>Material related costs</td>
<td>300</td>
<td>30</td>
<td>3</td>
<td>333</td>
</tr>
<tr>
<td>Overheads (50%)</td>
<td>450</td>
<td>45</td>
<td>(4.5)</td>
<td>495</td>
</tr>
<tr>
<td>Subtotal</td>
<td>1350</td>
<td>135</td>
<td>(13.5)</td>
<td>1494</td>
</tr>
<tr>
<td>Fee (10%)</td>
<td>135</td>
<td>13.5</td>
<td>--</td>
<td>&gt;153</td>
</tr>
<tr>
<td>Grand total</td>
<td>1485</td>
<td>148.5</td>
<td>13.5</td>
<td>1647</td>
</tr>
</tbody>
</table>

Overall yearly profit = \( \frac{153}{1647} = 9.29\% \)

The simplification, in our case, is that we have arbitrarily taken a zero percent increase in overheads. This will not, of course, be the case in a real situation. The increase, however, will in reality be relatively small and may, for example, depend upon the level of capacity utilisation. In cases where a considerable overcapacity is available (sufficient room, staff etc.), it is evident that this increase can be very low.

The obvious conclusion we can draw from the two tables (even if the accuracy of the figures is highly disputable) is that the overall profitability will even increase if the sharing ratio is not sufficiently large. In other words, the contractor will not be motivated to avoid these overruns.

Aiming for overruns and extra work, even at cost price, is a generally known technique, e.g. in civil contracting. Contractors know by experience that such a practice will indirectly increase their profit, by (relatively) decreasing their (constant) overheads.

The purpose of this simplified illustration is to show clearly the relationship between the cost incentive and the overhead costs. The contractor will only try to avoid overruns if he believes that they will have a negative influence on his total overall profitability.

This effect also clearly illustrates why contractors are not really impressed by Cost Plus Fixed Fee regulations. If the fee is fixed in absolute terms, it is clear that the relative fee will decrease in case of overruns. Indeed, if we consider a basic target cost of 100 units, with a fixed fee of 10%, then in case of a 10% overrun, the contractor will only get: 100 + 10 (10% overrun) + 10 (fixed fee) = 120 units. The client may conclude from this that the contractor loses 1 unit of profit (110 + 10% profit = 121 units). We have already seen, however, that the contractor will get a hidden profit via overheads in the order of 3 to 4 units. The effect of the fixed fee is therefore completely compensated: for each lost unit (via the fee), the contractor recovers 3 to 4 units (via the overheads). A Cost Plus Fixed Fee contract, therefore, is not an effective motivator to prevent overruns.
### 6.3 COST INCENTIVE MODEL

Taking into account the prerequisites for an effective controller (as explained in Chapter 5) and the key role of the overheads, we base our model upon the following principles:

1. Cost overruns should be made unattractive for the contractor.
2. The contractor must not be permitted to make additional profit via hidden overhead compensation.

---

**Figure 6.1** Schematic price composition (percentages are only indicative).

---

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit</td>
<td>100%</td>
</tr>
<tr>
<td>General and Administrative Expenses</td>
<td>90%</td>
</tr>
<tr>
<td>Manufacturing Expenses</td>
<td>80%</td>
</tr>
<tr>
<td>Direct Material and Other Direct Expenses</td>
<td>70%</td>
</tr>
<tr>
<td>Burden on Labour</td>
<td>60%</td>
</tr>
<tr>
<td>Direct Labour</td>
<td>50%</td>
</tr>
<tr>
<td>Total Costs</td>
<td>40%</td>
</tr>
<tr>
<td>Works Costs</td>
<td>30%</td>
</tr>
<tr>
<td>Prime Costs</td>
<td>20%</td>
</tr>
<tr>
<td>Overhead Costs</td>
<td>10%</td>
</tr>
<tr>
<td>Selling Price</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Computations**

\[ \text{II} + \text{IV} + \text{V} = \text{OVERHEAD COSTS} \\
\text{V} = \text{GENERAL AND ADMINISTRATIVE EXPENSES} \]
(3) The sharing ratio has be tailored to each, real, situation.
(4) In fairness, the contractor will have to be compensated for his indirect overhead losses in the case of underruns.
(5) We consider general and administrative expenses (see Fig. 6.1) to be an overhead factor that is relatively independent of contractual over- and underruns.

The following model can therefore be developed:

Say: \( C_d \) = direct cost;  
\( G \) = General and administrative expenses;  
\( A \) = General and administrative expenses, expressed as a part of the direct costs;  
\( S \) = Sharing ratio, which we wish to determine.

Then, in accordance with these definitions:

\[
A = \frac{G}{C_d} \quad (6.1)
\]

The client, however, will only be inclined to pay that part of the extra costs which are not augmented by the general and administrative expenses.

For the general cost, therefore, the client will identify \( S \) by definition as:

\[
S = \frac{G}{G + C_d} \quad (6.2)
\]

Combination of Eqs. (6.1) and (6.2) gives:

\[
A . C_d = S (C_d + A . C_d) \quad (6.3)
\]

or

\[
S = \frac{A}{1 + A} \quad (6.4)
\]

This formula gives us a clear relation between the sharing ratio (\( S \)) and the general and administrative expenses (\( A \)).

Three aspects have to be noted here. First of all this compensation will give a 'worst-case' situation. In reality, depending on the status of the contractor's capacity, general and administrative expenses will increase when the contractual volume increases. In other words, if we implement this formula, we can be sure that the contractor will be penalised for cost overruns and that the control will be effective.

Secondly, we could have used exactly the same line of reasoning for underruns: if the contractual amount decreases (in case of underruns), it is probable that overhead costs, in absolute terms, will not diminish. In other words, we have, in exactly the same way, to motivate the contractor by at least compensating for these overhead losses. Again, we can assume a small reduction in overhead costs, which means that, if this formula is used, underruns will become financially attractive to the contractor.

In most systems, the sharing ratio for overruns differs from that for underruns. In our approach, there is no reason to make such a differentiation.
A third, important aspect is the relation with time overruns. It is assumed that sufficiently large penalties are added for the case of time overruns (see further in Section 7.5). It is evident that a combination of time and cost overruns should strongly penalise the contractor.

6.4 ILLUSTRATION OF THE MODEL

The 'overhead' factors we consider in our model are specifically general and administrative expenses (see Fig. 6.1). These are the expenses to which Talley and Curry [9] refer when they quote a figure of 35.9% for weapons systems. Auditing of European industry has shown that those large aircraft manufacturers that have a space division have general and administrative expenses in this division that are larger than the average value for the company as a whole. This can be explained by a higher R & D budget and less serial production (higher contribution of one-shot development contracts). Within the European space industry, we can estimate this factor to be in the order of 50%.

Applying this figure to Equation (6.4) gives us the following calculation for the sharing ratio:

\[
S = \frac{0.50}{1 + 0.50} = 0.333
\]

This indicates the use of a sharing ratio in the order of 35% (65/35).

Discussions on sharing ratios are often dominated by other (political) elements. In several cases, this has resulted in some very low sharing ratios, such as 90/10, for example. (Here, the contractor takes only 10% of the overrun for his account.) In practice, these low ratios will not act as effective motivators. Moreover, in cases of existing overcapacity, such limited sharing ratios may have a negative (or, at least, neutral) effect. Contractors can reduce their overheads (relatively) by overruns. The 65/35 sharing ratio, which results from this systematic approach, therefore clearly reflects reality.

We have noted, earlier, the use of neutral zones in the case of cost sharing arrangements. It is evident that these neutral zones will influence the sharing ratios, as will be shown in the next section.

6.5 INFLUENCE OF NEUTRAL ZONES

Kahn [7] defends the introduction of neutral zones as follows:

'It is sometimes considered appropriate in view of the technical uncertainties that the contractor should not begin to contribute directly the moment that the target is exceeded, and a neutral zone is introduced.'

It is also of practical use, of course, that difficult discussions are avoided for relatively small overruns. Since, normally, a limit is placed on the sharing as well, the neutral zone will definitely influence the slope of the sharing, as can be seen in Figure 6.2.

The sharing ratio can be regarded as an equivalent expression for the slope (tangent) of the curve. The introduction of the neutral zone means that the slope will become steeper than that resulting from the original 35% sharing ratio.

With reference to Figure 6.2, X and Y can be expressed in terms of the target cost (e.g. as a percentage). If we wish to interrelate the two slopes, we can describe:
Figure 6.2 Influence of the neutral zone.

\[
\tan \alpha = \frac{Z}{Y} \quad (6.5)
\]

and

\[
\tan \beta = \frac{Z}{Y - X}
\]

thus

\[
\tan \beta = \frac{\tan \alpha \cdot Y}{Y - X} \quad (6.6)
\]

As \( \tan \alpha \) can be defined by analogy with \( S \) (if expressed as a percentage), introduction of Equation (6.4) gives us:

\[
S' = \frac{[A/(1 + A)] Y}{Y - X} \quad \text{or, } S' = \frac{Y}{Y - X} \cdot S \quad (6.7)
\]

where \( S' \) = the corrected sharing ratio.

We can, again, illustrate this formula by introducing actual figures from the pilot environment. Typically, in ESA, a 10% neutral zone (expressed as a percentage of the target cost) and a 40% maximum sharing zone are applied.
So, with $C_t = \text{target cost}$ and $A = 0.50$, we get:

$$X = 0.1 \ C_t \ \text{and}$$

$$Y = 0.4 \ C_t$$

or, in equation (6.7),

$$S' = \frac{[0.50/(1 + 0.50)] \ 0.4C_t \ \text{or} \ 0.33 \times 0.4}{0.4C_t - 0.1C_t} = 0.44$$

So, in such a case, the sharing ratio would tend rather to be in the 55/45 range for our pilot environment.

Note that, with a 5% neutral zone, the $S'$ value would have been 0.38. In other words, as a rough approximation we can use the following rule of thumb: beyond the neutral zone, the percentage value of this neutral zone (in relation to the target cost) has to be added to the contractor's percentage of the sharing ratio.

We should also notice here that the relative value of some figures will not justify ratios such as 69/31. In view of the accuracy of the parameters, too, the sharing ratios should be limited to round figures (80/20, 70/30 etc.).

### 6.6 CONCLUSION

In the case of development contracts, overheads are considered to be the major factor influencing the sharing ratio. In order to discourage the contractor from permitting overruns, and to give him a strong motivation for underruns, a sharing ratio is suggested, i.e.:

$$S = \frac{A}{1 + A}$$

where

A = general and administrative expenses (overheads).

A typical ratio for the European aerospace sector could be in the order of 65/35. Whenever a neutral zone is applied, this ratio has to be adjusted accordingly, by adding the percentage of this neutral zone to the contractor's percentage of the share ratio.
6.7 REFERENCES


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CHAPTER 7
DELIVERY INCENTIVES

7.1 GENERAL

Most authors dealing with the subject of incentives agree that delivery incentives are to be considered as effective motivators. There is, however, a general misunderstanding that delivery incentives are only valid when timely completion is important. Even when this is not essential for the client, the danger exists that the contractor will use the schedule as a trade-off for (more attractive) performance and/or cost incentives.

Parker and Belden [1] concluded, when considering cost overruns from an extensive analysis of military contracts:

'Underruns tend to be associated with early product delivery, and overruns tend to be associated with late product delivery.'

In practice, the contractor will indeed suffer extra costs if the work takes longer than planned (fixed costs). These costs will be transferred directly to the client in the case of cost reimbursement contracts or indirectly recharged to the client in the case of fixed price contracts. One way or another, delays will always cause extra costs, which the contractor will try to recuperate from the client.

Even if no direct charges are expected by the client, late deliveries will always cause extra costs for him as well. In the first place, the client's management activity will also be prolonged (project team, administration etc.). Furthermore, the non-availability of certain deliveries may cause considerable rescheduling problems and indirect financial losses (programme changes, associated equipment standing idle etc.).

In a number of cases, delivery times are extremely important. In aerospace work, such delivery times are often associated with so-called launch windows, which are dictated by, say, astronomical calendar dates.

Let us take the Giotto mission as an example. The Giotto spacecraft was specially developed to encounter Halley's Comet, which passes close to the Earth at approximately 76-year intervals. Theoretical considerations, taking into account distance to the Earth and the comet's orbital velocity, gave an optimum encounter opportunity on 14 March 1986. This date, in its turn, determined the launching date of 2 July 1985. Instruments were developed and calibrated for this specific encounter date. It is evident that a slippage in delivery, even in the order of a few days, would reduce the spacecraft's value virtually to its scrap value. Although this example is probably an extreme case, in general the existence of launch windows will dictate the delivery dates. The (scientific) value of a satellite can strongly decrease if these delivery dates are not met. This explains why, in aerospace activities, there is such an interest in delivery incentives.
As for the evaluation of these incentives, only few papers give practical considerations. Orkand [2] used the PERT-COST technique — relatively new at that time (1963) — to calculate delivery incentives on the basis of statistical data. Reality shows, however, that such data are very hard to obtain in development contracts where, moreover, uncertainty may be very high. Hollander [3], too, used a similar technique. His method is based upon activity cost functions, but seems only to be useful for traditional activities (such as building construction), where replacement and retraining of manpower is relatively easy. In development contracts, however, simply adding an extra crew will not be practically feasible, since training will take too long and transfer of know-how, at a later stage, will be too time consuming.

We should mention here that, in practice, delivery incentives are very often calculated as the negative value of the penalty. For example, when a penalty clause is basically set at 1 per mille per day delay, this is often translated into an incentive of 1 per mille per day earlier. The relation between this permillage and reality is not examined. In order to establish such relation, we shall construct a model in which this relation is maintained, using parameters which are readily available and understandable (but not based upon complex statistical computations, as previously referred to in References [2] and [3]).

7.2 CONSEQUENCES OF TIME REDUCTION

Most authors agree that a time/cost trade-off relation can be described as a piecewise linear function, with a lower bound on the time scale, known as the 'crash time'. (See, for example, Moder and Phillips [4], pp. 212 et seq.) The crash time is the theoretical minimum time needed to complete a project, even with unlimited resources. The first linear part is often estimated as approximately ten percent of the normal duration.

If we assume that this normal duration is the optimum, during which the project can be executed at minimum cost, we can consider this first linear part to be practically exclusively connected with overtime payments. These overtime payments will occur if the client wishes to reduce the duration to less than the 'normal' value.

It should, again, be noted that this reasoning is only valid for development contracts, where the use of extra staff, without overtime payment, is in practice impossible.

If we compensate the contractor for these overtime payments on a straight basis (i.e. without reductions or sharing), the contractor is well rewarded, since he then gets this in addition to the indirect profits accruing from reduction of the job's duration, through the consequently reduced overheads.

We can demonstrate this with the help of Figure 7.1. The contractor's total cost is made up of variable costs (which will increase with time reduction) and fixed costs (which will decrease with time reduction).

If we call:

\[
\begin{align*}
T_n &= \text{normal delivery time;} \\
T_c &= \text{crash time;} \\
T &= \text{desired (reduced) time;}
\end{align*}
\]

then, the contractor will have to make extra costs (C) to reach this (reduced) delivery time, but will earn (B) in terms of indirect cost reduction. So, if the client fully compensates for the costs (C), there will be a pure profit equivalent to (B) for the contractor. This pure profit will be the real (financial) incentive motivating the contractor. We can formulate this conclusion as follows:
The delivery incentive per time unit has to be at least equal to the overtime payments necessary to compensate for this time unit.

### 7.3 DELIVERY INCENTIVE MODEL

The following considerations were taken into account:

(1) Overtime payments are the leading factor (in discussions, this is generally also accepted by the aerospace contractors).

(2) This factor is only valid for a relatively short reduction in time, however; for longer periods, material delivery times will be dominant.

(3) The crash time is rapidly reached in development contracts, as only a limited core team can be deployed.

(4) As most theoretical studies in network techniques demonstrate, time reduction can be described as a piecewise linear function (as a function of a contractor's project costs).

(5) The contractor will be well rewarded if overtime payments are fully compensated for.

In order to develop this model further, we shall need briefly to analyse such overtime payments. Overtime costs consist mainly of two elements:

- straight overtime payments;
- lower efficiency.
Overtime work, indeed, has an adverse effect on labour efficiency. The human body and mind can only sustain a constant output over a maximum number of hours. Once this maximum is exceeded, efficiency will diminish.

Jones [5] has evaluated this efficiency factor and obtained a productivity relation. For the first (linear) part of this, we can deduce the following relation:

\[ Y = 0.83 \times X \quad \text{for } 40 \leq X \leq 60 \quad (7.1) \]

where

- \( Y \) = productive hours per week
- \( X \) = hours worked per week.

So, at \( T_m \), with:
- \( C_t \) = contractual cost
- \( C \) = extra costs due to time reduction
- \( m \) = manpower-related part of \( C_t \)
- \( T_m \) = contractual delivery time
- \( T \) = reduced time
- 0.83 = productivity factor [from Eq. (7.1)]
- \( R \) = overtime rate (as compared with normal rate, e.g. 1.5)
- \( d \) = delivery incentive per time unit

the manpower costs are equal to:

\[ m \times C_t \}

At \( T \), the manpower costs are composed of two parts:

(a) a part under conditions of 'normal working hours', equal to:

\[ m \times C_t \times \frac{T}{T_m} \]

and

(b) a part under conditions of 'overtime hours', equal to:

\[ \frac{R \times m \times C_t}{0.83} \times \left( \frac{T_m - T}{T_m} \right) \]

Consequently, the manpower costs at \( T \) are:

\[ m \times \frac{T}{T_m} + \frac{R \times m \times C_t}{0.83} \times \left( \frac{T_m - T}{T_m} \right) \quad (7.3) \]
which means that the extra costs, $C$, are the difference between (7.3) and (7.2) or:

$$C = m \cdot C_t \cdot \frac{T}{T_m} + \frac{R \cdot m \cdot C_t}{0.83} \cdot \left( \frac{T_m - T}{T_m} \right) - m \cdot C_t$$  \hspace{1cm} (7.4)

thus:

$$C = \frac{R \cdot m \cdot C_t}{0.83} \cdot \left( \frac{T_m - T}{T_m} \right) - m \cdot C_t \left( \frac{T_m - T}{T_m} \right)$$  \hspace{1cm} (7.5)

or:

$$C = m \cdot C_t \left( \frac{T_m - T}{T_m} \right) \left( \frac{R}{0.83} - 1 \right)$$  \hspace{1cm} (7.6)

or:

$$d = \frac{C}{T_m - T}$$ \hspace{1cm} (7.7)

(i.e. delivery incentive per time unit equals the extra costs per time unit) we obtain:

$$d = \frac{m \cdot C_t}{T_m} \left( \frac{R}{0.83} - 1 \right)$$  \hspace{1cm} (7.8)

The advantage of this formula (7.8) as compared with previous approaches in the literature is that the determining factors are usually available to both parties. As they can be derived from the contractor's cost evaluation, they constitute objective values. Indeed $C_t$ (the contractual cost) and $T_m$ (the contractual delivery time) are the basic elements of the contractual agreement. The factor $m$ (the manpower part) can be deduced from the (mandatory) cost breakdown and $R$ (overtime rate) is in general known or obtainable (by cost analysis). So, the formula (7.8) proves to be fully transparent and controllable to both parties, and it implies that the contractor will be rewarded for his overhead losses on a 'straight' basis.

### 7.4 QUANTITATIVE ILLUSTRATION IN PILOT ENVIRONMENT

It is evident that each formula should be adapted to each typical situation, as the parameters describe. We can, however, illustrate the formula with some typical data from the ESA environment, as follows:

- The manpower-related part of a typical ESA development contract can be estimated at 60% of the total costs, thus $m = 0.6$;
The overtime rate varies per manufacturer, but is typically 50% for the first part, thus \( R = 1.5 \);

A typical duration for a development contract does not of course exist and can vary widely. A contract duration of 48 months, however, can be regarded as a plausible average. (This should not be confused with the overtime period, which, in accordance with previous notations, equals \( (T_m - T)/0.83 \)).

So, using Equation (7.8), we find a typical delivery incentive per month to be:

\[
d = \frac{0.6}{48} \left( \frac{1.5}{0.83} - 1 \right) \cdot C_t
\]

or

\[
d = 0.01 C_t \tag{7.9}
\]

Note that in Equation (7.9) the delivery incentive is expressed in relation to the contract value. A typical delivery incentive for ESA development contracts should, therefore, be in the region of 1% per month.

Again, however, we have to stress the relation between the incentive and the overall contract duration. In the case of a shorter contract duration, delivery incentives per time unit have to be relatively higher in order to motivate the contractor adequately. Unfortunately, this effect is seldom taken into account.

### 7.5 SOME CONSEQUENCES FOR PENALTY SCALES

Technically, a penalty can be considered as a negative incentive, which does not imply, however, that the above-mentioned formula (7.8) can also be used to calculate penalties.

A delivery incentive is introduced in order to motivate a contractor to stay within the contractual delivery time. It even gives him an additional reward for reducing this time, since his additional costs will be compensated for. The rationale for this is that, without it, a contractor will generally not try to finish earlier which, in the case of problems at the end of a project (tests etc.) will automatically be reflected in time and cost overruns.

The actual situation can be completely different for delays. In certain circumstances, a product can even become completely obsolete if it is not delivered within a certain time frame. In such circumstances, the client may even refuse payment. A lot depends upon the time criticality of a certain project and the elasticity and consequences of delays. Under fixed price conditions, the contractor will suffer from these delays, since the increase in indirect costs will not be compensated for. Although he will try to seek compensation (change notices, claims for hardship etc.) by the client, the internal control system will give a feedback in the case of imminent delays.

From the client’s point of view, the situation is much more dangerous in the case of cost reimbursement contracts. Some partial resistance is often introduced (e.g. in ESA contracts) by nonpayment of escalation over periods beyond the contractual delivery date. (This is of course only permissible if the delay is not caused by the client himself.) Penalties are, however, strictly necessary to ensure that the contractor does not use the project to cover, say, his overcapacity.
The situation for penalties, therefore, is similar to that for cost overruns mentioned in the previous chapter. So, the penalty would again at least have to neutralise the contractor's hidden profit in the case of time overruns, in order to compensate for overcapacity effects.

As this 'share' was calculated to be:

\[ S = \frac{A}{1 + A} \]  

(7.10)

where \( A \) = general and administrative expenses (as part of the direct costs), the penalty (\( p \)) per time unit would have to amount to:

\[ p = \frac{A}{1 + A} \cdot \frac{C_t}{T_m} \]  

(7.11)

If we illustrate this for our typical ESA case with:

\( A = 0.50 \)
\( T_m = 48 \) (months)

then

\[ p = 0.007 C_t \]  

(7.12)

This penalty, which is in the order of 0.7% per month, is approximately twice the actual value implemented in ESA contracts. Again, however, equation (7.11) implies that the contract duration has to be taken into account and that no 'standard' rate can be used in all contracts.

Referring to our 'reality' principle, we have to remark here that this equation can only be realistic for deliveries that are (relatively) uncritical from the point of view of time. It is evident that for cases where delivery times are extremely critical and essential, penalties have to take this reality into consideration and should be framed accordingly, even in certain circumstances including complete rejection after a certain period or much steeper penalty curves.

### 7.6 CONCLUSION

A delivery incentive is regarded as an effective motivator and safeguard against time and (associated) cost overruns. Within the framework of effective control, overtime payments to the contractor's staff are considered to be a key element when this incentive is determined.

A formula has been developed, which gives the relation between:

\( d = \) delivery incentive per time unit;
\( C_t = \) project cost;
\( m = \) manpower-related part of project;
\( R = \) applicable overtime ratio;
\( T_m = \) contractual delivery time;

as
This results, for the ESA environment, in typical delivery incentives in the order of 1% per month of total contract costs.

Different considerations have to be taken into account for penalties. A normal penalty scale can be determined, with:

\[ p = \text{penalty per time unit} \]
\[ A = \text{general and administrative expenses (overheads)} \]

as

\[ p = \frac{A}{1 + A} \cdot \frac{C_t}{T_m} \]

Again, for the ESA environment, this results in typical monthly penalty scales of 0.6 percent of the total project cost (approximately twice the actual value).

Both scales, incentives as well as penalties, should be regarded per case. As the time factor plays a determining role, a standard scale can never reflect reality for all cases. The criticality of the delivery time, moreover, has to be taken into account.

7.7 REFERENCES

CHAPTER 8
PERFORMANCE INCENTIVES

8.1 GENERAL

The basic principle of performance incentives is to reward a contractor whenever he achieves one or more specified levels of performance related to one or more performance elements of the product specification.

The basic selection of the performance parameter and definition of the performance target are, evidently, the most important elements in this context. In this connection, we can distinguish two categories:

(a) Pure performance incentives;
(b) Reliability incentives;

(a) Pure performance incentives

These relate to performances which can be accurately specified and relatively well simulated or tested before acceptance. Typical examples of such performances (found in the literature) are:

- mass (e.g. satellites);
- speed (e.g. aircraft);
- action range (e.g. aircraft);
- power (e.g. solar panels).

For satellites, one very important performance, which cannot be measured in advance, is the lifetime. It is evident that the lifetime of a satellite can lead to very attractive economical trade-offs. Certainly, for satellites placed in a geostationary orbit (36,000 km), the possibility of undergoing repairs cannot be envisaged in the near future. In view of the importance of this element, we shall deal with it in a separate paragraph.

For our specific field of application, some specific general factors have to be mentioned here. First of all, in development contracts, targets tend to be based upon expectations rather than on experience. This will, in general, make the target very relative. Neither party can guarantee the feasibility of such a target and the contractor will certainly run a considerable risk if he links his profit to such a target.

A point discussed in some detail by Parker and Belden [1] is the selection of criteria; they conclude that contractors tend to earn performance incentives, regardless of contract cost outcome. This is, in their opinion, usually due to the contractor’s careful selection of the criteria or to his manipulation of the targets during execution of the contract. In our opinion, however, a more important influence on this effect is the attitude and professional pride typical of (research) engineers.
Overall, performance incentives are built-in to compensate for unhealthy cost-performance trade-offs (‘gold plating’). The noninclusion of performance incentives may be interpreted as a negative message by the contractor, i.e. he may see the lack of performance incentive as a message that the client has no real interest in performance.

(b) Reliability incentives

These are more generally used for military equipment and commercial airlines. For military equipment, the main key of measuring reliability is the operational readiness at low total cost. For commercial airlines, maintenance costs are considered to be the major factor.

For military equipment, the MTBF (Mean Time Between Failures) or a similar objective factor is therefore used. Some examples follow.

Sledge [2] reports on the increasing use of reliability incentives by the Royal Air Force (Hawk, Tornado etc.).

Mitchell et al. [3] report similar schemes used for the Hornet strike fighter. In this case, a number of new parameters were experimented with in order to measure the reliability:

1. Mean Flight Hours Between Failures (MFHBF).
2. Unscheduled number of maintenance manhours per flight hour.
3. Direct maintenance manhours per flight hour.
4. Mean flight hours between maintenance actions.

In order to illustrate the importance of these factors, 6.18 MFHBF and 10 maintenance manhours per flight hour were established as targets. Also Augustine [4] studied this reliability and makes the correlation with electronic components. He concludes that, in practice, a maximum MTBF of 10 hours can be obtained in operational units. Such figures are, of course, frightening in terms of operational reliability. When the hypermodern tank M60A2 (with no less than 35 000 electronic components in the turret alone) was introduced, even the director of defense research and engineering, John Foster, admitted that the best way to defeat an assault by these tanks was:

‘Give them plenty of room to run around and they will all break down’.

This resulted in Augustineine’s even more cynical law:

‘If you are willing to spend enough money on an item of electronics, you can virtually guarantee that it can be made not to work’.

An important element of reliability incentives should here be highlighted: evaluation can only take place after a certain observation period. This might make them less attractive to industry (cash-flow, administrative costs etc.). Another significant element is the relative subjectivity: the contractor can always claim that failures are due to the buyer’s operational shortcomings (operations and maintenance).

Springer [5] therefore advises using the following factors to improve objectivity:

1. Designate exclusion factors (carelessness of operators, damage etc.).
2. Provide time for testing (before the start of the warranty period).
3. Improve field operations and maintenance conditions (by training operators, providing clearly written manuals etc.).
4. Seal the equipment.
5. Monitor storage, handling and shipment.
6. Evaluate equipment failure.
(7) Simplify equipment modification procedures.
(8) Build testing devices into the equipment (in order to prevent damage during removal and transport).
(9) Limit coverage to black boxes (in order to avoid administrative costs of replacing subcomponents).
(10) Request a clear definition of the operational environment.
(11) Request MTBF to be measured in operating hours, never in calendar time. (Note that this is partly contradictory to the procedure given by Mitchell [3], who advocates measuring flight hours between maintenance actions.)

8.2 AWARD INCENTIVES

These are also paid to the contractor after evaluation of performance measured against criteria in the contract; the difference between this and the two previous categories is that the criteria are not quantified. The criteria are therefore more subjective (good performance, good service etc.) and are consequently only applicable when the contract is not susceptible to a finite measurement of performance.

In exceptional cases (support or service contracts), this principle is implemented as a motivational management technique. The effect of award fees has been studied extensively by, for example, Rule and Cravens [6], Hunt [7] and Jenkins [8]. They note significant disadvantages such as:

— Costly administrative efforts (meetings, discussions etc.) are demanded of both client and contractor.
— The contractor is not protected against arbitrary and capricious evaluations.
— Contractors feel vulnerable under systems of this type and have problems with financial planning (fee is uncertain).

Kolcum [9] reports on the managerial consequences of award fees. The award fee associated with Shuttle operations was rapidly decreasing. The contractor, Lockheed, considered this as a loss of reputation (more than the loss of direct fee) and the three responsible Shuttle Processing Managers were replaced.

For such 'subjectivity' reasons, contractors are reluctant to accept such award incentives. Certainly, in a governmental environment, where influences of a nontechnical nature are likely to be active, the chances of success are very limited. Under these circumstances, although not always a satisfactory solution, it is advisable to relate the incentive to a quantitative parameter. Award incentives, in the sense of performance incentives with nonquantified parameters, should be used only to an extremely limited extent.

8.3 LIFETIME INCENTIVES FOR SATELLITES

As has been mentioned above, the main factor determining the success of a spacecraft is its lifetime in orbit. In an extensive study, Bloomquist [10] reports the results of analysing 374 spacecraft, including 2500 anomalies which occurred over 3.75 million in-orbit hours. One important finding was that, at the time of the study (1984), on the average not less than 2.8 times the design life was obtained. This is considered as a remarkable conclusion*. Another

* A reason for this good result could be that only those satellites that had survived launch (the severest conditions to which a spacecraft is subjected) were taken into account.
conclusion was that no relation could be found between operating life and relative complexity
of the spacecraft.

If we consider the median, i.e. the 50% line showing anomalies which are the reasons for
failure, we can see that until 1984 five classes of anomalies accounted for 50% of all in-orbit
problems, viz:

(1) Scientific instruments;
(2) Propulsion (chemical);
(3) RFI/EMI (radio-frequency and electromagnetic interference);
(4) Telemetry sensing;
(5) Tape recorders.

(Other classes, responsible for fewer failures, are, in order of importance: thermal control,
batteries, gyros, deployable structures, transmitters, solar array, timers, sensors, camera
equipment, reaction wheels etc.)

Erdle et al. [11] describe reliability programmes for commercial communication satellites,
which are currently being designed to provide adequate service for 7 to 10 years. The authors
consider the following procurement policy factors as essential:

(1) Product assurance provisions in requests for quotations and contracts;
(2) On-site representation, attendance at review boards and presence during hardware testing;
(3) Incentives as a means of minimising the contractor's risk and maximising long-term
satisfactory system reliability and performance.

As practical implementations, lifetime incentives are reported as a part of multiple incentives.
We find this again in Couillard [12], who describes the incentive scheme employed for SPOT,
a French satellite. First, a relation was established between the costs of a satellite and the
(theoretical) lifetime. A simple graphical relation is used to award the incentive as a function
of lifetime as well as of performance (measured in terms of energy produced).

Lafay [13] reports on the management scheme of the European satellite ESRO-IV. Seventy-
five percent of the incentive fee was related to in-orbit performance. The maximum lifetime
for the purpose of the contract was taken to be 450 days. The first 180 (minimum requirement)
and the resulting 270 days were valued separately; the satellite actually worked for 330 days.
The authors recognized that the incentive scheme had worked as an important motivator.

A factor that we cannot neglect in these lifetime performances is the effect of the successful
launch. In general, a special clause foresees the event of a launch failure and the resulting
agreement. As, sometimes, payments up to 50% of the in-orbit incentive have been negotiated
in case of launch failure, this is evidently a considerable risk for the client.

8.4 PERFORMANCE INCENTIVE MODEL

As a general outline we can state:

(1) The client will reject products that do not meet minimum performance requirements.
(2) The client is basically not interested in performances lower than specified.
(3) The client is only partially interested in higher-than-specified performances.
(4) Only a good cost/performance trade-off will be accepted.
(5) The performance measurement must be as objective as possible.
(6) If possible, a relation with future savings should be made.
Performance depends upon a specific set of requirements and circumstances. Some characteristics will be more important than others; this can only be determined on a case by case basis. Moreover, since it is most important to put the incentives on the essential elements of performance, one cannot lay down a 'general' performance incentive formula.

We can, qualitatively, represent the requirements of our model in Figure 8.1. The considerations that:
- we are only marginally interested in overperformance and
- rapidly lose interest as performance diminishes
lead to a curve with an asymptotic character.

Figure 8.1 General performance/cost relation.

With $X_t = \text{target performance}$ and $C_t = \text{target cost}$, this means that (see Fig. 8.1):
- $b$ will be much higher than 1 (the client is only willing to pay more if the performance is very high);
- $d$ is only slightly higher than 1, e.g. 1.10 (i.e. the client is prepared to pay only slightly more for a higher performance);
- $a$ is smaller than, but close to 1, e.g. 0.95 (i.e. the client will only accept performances slightly lower than specified).
The maximum extra money the client is prepared to pay will only be a part \( f \) of \((dC_t - C_t)\). The maximum performance incentive will therefore be equal to:

\[
f (d - 1)C_t
\]

\[(8.1)\]

### 8.5 ILLUSTRATION OF THE MODEL

Within the ESA environment, much attention is given to so-called HI-REL parts (HiReliability). Within the material cost, extra money and R&D overheads are paid to the contractor whenever such parts are procured. In fact, in view of the practical impossibility of performing repairs in orbit, wide safety margins (redundant (doubled) circuits) are built into the design of a satellite. From this point of view, it is felt within ESA that the contractor is already paid to obtain this excellent performance.

On the other hand, better-than-specified performances are, in most cases, not interesting. Scientific satellites are built to perform a certain mission. The fact, for example, that they emit a better qualitative signal than expected can be interesting for practical reasons; the extra value of this, compared with the basic mission, is, however, marginal.

The same reasoning can be followed for other types of satellite, although the situation will change when repairs and servicing of satellites become possible (which, in low orbits, is now already feasible). Products with lower performance are not interesting: if the signal of a telecommunication satellite is slightly too weak and reception only possible if atmospheric conditions are optimum, the value of the satellite is practically zero.

Schematically, we can represent these elements in the manner shown in Figure 8.2, the qualitative character of which has a slightly higher degree of refinement than that of Figure 8.1. It is still not feasible to present a generalised quantitative model for this specific case, however.

Typically with

\[
X_t = \text{target performance}
\]

\[
C_t = \text{target cost}
\]

this represents an incentive zone between \(X_t\) and \(2X_t\) and between \(C_t\) and \(1.05C_t\).

Or:

\[
\frac{C}{C_t} = 1.05 \frac{X}{X_t} - 1.05 \quad \text{for} \quad 1 \leq \frac{X}{X_t} \leq 2
\]

\[(8.2)\]

### 8.6 QUANTITATIVE ASSESSMENT OF THE SATELLITE LIFETIME PERFORMANCE INCENTIVE

First of all, we have to note that a number of assumptions have been made in order to permit this quantitative assessment. The absolute value of these assumptions is open to discussion.

As has been mentioned above, statistical analysis has shown that an average lifetime of 2.8 times the designed lifetime can be found in practice (this illustrates the statement made in the last section concerning the wide safety margins generally incorporated in the design of
satellites). If we assume this factor to represent the 50% case, then a factor of 5.6 is a feasible upper limit (no better data on the distribution are known).

Let us further assume that the client spends 50% of the performance incentive on in-orbit performance (the remaining 50% on on-ground performance)*. In accordance with Figure 8.2 (d = 1.05) and equation (8.1), this would represent a maximum lifetime incentive of:

$$0.5 (1.05 - 1) C_t = 0.025 C_t$$

If we combine both elements, this would mean that, with

$L_t =$ target lifetime
$L =$ measured lifetime

---

* This 50% represents a pragmatic halfway compromise between the two parties: the client would prefer 100% to be put against in-orbit performance, the contractor would prefer 100% against on-ground performance.
then,

\[ \frac{L}{L_t} = 1, \quad \text{the client will pay no incentive, while} \]

\[ \frac{L}{L_t} = 5.6, \quad \text{the client will be willing to pay the maximum incentive, which is} \]

\[ 0.025 C_t. \]

If we assume, again, that the function is linear, this results in the following equation:

\[ P = (0.0055 - 0.0055) C_t \]

for \( 1 \leq \frac{L}{L_t} \leq 5.6 \) \hspace{1cm} (8.3)

In practical terms, this means that the client is willing to pay a 2.5% fee for a lifetime 5.6 times the design lifetime.

8.7 CONCLUSION

In order to show his interest in a good performance, the client is recommended to add a performance incentive part to his incentive formula. The main objective is to avoid unhealthy cost/quality trade-offs by the contractor. As the contractor will try to avoid subjectivity in the assessment, he will prefer pure performance incentives (measurable before delivery) to reliability incentives (only measurable after a defined observation period) and will try to avoid award incentives (based upon non-quantified criteria).

As each performance incentive has to be tailored to the specific situation and characteristics, it is impossible to develop a general model. A qualitative assessment is therefore described, which is refined for the pilot environment. Only for satellite in-orbit lifetime is a quantitative formula presented.

8.8 REFERENCES


CHAPTER 9
MULTIPLE INCENTIVES

9.1 GENERAL

The client is not always a priori interested in obtaining a product at the lowest cost. The ultimate objective is generally to attain an appropriate balance between performance, schedule and cost. More emphasis on one of these elements will in general be determined on a case by case basis. It is perhaps interesting to note that Naisbitt ([1], p. 231) regards this type of evolution as more generalised. He describes this change as 'From either/or to multiple option'. In the 1960's, it was either/or:

— Either we got married or we didn't;
— Either we worked or we didn't;
— We liked either chocolate icecream or vanilla;
— Telephones were black, bathtubs white.

In other words, homogeneous tastes were easily satisfied with few product choices. There is most probably a correlation between the diversification in products from the late 1960s onwards (in society) and the nearly parallel diversification in customised contract types.

The main purpose of a multiple incentive is that it should be exactly 'tailored' to the contract in hand. Multiple incentives must identify the alternative technical levels of performance and place a relative value on the alternatives as they are affected by the inherent interrelation between cost, schedule and performance. The multiple incentive can as such guide the contractor in the trade-offs he will make during contract execution. Indeed, by putting a higher relative value on one of the elements of the incentive fee, the client compels the contractor to put more emphasis on this element.

In order to avoid misunderstandings, a few remarks should be made. First of all, there is no need to incorporate all elements into one formula. There is, for example, an automatic feedback mechanism that is a function of the delivery time: the longer the delivery time, the higher the costs (if one starts with a normal delivery time). So, under fixed price conditions, the contractor will generally try to reduce delivery times on his own initiative. A delivery incentive can, however, emphasise and strengthen this element. A contract containing a cost and a performance incentive can thus also be considered as a multiple incentive contract.

Furthermore, each fixed price contract contains de facto a cost incentive. We can indeed state that the overrun sharing will be 100%. In other words, the contractor will bear the full cost of all overruns. So, every fixed price contract containing another incentive can be regarded as a multiple incentive contract.

Historically (see also Chapter 3), we see a transition from cost incentives only via independent to interdependent multiple incentives. Owing to the failure of the cost incentive (negligence in quality and unhealthy cost/performance trade-offs), the client started to add other
incentives. These multiple incentive plans were purely additive in nature, i.e. the total incentive fee was a sum of cost, performance and incentive fees. Owing to this purely additive character, we call them 'independent'.

With

\[ F_i = \text{incentive fee} \]

\[ F_{i \text{ max}} = \text{maximum incentive fee} \]

\[ F_c = \text{cost factor, lying between 0 and 1} \]

\[ F_p = \text{performance factor, between 0 and 1} \]

\[ F_d = \text{delivery factor, between 0 and 1} \]

we can describe this independent multiple incentive fee as

\[ F_i = (aF_c + bF_p + cF_d) F_{i \text{ max}}, \]

where

\[ a + b + c = 1. \]

It was recognized later that this purely additive character did not fully reflect reality, as the value of one improvement quite often depends on the achievements in other areas.

For the Gemini project, therefore, a new method was developed called PIIM (Planned Interdependency Incentive Method). This method involved a fee surface, such that the fee paid was a joint function of cost and performance. (For further description see Schneider [2], for example.)

Since then, a number of complex multiple incentive arrangements have been introduced (e.g. MICAP: Multiple Incentive Contract Analyzer Procedure), which finally, in 1968, resulted in the creation of POESMIC.

POESMIC stands for Program Office for Evaluating and Structuring Multiple Incentive Contracts. This office was created jointly by the US Army, Navy and Air Force procurement services and was also used by NASA. In principle, all military incentive contracts having a value over $ 5 000 000 required the involvement of this office. The principal tasks were (see also Hines [3] and NASA [4], p. 144 et seq.):

- Provision of computer capability to aid in analysing, evaluating and structuring multiple incentive contracts;
- Provision of technical advice and assistance to program users;
- Performance of research in advanced multiple-incentive methodologies and topics.

POESMIC techniques comprised a seven-step procedure:

1. Identification of key performance elements.
2. Formulation of the performance range.
3. Definition of the performance rating scale.
4. Evaluation of the performance arrangement (curves etc.) and appropriate choice.
5. Relation of cost estimates to the technical combinations selected.
7. Analysis of the entire incentive structure, and, if needed, iterative adaptation.

As a result of the need to deal with this large number of inputs, with sometimes complex mathematical relations, computerised processing was necessary.

POESMIC would perhaps have a better chance of success nowadays, with remote data links...
and smaller (portable) computers. In the late 1960s, however, processing times were
inordinately long and it never worked adequately. Although several directives and guidelines
were published, practitioners never really accepted the tool, which needed days to produce a
result. It goes without saying that such a tool is quite useless during negotiations.

With POESMIC, the tendency to move towards complex interdependent incentive techniques
came to an end.

Evaluating past contracts, both Schick and Pace [5] and Kennedy [6] came to the conclusion
that the early multiple incentive contracts did not work for two main reasons:

(1) Variables were not interdependent (mainly cost and performance variables).
(2) Arrangements were too complex.

One aspect should, however, be added to this second reason: even relatively complex
arrangements can, in certain cases, be made transparent by using graphical presentations.
Moreover, an aspect which we should not overlook in these considerations is the appropriate
balancing of the relative factors.

9.2 USE OF GRAPHICAL AIDS

In order to permit a quick appraisal on options taken, some graphical aids have been
developed. We mainly refer to these as:

— isofee curves;
— incentive nomographs.

An isofee curve is a constant fee trade-off matrix showing the applicable cost range on one
axis and the corresponding performance or delivery range on the other. In the case of
independent factors, these curves are linear; in the case of interdependency, these curves are
nonlinear and can be obtained by solving the underlying differential equations.

An example of a cost performance curve with interdependent factors is given in Figure 9.1.
It enables management to make relatively quick appraisals.

![Figure 9.1 Cost/performance isofee.](image-url)
The disadvantages of such an isofee curve are obvious. First of all, it is practically impossible to combine the three factors (cost, schedule and performance). One could overcome this by using a set of isocurves (always keeping one parameter constant). In practical terms, however, this results in a set of inaccurate curves. This inaccuracy is the main disadvantage of these isofee curves: if one tries to introduce too many curves (e.g. per tenths of profit percentage), the overall aspect is rapidly overloaded and visibility is lost.

The use of nomographs gives more flexibility and accuracy. In the case of two factors (e.g. cost and performance), the construction of such a nomograph is relatively simple. Even when three factors are included, a so-called cross-nomograph can be used. An example is given in Figure 9.2.

An additional advantage of nomographs, as compared with isofees, is that accuracy can be improved (one can read the result on one of the axes, which makes interrelation visually easier) and that the three factors can, if so required, be combined on one chart.

It is true that in the case of interdependent relationships, the construction of such a cross nomograph can become relatively complex and accuracy relatively limited. (Note, however, that a relatively high accuracy can be obtained if only two factors are considered.)
9.3 MULTIPLE INCENTIVE MODEL

In the first instance, our model should try to avoid the recognized drawbacks of previous multiple incentives: complexity and lack of interdependency. Both these elements are, to a certain extent, conflicting. Interdependency will easily lead to more complex calculations; we will therefore try to introduce a pragmatic compromise.

This simplification can be found in the delivery incentive. Figure 9.3 (a repeat of Figure 7.1) clearly shows the delivery-time/cost relation. If a near optimum time (from the contractor's point of view) has been concluded in the final contract, a negative feedback mechanism is automatically built in. Owing to the rising (indirect) costs, the contractor's internal control will react as soon as delays are envisaged. So, in most cases, the contractor will try to meet the delivery time and may even try to shorten it. This can be translated into the fact that no (second) linkage between cost and delivery incentive has to be introduced in the multiple incentive.

If, however, the client's negotiators feel that the contractor has accepted a delivery time that is shorter than his 'normal' delivery time, a delivery incentive is always worth considering. Without this incentive, indeed, the contractor might later have the tendency to overrun this contractual delivery time. Penalties are, of course, the established contractual safeguards.

Figure 9.3 Time reduction versus costs.

In general, such graphical aids are worth considering if quick appraisals are needed at top management level. They only give an indication; exact assessments always have to be done by calculations. When trade-offs or trends are discussed, these curves and nomographs can be considered useful management tools.
against such behaviour. Their effect is, however, highly disputable: the danger exists that much effort will be spent in trying to prove that delays have been the client's fault (schedule changes, claims etc.). The implementation of penalties is, in a political environment, never simple. Delivery incentives are felt to be more efficient motivators in this context.

Taking these aspects into consideration, we will base our multiple incentive model upon the following principles:

1. Simple (linear) relations will be used (see references [5] and [6]).
2. Performance and cost (incentives) will be made interdependent (see reference [5]).
3. A delivery incentive can be independently added.
4. The importance given to each of the incentive elements will bear a relation to the relative importance of the associated parameter (cost, schedule, performance) within the specific project considered.
5. The total of basic fee and incentive fee is limited.

So, with:

\[ F_{i_{tot}} = \text{the total fee paid} \]
\[ F_n = \text{the basic fee} \]
\[ F_i = \text{the incentive fee} \]
\[ C_t = \text{the target cost} \]
\[ F_c = \text{the cost fee factor} \]
\[ F_p = \text{the performance fee factor} \]
\[ F_d = \text{the delivery fee factor} \]
\[ a = \text{the (weighting) factor associated with } F_c \]
\[ b = \text{the (weighting) factor associated with } F_p \]
\[ c = \text{the (weighting) factor associated with } F_d \]

we can state:

* \[ F_{i_{tot}} = F_n + F_i \] (9.1)

(where we should note that \( F_n \) can also be zero, when no basic fee is foreseen);

* \[ a + b + c = 1 \] (9.2)

which is inherent to the character of these weighting factors;

* \[ F_{i_{tot}} = x C_t \] (9.3)

where \( x = \) the maximum portion of the target cost that the client is willing to pay to the contractor (e.g. 0.16);

* \[ F_n = y C_t \] (9.4)

where \( y = \) the minimum portion which the client wishes to attribute to the contractor (typically, 0.04, but, as already mentioned, can also be zero).

Combination of Eqs. (9.1), (9.3) and (9.4) gives us:

\[ F_i = (x - y) C_t \] (9.5)
and, consequently:

\[ F_i = a(x - y)C_i \]  
\[ F_p = b(x - y)C_i \]  
\[ F_d = c(x - y)C_i \]

(9.6)  
(9.7)  
(9.8)

We shall now introduce a performance result \( r \), such that \( r = 1 \) represents the minimum performance accepted, \( r = 2 \) the maximum performance rewarded. Bearing in mind that the cost incentive will be negative for cost overruns, we can therefore propose the following formula:

\[
F_i = F_d + (r - 1)F_p + \frac{rF_c}{2}
\]

(9.9)

We can note that:

* The maximum fee (for \( r = 2 \)) is indeed

\[
F_i = F_d + F_p + F_c
\]

(9.10)

which, if we introduce Equations (9.2), (9.6), (9.7) and (9.8), gives us again

\[
F_i = (x - y)C_i \quad (= \text{Equation (9.5)})
\]

* The last factor, \( \frac{rF_c}{2} \), gives the feedback mechanism: if the unhealthy trade-off were made to boost-up performance at the cost of extra expenditure, the contractor would be penalised accordingly, owing to the negative factor \( F_c \).

The weighting factors \( a, b \) and \( c \) have to be tailored in accordance with the requirements of the specific project. The considerations here have a rather qualitative and descriptive character. We will, again, try to give more practical implementations, using the ESA pilot environment.

9.4 ILLUSTRATION IN THE PILOT ENVIRONMENT

In the previous chapter, we concluded that no generalised quantitative expression could be fixed for the performance incentive. As this element is an integral part of the multiple incentive, it will therefore also be impossible to quantify this multiple incentive for general cases. We can, however, deduce some guidelines per particular case, here illustrated for the ESA environment. Let us take a 'typical' ESA project, as we have defined it in the previous paragraphs. We concluded, for such a typical project:

* As for the delivery incentive, a maximum incentive in the order of 0.05 \( C_t \) can be assumed (see Chapter 7). Indeed, if we limit the delivery incentive to 10% of the delivery time (linear part), a typical maximum delivery incentive would be:
\[ F_d = 0.1 \frac{T_m}{T_m} \times \frac{0.6 C_i}{T_m} \left( \frac{1.5}{0.83} - 1 \right) \]

(9.11)

[see also Eq.(7.8)]

or

\[ F_d = 0.05 C_i \]

(9.12)

* As for the performance incentive, we have noted, in Chapter 8, that a maximum value could be in the order of 0.05 \( C_i \) (for \( F_p \)) for the ESA environment; thus:

\[ F_p = 0.05 C_i \]

(9.13)

* On the other hand, the total maximum fee is, in accordance with ESA directives, limited to 16% (0.16 \( C_i \)); thus (with \( F_n = 0 \)):

\[ F_i = 0.16 C_i \]

(9.14)

Taking all these upper limits into consideration, we can calculate a corresponding cost incentive as follows. Equations (9.5) and (9.10) result in:

\[ F_i = 0.16 C_i = F_d + F_p + F_c \]

or, after the inclusion of Eqs. (9.12), (9.13) and (9.14):

\[ F_c = 0.16 C_i - 0.05 C_i - 0.05 C_i = 0.06 C_i. \]

So, we can deduce the following relative values:

\[ a = \frac{0.06}{0.16} \text{ or 40 percent for cost incentives;} \]

\[ b = \frac{0.05}{0.16} \text{ or 30 percent for performance incentives;} \]

\[ c = \frac{0.05}{0.16} \text{ or 30 percent for schedule incentives.} \]

This theoretical consideration seems to be in line with heuristic formulas and tendencies. Van Reeth [7] reports on the HEOS-1 incentive scheme with \( a = 43\% \), \( b = 40\% \) and \( c = 17\% \).

Kahn [8] gives as a general guideline that typical schedule factors account for some 20% of the whole incentive. He also points out that in exceptional cases, where schedule is of overriding importance, this percentage will be higher. This illustrates again the very important element of tailoring the percentages as a function of the relative importance of the parameters, on a case-by-case basis. Note that we have a slight discrepancy between the theoretical and the practical figures, mainly owing to this 'tailoring' principle.
9.5 CONCLUSION

In order to avoid unhealthy trade-offs, mainly between performances (quality) and costs, it is strongly recommended that elements be combined into one multiple incentive formula. Overcomplexity has led, in the past, to the failure of such multiple incentive formulas and should therefore be avoided. An appropriate distribution of the incentive pool over the relevant elements should be carefully performed on a case by case basis. Any multiple incentive should be tailored to the specific objectives of the project.

An interdependence between cost and performance incentive is strongly recommended; the delivery incentive can easily be kept separate. These considerations lead to the general formulas presented in equation (9.9) of this chapter:

\[ F_i = F_d + (r - 1) F_p + \frac{r F_c}{2}, \quad \text{with } 1 \leq r \leq 2 \]

A typical distribution of the incentive fee, for the pilot environment, could be in the order of:

- 40 percent cost incentive;
- 30 percent performance incentive;
- 30 percent schedule incentive.

9.6 REFERENCES

CHAPTER 10
ENVIRONMENTAL AND RELATED FACTORS

10.1 GENERAL

In the foregoing chapters, we have endeavoured to incorporate practical and real-life elements. Nevertheless, we cannot disregard the fact that our system will be influenced by environmental factors, which have not yet appeared within our client/contractor (control) system.

Veld ([1], p. 11) defines this environment as follows:

"The environment of the system under consideration is composed by those elements of the universe which influence the characteristics or the values of these characteristics of the system elements, or, vice versa, are influenced by the system."

We cannot neglect these environmental factors in our control system, as they will strongly influence practical implementations. In order to address these elements under a discrete number of headings, we shall refer to them under the following headings:

(A) Management motivation;
(B) Cross-cultural differences;
(C) Administrative aspects;
(D) Changes;
(E) Future developments.

(A) Management motivation

In this age of 'man/machine interfaces', the aspect of human compatibility has been fully recognized. Tools can be worked out in a laboratory environment; the success of these tools can, however, only be guaranteed if people who have to manage them will support their introduction. Moreover, the introduction of a wide range of contract types will only be successful if the managers, who will ultimately have to use them, consider them an asset.

(B) Cross-cultural differences

Management styles are strongly influenced by our cultural background. Ever since men became involved in large-scale trading activities, manuals and guidelines have been issued (verbal or in writing) on how to deal with foreign cultures. Nowadays, each manager has such a pocket-guide in his luggage. (This did not prevent a European businessman from presenting his range of liqueur chocolates in Saudi Arabia, a few years ago. His head was not chopped off — his connections were!)

Although, initially, it may be good to know about such guidelines, a wider background knowledge of cultural behaviour is more useful. If, for example, one intends to deal with
muslims, it is better to have read Lawrence’s Seven Pillars of Wisdom than to have learnt by heart how many cups of tea may be taken with which hand.

Such cultural differences are very liable to tempt us into racial or national discrimination. We must be on our guard against this, since our European habits are quite as ‘exotic’ in the eyes of people from other cultures as theirs are in ours.

These are just qualitative statements; Hofstede [2] has done extensive research the objective of which was to map and quantify such differences. We shall use some of his results to demonstrate the effects on our contract choice problem.

(C) Administrative aspects

There is a close relation between contract type and the degree of control (see also Figure 2.8). Consequently, there will also be a strong relation between administrative burdens and the contract type chosen. This factor cannot be neglected and should therefore be dealt with. In fact, we shall demonstrate later that this factor may even on occasion dictate the choice of contract type.

There are also, however, a number of related administrative factors that will play a rôle, internally (budget control, rules) as well as externally (e.g. legal restrictions).

(D) Changes

In development contracts, it is seldom possible to present a clear specification. Some performance parameters are only ‘guestimates’. The accuracy of these elements cannot be evaluated by those responsible for running the contracts; they have to rely on the technical judgement of, sometimes, pure theoreticians. There is inherently a danger of underestimation in this area. Scientists tend to minimise technological constraints and always expect outstanding performances with minimal resources. This optimism becomes evident, to both parties, during contract execution. Not only may the client’s management have been indulging in wishful thinking — in hi-tech fields, the contractor also has to base his cost estimation on researchers’ opinions.

During the execution of the contract, the resulting conflicts will lead to claims and change-order discussions.

(E) Future developments

Although forecasting remains a risky subject, a number of generally agreed opinions have a relatively high probability of becoming reality. Such trends can be deduced from current technological achievements, which can be expected to be generally available within a few years. Most futurologists (Toffler, Naisbitt etc.) predict a transfer to an information society. Naisbitt concludes his findings ([3], p. 251) as follows:

'The computer will smash the pyramid: we created the hierarchical, pyramidal, managerial system because we needed it to keep track of people and things people did; with the computer to keep track, we can restructure our institutions horizontally.'

The consequences of these predictions on the control mechanism are evident and cannot be neglected in this context.
10.2 MANAGEMENT MOTIVATION

Early authors who studied the economics of incentive contracting considered one major motivating factor: fee maximisation as the leading motivator for development contractors. Peck and Scherer ([4], pp. 461-503) and Weiner [5] are convinced that contractors' behaviour is dictated by (short-term) fee maximisation, leading to (long-run) profitability.

This opinion was maintained during the 1960s; from the 1970s onwards, the tendency was to consider risk as a leading element. Hunt ([6], p. 151) concluded that R&D contractors are basically a

'Risk-averse group of firms ... (that could) best (be) described as profit satisfiers.'

Since then, a number of studies have been made of contractors' behaviour under the assumption of this risk-averse attitude, which has resulted in the development of several economic 'equilibrium' models (see, for example, Gandhi and Saunders [7] and Murphy [8]). Most of these studies consider the contract choice from the contractor's point of view. If we introduce the client's point of view, risk will have a slightly different dimension. The contractor's profit will not be the prime concern of the client; motivation of the contractor via the profit is, for the client, much more important.

At the negotiation table, both managers (the client's and the contractor's) will predominantly consider another factor: their own personal position.

There is, indeed, a major difference between the firm's objectives and those of its individual employees. The 'theory of the firm' assumes that the decision maker is the owner-manager. In reality, however, individual managers will be constrained by the organisation's goals, but will not necessarily reflect these goals precisely. The objectives of an organisation are 'translated' by top management and 'executed' by individuals. As such, the company's behaviour (within certain boundaries) will be dictated by the composite actions of many individuals. The contract choice will reflect this 'fact of life'. Most managers show a considerable risk-aversion attitude; their long-term goals are continuity and growth, not the company's short-term profit optimisation.

Vroom's expectancy theory [9] holds that a person will work towards something when he expects the consequence of doing so to be both favorable and probable. Only if the manager feels that the outcome of a contract will be successful and that the successful performance in turn will lead to a reward (e.g. promotion), will he support the contract.

We can draw two conclusions from these considerations. First of all, managers will, on both sides, emphasise those elements in the contract that will be 'honoured' in the organisation. The contractor's project manager's reluctance to accept fixed prices and cost incentives can be explained by this 'appreciation' factor. Industry tends to reward those managers who have a tendency to stay within the budget (which is not always in line with long-term profitability; e.g. some managers are 'experts' in using other 'resources', indirectly influencing overheads). The expectancy theory can also explain the client's choice. Non-profit organisations have by definition no profit yardstick; project managers are often rewarded as a function of the scientific outcome and will therefore sometimes put more emphasis on, say, in-orbit performance.

A second element which can be concluded is the direct rewarding of managers. ESA has achieved excellent results in several experiments where a part of the incentive fee was distributed over the project manager's team.

There is a certain rationale behind this: a considerable part of the risk, in an incentive contract, will be placed in the hands of the manager in charge. In general, top management will accept a contract type, but will 'delegate' the responsibility of the final outcome to the
The project manager will always be able to defend himself against overruns (technical changes, unforeseen elements, estimates made by another department etc.). He will have more difficulty in defending the loss of incentives. The situation is even worse in the case of award incentives; a typical example can be found in Kocum [10], who describes the 'launching' of Lockheed's Shuttle managers, due to failing Shuttle launches and resulting award fee decreases. Meiners [11], too, defends direct rewarding of managers and illustrates the very positive spin-off of such actions.

We have, however, to draw attention to a number of restrictions in this area, such as:

— Legal restrictions;
— Agreement of contractor's management and, in some cases, trade unions;
— The fair distribution of the premium over the various team members.

In general, introduction of such direct rewards is more easily accepted in companies where a form of in-house profit sharing is already in existence (which to some extent reduces the inconsistency of rewarding line functions and not support functions). Top management can, in such cases, decide to (partially) replace the in-house profit sharing scheme by one managed by the client.

10.3 CROSS-CULTURAL DIFFERENCES

The effect of cultural influences has already been noted by Sayles and Chandler [12], p. 288). They conclude that Japanese culture has rejected American-style incentive systems as an insult to the company. Japanese companies consider top-quality work as a matter of organisational pride, where recognition is gained via the award of new contracts and continuity. American-style performance incentives are considered to imply that performance could be obtained through the payment of money.

In order to evaluate such differences qualitatively, we refer to the previously quoted work by Hofstede [2]. In the period between 1967 and 1978, 116 000 questionnaires were collected, reflecting the behaviour of individual persons in 40 countries (later extended to 50). Interviews completed the data, which were stored and analysed in computerised databanks. Four main elements (called dimensions by Hofstede) were analysed (as well as their interdependency):

(1) Individualism versus collectivism;
(2) Large or small power distance;
(3) Strong and weak uncertainty avoidance;
(4) Masculinity versus femininity.

Each dimension is represented, per country, by an index.

In our specific case, we are particularly interested in the 'Uncertainty Avoidance Index' (UAI). Hofstede [13] describes the fundamental issue of this UAI as how society deals with the fact that time runs only one way; that is, we are all caught in the reality of past, present and future, and we have to live with uncertainty because the future is unknown and always will be. Some societies socialise their members into accepting this uncertainty and not becoming upset by it. Such societies can be called 'weak uncertainty avoidance' societies; they are societies in which people have a tendency to feel relatively secure.

Other societies socialise their people into trying to beat the future. In such societies there will be a higher level of anxiety in people (nervousness, aggressiveness etc.). Such societies are called 'strong uncertainty avoidance' societies.
According to Hofstede ([2], p. 187), in a business environment, a low UAI reflects, among other things:

- Managers are more involved in strategy;
- Managers are more oriented towards interpersonal relations and are flexible in their style;
- Managers are more willing to make individual and risky decisions.

On the other hand, a high UAI reflects:

- Managers are more involved in details;
- Managers are more task oriented and consistent in their style;
- Managers are less willing to make individual and risky decisions.

So, a high UAI reflects a risk averse and more conservative style; a low UAI reflects a more flexible style and less risk aversion.

Consequently, in view of control delegation and risk acceptance, the lower the UAI, the better incentive contracts would be accepted. In order to prove this statement, we concentrate on one area (aerospace) and similar, specific, clients (space agencies).

(a) NASA (US space agency): some 75% of the total contract amount contains incentive clauses.
(b) ESA (European Space Agency): some 50% of the total contract volume includes incentive clauses.
(c) NASDA (Japanese space agency): incentives are only marginally implemented (< 10%).

In view of its multinational character, we have to fit the ESA situation. For this purpose, we take the geographical distribution of contracts (total of period 1972 - 1984) and add the relevant UAI figures from Hofstede ([2], p. 165). Table 10.1 shows the resulting build-up of an 'average ESA UAI figure'. Note that this ESA index is rather artificial, as it does not reflect a nationality as such. It only reflects the weighted factor for the ESA community, as the percentage of contracts is closely related to the nationalities (owing to the stringent geographical distribution requirements).

If we add the figures for USA and Japan, Table 10.2 clearly demonstrates our statement:

The lower the uncertainty avoidance index, the more readily incentive provisions are accepted.

Knowing the rationale behind this statement, the client or the contractor can use this result as a tool to evaluate his chances of success when proposing an incentive-type contract.

10.4 ADMINISTRATIVE ASPECTS

During contract execution, fixed price contracts involve a minimum of administrative efforts for both parties. Cost reimbursement contracts, however, do require from both parties a substantial effort in:

- timesheet recording;
- time and material control;
- scheduling and project control;
- invoice recording and checking;
- payment control etc.
TABLE 10.1 ESA UAI

<table>
<thead>
<tr>
<th>ESA MEMBER STATE</th>
<th>PERCENT SHARE OF CONTRACTS</th>
<th>NATIONAL UAI ACCORDING TO HOFSTEDE[2],p165</th>
<th>WEIGHTED UAI (% CONTRACTS × NATIONAL UAI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>3.6</td>
<td>94</td>
<td>3.4</td>
</tr>
<tr>
<td>Denmark</td>
<td>1.6</td>
<td>23</td>
<td>0.4</td>
</tr>
<tr>
<td>France</td>
<td>34.0</td>
<td>86</td>
<td>29.2</td>
</tr>
<tr>
<td>Germany</td>
<td>24.6</td>
<td>65</td>
<td>16.0</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.1</td>
<td>35</td>
<td>0.1</td>
</tr>
<tr>
<td>Italy</td>
<td>10.9</td>
<td>75</td>
<td>8.2</td>
</tr>
<tr>
<td>Netherlands</td>
<td>4.1</td>
<td>53</td>
<td>2.2</td>
</tr>
<tr>
<td>Spain</td>
<td>2.5</td>
<td>86</td>
<td>2.2</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.9</td>
<td>29</td>
<td>0.5</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1.8</td>
<td>58</td>
<td>1.0</td>
</tr>
<tr>
<td>U.K.</td>
<td>13.5</td>
<td>35</td>
<td>4.7</td>
</tr>
<tr>
<td>Austria</td>
<td>0.3</td>
<td>70</td>
<td>0.2</td>
</tr>
<tr>
<td>Norway</td>
<td>0.1</td>
<td>50</td>
<td>0.1</td>
</tr>
<tr>
<td>Canada</td>
<td>1.0</td>
<td>48</td>
<td>0.5</td>
</tr>
<tr>
<td>Total of all ESA contracts</td>
<td>100</td>
<td>---</td>
<td>ca. 70</td>
</tr>
</tbody>
</table>

TABLE 10.2 Comparison between agencies

<table>
<thead>
<tr>
<th>AGENCY</th>
<th>PERCENT INCENTIVE CONTRACTS (APPROX.)</th>
<th>RELATED UAI FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASDA</td>
<td>10</td>
<td>92</td>
</tr>
<tr>
<td>ESA</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td>NASA</td>
<td>75</td>
<td>46</td>
</tr>
</tbody>
</table>

(It has been evaluated that these extra efforts can be in the order of 2-3% of the total contract cost.)

Already in the early implementation period (1969), Walker [14] pointed out that incentive provisions can also influence some internal managerial aspects, such as:

— planning and control;
— financial functions;
— technical functions;
— personnel functions.
Incentive provisions have, in the past, occasioned painful and costly discussions (it should be noted, however, that in some cases they have had the opposite effect; this was when incentives were used as trade-offs during hard change negotiations).

There are two essential points to remember in this context. First of all, simple and transparent incentives will to some extent avoid discussions afterwards. This has been clearly stated earlier (see Para. 5.3.3) and also explains the problems with award fees. All authors agree that a lack of objective parameters will inevitably lead to long discussions and administrative burdens.

The second point, introduced among others by Peeters [15], is the gradual introduction of incentives. No organisation will be able to cope directly with complex multiple incentive schemes. There should be a certain learning process. Introduction of simple incentives (e.g. delivery incentives) is suggested as a smooth starting point.

An important consequence of these administrative efforts is that, although it may be illogical, some organisations will accept a type of contract that is less appropriate, just because it is easier to manage. Small R&D studies are often contracted out at a fixed price by ESA, simply because the administrative and control staff are not available to allow proper management of such contracts under cost plus conditions.

A point that cannot be neglected in this context is that of budgetary problems. It is evident that fixed price contracts are, in principle, easier to handle for governmental organisations having strict internal budgetary rules.

The inflexibility of budget systems may lead to a preference for agreeing to fixed prices, including a certain margin (known to both managers). This problem can be solved in cost plus reimbursement contracts by fixing a realistic target and, if necessary, a ceiling. The key to this problem is accurate and realistic cost estimation.

Incentives induce a specific sort of budgetary problem: what amount has to be included in a project budget for incentives. When confronted with an important case, the author corresponded on this subject with the budgetary expert Professor Delbeke [16], which led to the following conclusions:

Whereas the general opinion is that the figure included in the budget should be the most probable, we consider this to be rather unrealistic. First of all, the calculation of the probability of this figure is one of doubtful accuracy, since there is in general no basis for performing it (the probability distribution of the incentives is unknown for development contracts). If a probable figure, smaller than the maximum incentive, can be assessed, we should question the realism of the incentive: it makes no sense to promise an incentive if one feels that it cannot fully be obtained anyway.

For these reasons, and in the spirit of a self-confirming budget approach, Delbeke feels that the full amount of the realistic incentive has to be taken into account when establishing the budget (note that this can also be considered as an 'elegant' buffer against first overruns).

Another important constraint is the consideration that administrative instructions do not always allow the use of incentive provisions, simply because it has not been foreseen in procurement regulations.

A working group of the International Chamber of Commerce has performed a comparative study in this field. Schneider [17] reported that, per country, diversification in types of contract used is quite small. Most European governmental regulations do not explicitly include the possibility of using incentive clauses, although interpretation of certain regulations leaves the possibility open to include some incentive provisions.
On a relatively experimental basis, this opportunity has sometimes been taken. Some examples quoted:

— In Belgium: 70/30 cost sharing in ‘Zeebrugge port’ project.
— In The Netherlands: 50/50 cost sharing in ‘Oosterschelde’ project.
— In Germany: the roof of the Munich Olympic Stadium: cost premium.

10.5 CHANGES

Development contracts often change in their basic scope, or even basic requirements, during the execution. This will, in most cases, influence performance, costs, delivery times or a combination of these elements. Change orders have a direct relation with the economic climate. In the case of severe competition, some contractors will depend on or expect profitable change orders. Good client relations, reputation and follow-on contracts become of secondary importance when economic survival is concerned. Low price bidders may, under such circumstances, ultimately turn out to be very expensive.

In general, the client will try to protect himself against changes by issuing complete specifications and change clauses. Such complete specifications are, in general, utopian in development contracts. Some of the drawbacks can be countered by issuing performance specifications, in which target performances are realistically specified, without any stipulated design for meeting them.

As stated, another element is the introduction of clearly defined change procedures. Kahn [18] has described the state of the art on such modification clauses. As an example, ESA clauses do foresee a clear classification into Class A and Class B changes. Class A changes are defined as changes influencing the contractual baseline, costs being reimbursed by the Agency. Class B changes, however, are considered the contractor’s responsibility;

— either they will not be reimbursed, under fixed-price contract conditions;
— or only costs will be reimbursed (without profit and without change of target), under cost-reimbursement conditions.

Strict procedures and formalities have to be observed in administering these changes (including change review and arbitration boards). Certainly, the strictly defined ‘classification’ principle has successfully avoided a number of discussions.

In addition to a clear, performance-oriented specification and a clear change procedure, maintenance of project discipline is also an effective way of avoiding changes. This includes, among other things:

— Clear change-request forms;
— Centralised responsibility for change administration (e.g. in a board);
— Keeping to original project objectives;
— Restraining from over-influencing contractor’s decisions;
— Minimising the number of ‘nominated’ subcontractors;
— Preference to be given to well-known and tested solutions
— Constant trade-offs to be made, in order to avoid ‘gold plating’;
— Freezing design in an early stage;
— Decisions to be documented and countersigned by both parties;
— Strict configuration control (working with up-to-date drawings).
In development contracts, even with these precautions, changes are unavoidable. The degree to which these changes will be presented to the client will be strongly influenced by the type of contract.

Under cost-reimbursement conditions, changes will only, in general, appear when the target is being reached. Under fixed-price conditions, this will usually happen earlier (unless the contractor feels that he can easily absorb them in his margin).

Under incentive conditions, the additional problem is that the incentive formula may have to be adjusted as a result of the changes (e.g. delivery time). It is therefore strongly recommended that the parties should agree, before the contract is concluded, to the procedure

---

**Figure 10.1 Change order logbook.**

<table>
<thead>
<tr>
<th>Change Number</th>
<th>Date</th>
<th>Category</th>
<th>Short Description</th>
<th>Contractual Paragraphs Affected</th>
<th>Influence Delivery Inc.</th>
<th>Influence Perf. Inc.</th>
<th>Influence Cost Inc.</th>
<th>New Targets</th>
</tr>
</thead>
</table>

---
to be followed in adapting incentive formulas. A number of proposed procedures are given in the U.K. Defcon Guide ([19], pp. 30-42). Another recommendation is that parties should keep a change-order control logbook (see, for example, Fig. 10.1). Note that such a sheet will also assist in post-project documentation (which is often neglected).

10.6 FUTURE DEVELOPMENTS

It is evident that future management techniques will be strongly influenced by increased information and data management. Meredith and Mantel ([20], p. 437) conclude, after examining a series of socio-economic and technological influences:

'We see an increasing use of the several forms of project organisation, with special emphasis on matrix organisations. In our opinion, increased use will be made of professional project managers, individuals who are project managers by training and vocation rather than scientists or marketing specialists by training and project managers by necessity. The project manager will do less technical work in the future and will specialise more in coordinating the technical and behavioral aspects of the project.'

Kerzner [21] lays strong emphasis on 'flexibility'. Less flexible and less creative methods will be executed by computers or robots. He considers a broad experience, a flexible approach and a 'people-oriented' leadership style as essential prerequisites for tomorrow's project managers.

Another important element, according to Kerzner, will be a more objective performance measurement. Expanded use of information system data bases will permit more accurate analysis and better evaluation of project management results. Based on full information and powerful computer support, the real simulation of managerial performance will shift from 'What happened to the original plan?' to 'How do we achieve the intended plan?' It will also be easier for top management to control if their objectives are carried out by individuals. Analytical tools will make the disguising of information more difficult. In general terms, control will become less expensive and easier for the client (recording of computer time, compatibility of software, automatic registrations etc.).

With reference to what has been said in previous chapters, there is a fair chance that this will have two main effects. First of all, we seem to be evolving towards a society promoting a lower 'Uncertainty Avoidance'. Managers will be requested to be more flexible and more involved in (transparent) strategic decisions. In view of the greater objectivity in criteria, risks for individuals may become smaller. In accordance with our statement in Section 10.3, this lower UAI should lead to an increased use of incentive contracts. As a second effect, the greater ease of control may induce a shift from fixed-price to cost-reimbursement contracts, certainly for smaller contracts.

10.7 CONCLUSIONS

A number of environmental factors will influence the choice of contract type. Major influences are:

(A) Management motivation

The attitude of individual managers towards accepting a certain risk will strongly influence
the choice of contract type. The organisation can influence this aspect by laying down clear performance-rating criteria for managers. Direct rewarding of managers, under controlled conditions, may be considered.

(B) Cross-cultural difference

An index, the Uncertainty Avoidance Index, has been used as an important parameter. As such indices are available per country, the opportunities for introducing incentives and fixed-price contracts can be associated with different nationalities.

(C) Administrative aspects

Cost reimbursement and incentive contracts require more administrative efforts. A gradual introduction of incentive provisions is therefore recommended (training). It is, furthermore, suggested that a maximum incentive be included in the project budget.

(D) Changes

Performance-oriented specifications and strict change control procedures are recommended. It is, moreover, suggested that a change-order control logbook be kept, in order to enable both parties to keep track of the changing contractual arrangements.

(E) Future developments

In view of generally accepted trends in managerial behaviour, it is expected that in the future:
— more incentive clauses will be used;
— more cost-reimbursement contracts will be concluded.

This might thus lead to an increased use of CPIF (Cost Plus Incentive Fee) contracts.

10.8 REFERENCES


CHAPTER 11
SYSTEMATIC CHOICE OF A CONTRACT TYPE

11.1 GENERAL

The objective of this chapter is to give an overall appraisal of the contract choice, bearing in mind the consequences of the subsequent elements. In previous chapters, we have concentrated on the systematic evaluation of major contractual elements. Most authors have followed a 'top-down' approach: they first attribute criteria for each contract type and thereafter highlight the latter's typical properties.

We have, on purpose, preferred to follow a systematic 'bottom-up' approach. First we tried to make a model for the essential parameters and elements, as we felt that the separate models would give us a better background against which to evaluate their impact on the contract choice.

This is inherent to a prerequisite we have maintained: we consider all elements of the system to be in a 'steady state'. In our context, this means primarily that the consequences of the contract elements are assumed to be sufficiently well known to both parties. In an initial period (the 'transient state'), a trial-and-error experimentation is typical. No practical results are known when new contract types are introduced for the first time. Some contract types looked very promising from a theoretical point of view: the practical drawbacks only became evident during contract execution and post-contract evaluations. Examples of this are award fees (nowadays disappearing owing to their huge administrative consequences) and such ambitious programmes as POESMIC (never adequately applied owing to its high level of complexity).

As has already been mentioned, we assume a certain degree of familiarity for both parties, which means that both the contractor and the client are at least fully informed on the consequences of accepting a certain type of contract. In Chapter 10, we have recommended a gradual introduction of these contractual tools. Here, we assume that such a 'transient' phase has taken place.

Undoubtedly, smaller companies that have, over a number of years, worked with certain contract conditions, have suffered from the consequences of this assumption. Being accustomed, as a typical example, to introduce product changes and modifications, contractors have suffered considerable losses after having accepted stringent fixed-price contracts. Some contracting authorities (e.g. ESA) have well-defined procedures for evaluating the effect of accepting such modifications. Contractors who are unaware of this are often surprised when they themselves have to bear the costs (and consequences) of the modifications.

In reality, of course, this is an iterative process: on a subsequent occasion, the same contractor will be more careful when a certain type of contract is discussed. Our evaluation will reflect this stage and the consequent decision criteria.

A second remark that should be made is that we assume that, to a certain extent, the contractual pricing elements are realistically implemented. In other words, we assume that the control instruments are effective and in line with previous chapters. For example, we do not
feel that a 5% cost sharing, combined with a 10% neutral zone, can be considered as a cost incentive at all. So, practically, if we recommend the introduction of a certain element, we assume it to be in line with previous chapters.

In connection with this remark, we should not neglect the influence of environmental factors. When (see Chapter 3):

— McNamara decided to limit CPFF contracts (1962);
— the U.K. Ministry of Defence decided to cut cost-plus contracts to well under 10% of the total procurement spending (1986);

it is obvious that such political decisions influence contract choice considerably more than any technical evaluation.

Such an effect can also occur at company level. The contract for the IPS development was awarded to Dornier. IPS stands for Instrument Pointing System, an instrument designed to aim Spacelab payloads (e.g. telescopes) accurately at selected targets. Dornier accepted a fixed price arrangement for this contract, although a number of specifications were very loosely defined and technical uncertainties very high. It soon became evident that Dornier had underestimated the engineering effort. Typical underestimations were compatibility with Shuttle software (IPS required finally 200 000 software statements, compared with about 6000 for an independent satellite) and the Shuttle’s lower-than-expected stability. In the end, about 50% more manhours were required than had been planned for, and the company suffered considerable losses. As a direct reaction, Dornier’s director of space projects issued the instruction: ‘In the future, we shall work on a cost-plus basis only’ [1]. Although the implementation of such statements always moderates after a few years, they have a considerable effect on contract negotiations. Such an imperative policy can, of course, jeopardise all systematic considerations.

A sensitivity analysis, presented in the next chapter, will show that the results obtained are not critical in terms of deviations in the parameters. Such deviations, therefore, can be accepted and do not influence our model too strongly.

In line with previous chapters, we shall again illustrate the model with case studies from the ESA pilot environment. First, however, we shall try to summarise a number of evaluation criteria that are used by certain authors.

### 11.2 CONTRACT CHOICE CRITERIA IN THE LITERATURE

DOD and NASA ([2], p. 203) often propagate the use of confidence as an objective criterion for choosing a certain type of contract. Confidence is defined as the estimate of the amount by which final costs might deviate from target. The criterion can be summarised as in Table 11.1.

<table>
<thead>
<tr>
<th>CONFIDENCE</th>
<th>RECOMMENDED CONTRACT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better than 10%</td>
<td>Firm Fixed Price (FFP)</td>
</tr>
<tr>
<td>10 - 20%</td>
<td>Fixed Price Incentive (FPI)</td>
</tr>
<tr>
<td>Worse than 20%</td>
<td>Cost plus Incentive Fee (CPIF)</td>
</tr>
</tbody>
</table>
The choice of this single criterion gives arbitrary results, as other elements are not considered. Furthermore, it is doubtful whether one of the parties can accurately quantify this confidence; it is practically excluded that both of them will be able to do so. Nevertheless, this criterion is still widely in use.

A number of statistical techniques have been introduced by Worm [3], in order to allow quantification of this risk/confidence factor. Statistical results, however, always require a minimal sample to permit one to deduce the necessary parameters for the statistical distribution. Practical results of such techniques are, therefore, not readily available for our specific case.

The U.K. Ministry of Defense Guide ([4], p. ii) avoids quantification with the following statement:

'The MOD preference continues to be to place fixed price contracts whenever possible. Target cost (incentive) contracts can however provide appropriate incentives in situations where the risks are too great to enable fixed prices to be negotiated but not so great as to justify the use of cost plus contracts.'

Gaisor [5] feels that cost uncertainty must be based on the range of probable cost outcomes generated by technical uncertainty. On the basis of this principle, he formulates the following guidelines:

— Fixed price contracts should be used only in those cases where no substantial uncertainties in cost, performance or schedule outcomes are expected.
— Incentive contracts may allow uncertain cost outcomes, as long as the contractor is considered to be able to control them (at least partially).
— If there is a broad range of probable cost outcomes, use of a straight cost-plus-fixed-fee or cost-plus-award-fee contract is recommended.

Herten and Peeters [6] question the previously mentioned approaches, especially the use of only one criterion. As an example, they point out that the degree of control which is required can also considerably influence the decision. Moreover, the client should realise that some contract types need a considerable control effort; he will, therefore, sometimes prefer an easier type of contract, compared with his pure risk/uncertainty criterion. The relation and combined control/risk element is shown in Table 11.2.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>TYPE OF CONTRACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>High risks, high control</td>
<td>CPFF (Cost Plus Fixed Fee)</td>
</tr>
<tr>
<td>High risks; but lower control</td>
<td>CPAF (Cost Plus Award Fee)</td>
</tr>
<tr>
<td>Low risks, but higher control</td>
<td>CPIF (Cost Plus Incentive Fee)</td>
</tr>
<tr>
<td>Low risks, low control</td>
<td>FPI (Fixed Price with Incentive)</td>
</tr>
<tr>
<td></td>
<td>FFP (Firm Fixed Price)</td>
</tr>
</tbody>
</table>

Kerzner and Thambain ([7], p. 209) try to relate the type of programmes with typical contract types, as represented in Table 11.3. Although they warn the reader that other elements may
play an important rôle, the danger of presenting such a rigid table is considerable. A wide range of technical uncertainty can be related to each of the programmes mentioned; this makes it impossible to group all such programmes under one unique contract type.

**TABLE 11.3**  
*Contract types vs typical programmes*  
(as suggested by Kerzner and Thambain ([7], p. 209))

<table>
<thead>
<tr>
<th>CONTRACT TYPE</th>
<th>TYPICAL PROGRAMMES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed-price contracts</strong></td>
<td></td>
</tr>
<tr>
<td>FFP - Firm Fixed Price</td>
<td>Well-defined programmes with predictable cost and low implementation risk:</td>
</tr>
<tr>
<td></td>
<td>• Production to specifications</td>
</tr>
<tr>
<td></td>
<td>• Training programme</td>
</tr>
<tr>
<td>FPE - Fixed Price with Escalation</td>
<td>Well-defined programmes with predictable effort but with uncertain stability of market and labour conditions:</td>
</tr>
<tr>
<td></td>
<td>• Long-range programmes</td>
</tr>
<tr>
<td>FPI - Fixed Price plus Incentive fee</td>
<td>Variation of FFP type used in situations where cost information or performance requirements are not sufficiently developed to permit negotiation of firm targets:</td>
</tr>
<tr>
<td></td>
<td>• Development programmes</td>
</tr>
<tr>
<td><strong>Cost-plus contracts</strong></td>
<td></td>
</tr>
<tr>
<td>CPFF - Cost Plus Fixed Fee</td>
<td>Exploratory or development types of programmes with uncertain level of effort and cost:</td>
</tr>
<tr>
<td></td>
<td>• Research programmes</td>
</tr>
<tr>
<td></td>
<td>• Study programmes</td>
</tr>
<tr>
<td></td>
<td>• Advanced developments</td>
</tr>
<tr>
<td></td>
<td>• Consulting</td>
</tr>
<tr>
<td>CPIF - Cost Plus Incentive Fee</td>
<td>Especially development and test programmes:</td>
</tr>
<tr>
<td></td>
<td>• Equipment developments</td>
</tr>
<tr>
<td></td>
<td>• Prototype developments</td>
</tr>
<tr>
<td></td>
<td>• Proposal developments</td>
</tr>
<tr>
<td>CPAF - Cost Plus Award Fee</td>
<td>Complex programmes with performances that are difficult to measure:</td>
</tr>
<tr>
<td></td>
<td>• Development programmes</td>
</tr>
<tr>
<td></td>
<td>• Research programmes</td>
</tr>
<tr>
<td></td>
<td>• Studies</td>
</tr>
</tbody>
</table>

The danger of such one-criterion-decision charts is that they will be used in a purely bureaucratic way. An administrator might have the tendency to accept such a table as his bible and might disregard specific circumstances (why should he start thinking if somebody else has done this already?).
Kahn [8] represents the more flexible trend towards tailoring the contract type as a function of the specific programme circumstances. He states, for example:

'The Agency (ESA) has always to strike a balance between, on the one hand, the striving for technical excellence and the optimisation of technical performance that the users desire, and on the other hand the budgetary certainty, administrative simplicity and discipline that a fixed price imposes. Industry, motivated primarily by the desire to maximise profit, also has to weigh up the advantages of a modest cost-reimbursement gain with little risk against the chance of higher profit or loss. It also considers the future market potential of the product and, not insignificantly in this field, its reputation. In practice, and at the risk of some oversimplification, the policy has worked out as follows. Scientific and pre-operational (development) applications satellites are usually placed at cost-reimbursement.... Satellites with relatively little new development effort, and in particular follow-on models of application satellites, are contracted for at a full fixed price.'

It is precisely this multi-criterion approach that we shall develop in our overall contract choice model.

11.3 CONFLICTING CLIENT/CONTRACTOR INTERESTS

It is evident that, for the same programme, there will initially be differing views concerning the (preferred) contract type. In order to evaluate this factor systematically, we shall first describe the advantages and disadvantages per contract type, from both the contractor's and the client's point of view. These considerations are summarised in Tables 11.4 and 11.5.

Unfortunately, most interests are highly conflicting: an advantage for one party represents an equivalent disadvantage for the other party. This leads us to our first conclusion: a contract type chosen is, in general, the result of a compromise, acceptable to both parties. This element of compromise, of course, implicitly means that both parties have the ultimate aim of concluding a contract and are therefore willing to make some concessions. To what extent these concessions will be made will depend on a number of factors, some of which are the following:

- Familiarity with the other party's flexibility. This is one of the reasons why a particular set of contractors have a certain 'continuity' with clients. Besides other influencing elements (personal relations, small gifts etc.), the contractor will generally know, say, how 'fixed' a fixed price is, what the chances for change orders are and so on. A new contractor cannot assess these factors and will therefore calculate margins in his cost price (which, often, makes him more expensive).

- The cash-flow position of the contractor. Unfortunately, some contractors are willing to accept contracts which are attractive in terms of advance payments (this is, in general, more the case with fixed price contracts). It is questionable if this is a good choice for the client: either the contractor fails anyway and goes bankrupt during contract execution or the contractor will survive and will afterwards fight back with change orders and claims.

- Instructions from top management (see earlier examples).

- The attractiveness of certain elements, such as very attractive incentives and ... prices.

- The ability of the negotiators.

- The chances of obtaining follow-up contracts.
### TABLE 11.4 Analysis of advantages of various contract types

<table>
<thead>
<tr>
<th>CONTRACT TYPE</th>
<th>CONTRACTOR'S ADVANTAGES</th>
<th>CLIENT'S ADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFP (Firm Fixed Price)</td>
<td>• Large profit possible</td>
<td>• Limited (financial) control</td>
</tr>
<tr>
<td></td>
<td>• Minimal administration</td>
<td>• Better defined budgets</td>
</tr>
<tr>
<td>FPE (Fixed Price with Escalation)</td>
<td>• As FFP +</td>
<td>• As FFP, but budget less well defined (escalation to be estimated)</td>
</tr>
<tr>
<td></td>
<td>• Protection against price fluctuations</td>
<td></td>
</tr>
<tr>
<td>FPI (Fixed Price with Incentives)</td>
<td>• As FFP +</td>
<td>• Additional protection against unhealthy trade-offs</td>
</tr>
<tr>
<td></td>
<td>• Profit more moderate</td>
<td></td>
</tr>
<tr>
<td>CP (Cost Plus reimbursement contracts, general)</td>
<td>• No financial risk</td>
<td>• More flexibility to redirect specifications</td>
</tr>
<tr>
<td>CPFF (Cost Plus Fixed Fee)</td>
<td>• No risk at all</td>
<td>• Built-in incentive (fixed fee) vs. pure CP</td>
</tr>
<tr>
<td></td>
<td>• Possibility of high profit at low cost</td>
<td></td>
</tr>
<tr>
<td>CPIF (Cost Plus Incentive Fee)</td>
<td>• No risk for costs</td>
<td>• Can give better protection against budget overruns</td>
</tr>
<tr>
<td></td>
<td>• Few risks for fee (especially if a minimal fee is foreseen)</td>
<td></td>
</tr>
<tr>
<td>Performance Incentive</td>
<td>• Better control of project team</td>
<td>• Better guarantee of quality</td>
</tr>
<tr>
<td></td>
<td>• Additional profit if technical specification is feasible</td>
<td></td>
</tr>
<tr>
<td>Schedule Incentive</td>
<td>• Better control of project time (cost related aspect)</td>
<td>• Better guarantee of timely delivery</td>
</tr>
<tr>
<td></td>
<td>• Additional profit possible if contract duration is acceptable</td>
<td>• Better guarantee of stable budgets (contract cost and in-house manpower)</td>
</tr>
<tr>
<td>Award Incentive</td>
<td>• Additional fee if organisation is adequate</td>
<td>• Better control possible</td>
</tr>
</tbody>
</table>
**TABLE 11.5 Analysis of disadvantages of various contract types**

<table>
<thead>
<tr>
<th>CONTRACT TYPE</th>
<th>CONTRACTOR’S DISADVANTAGES</th>
<th>CLIENT’S DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FFP</strong> (Firm Fixed Price)</td>
<td>● Extremely high risk</td>
<td>● Can result in extremely high costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Claims and change order discussions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Limited flexibility</td>
</tr>
<tr>
<td><strong>FPE</strong> (Fixed Price with Escalation)</td>
<td>● High risk, except for price increases</td>
<td>● As FFP +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Additional budget uncertainty</td>
</tr>
<tr>
<td><strong>FPI</strong> (Fixed Price with Incentives)</td>
<td>● Risk still high, but limited in certain areas</td>
<td>● As FFP +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Budget uncertainty</td>
</tr>
<tr>
<td><strong>CP</strong> (Cost Plus reimbursement contracts, general)</td>
<td>● High administrative costs</td>
<td>● Budget uncertain</td>
</tr>
<tr>
<td></td>
<td>● Can lead to goodwill loss in the case of overruns</td>
<td>● High administrative costs</td>
</tr>
<tr>
<td><strong>CPFF</strong> (Cost Plus Fixed Fee)</td>
<td>● As CP, but</td>
<td>● As CP, but</td>
</tr>
<tr>
<td></td>
<td>● Less profit in the case of overruns</td>
<td>● Risk of paying excessive profits (if costs turn out to be low)</td>
</tr>
<tr>
<td><strong>CPIF</strong> (Cost Plus Incentive-Fee)</td>
<td>● As CPFF, but</td>
<td>● As CPFF, but</td>
</tr>
<tr>
<td></td>
<td>● More administrative and budgetary problems</td>
<td>● Budgetary uncertainties are higher</td>
</tr>
<tr>
<td><strong>Performance Incentive</strong></td>
<td>● Risk of ‘penalty’ in the case that performance is not obtained</td>
<td>● Additional budget uncertainty</td>
</tr>
<tr>
<td></td>
<td>● Loss of reputation possible</td>
<td>● Less flexibility in requirement changes</td>
</tr>
<tr>
<td><strong>Schedule Incentive</strong></td>
<td>● Risk of lower fee</td>
<td>● Additional budget uncertainty</td>
</tr>
<tr>
<td></td>
<td>● Loss of reputation possible</td>
<td>● Additional budget uncertainty and more intensive change control</td>
</tr>
<tr>
<td><strong>Award Incentive</strong></td>
<td>● Subjectivity in appraisal</td>
<td>● Additional budget uncertainty</td>
</tr>
<tr>
<td></td>
<td>● Loss of reputation possible</td>
<td>● Risk of (unpleasant) discussions</td>
</tr>
<tr>
<td></td>
<td>● Fee uncertain</td>
<td></td>
</tr>
</tbody>
</table>
The portion of the specific contract in the overall turnover: less importance will be given if a large contractor has to discuss a minor side-contract with the same client.

For both parties, the key question remains: 'Can I accept the proposed contract type and/or am I able to negotiate?' The subsequent decision cycle is given in Figure 11.1. The contractor will have a number of inputs and will compare these inputs with the contractual arrangements. Depending upon his interests in obtaining the specific contract, the contractor will take his decision.

Figure 11.1 Contractor's decision chart for negotiations.

Note that the opposite situation can also occur. In practice, we have noticed that there are considerable disadvantages for the client as well. So, the situation is not unrealistic where the client, too, cannot accept a certain type of contract (e.g. owing to budgetary constraints).

11.4 FINAL DECISION CRITERIA

In Section 11.2, we have emphasised that there is an important risk when only one (or few) criteria are considered. We feel that it is impossible to make an unambiguous decision based upon one consideration only; therefore a number of decisive criteria will be considered in our model.

On the other hand, however, transparency can be lost by introducing too many elements. As a compromise between these two constraints, we have chosen the following criteria:

- Cost uncertainty;
- Technical uncertainty;
- Available extra resources;
- Schedule criticality;
- Performance criticality;
- Long-term motives.

The order in which the criteria are given, represents, in general, the decreasing order of importance given by the contractor. This is not always the case for each specific project,
however, and can vary strongly as a result of specific circumstances (for example: continuity may be considered of great importance, particularly in periods of persistent undercapacity).

As contractors are still profit oriented, the cost factor and related uncertainty (also including such elements as payment currency, guarantees, reputation of the client etc.) will in general dominate the decision. We should not, however, neglect the technical uncertainty. If a contractor feels that the technological background needed falls outside his field of competence, his cost uncertainty will be influenced. Every contractor feels himself comfortable in a certain technological field and is generally rather reluctant to enter (and invest in) other areas. Only if a contractor feels the need to expand his activities in such areas (new markets), may he be interested in doing so.

Availability of extra resources has been extensively discussed in the chapter on cost incentives. A large overcapacity will make a contractor more flexible. Indeed, a cost overrun under cost-reimbursement conditions will only be favourable. On the other hand, even under fixed-price conditions overcapacity will make losses less painful: the general and administrative expenses are covered anyway and cannot, therefore, be considered as 'losses'.

Schedule and performances are generally well defined in the request for quotation. Whereas previous elements were more important for the contractor and normally unknown to the client, these last two elements are equally important for both parties, certainly when incentives are considered.

Under the item 'long-term motives', a number of elements are grouped, such as:

— does the contract contribute to the contractor's know-how (spin-off)?
— how much importance does the contractor attach to goodwill and prestige?
— contractor/client ties and continuity (it is often more profitable to accept a small loss than to let a competitor enter the market);
— chance for follow-up contracts (often plays a role in study phases);
— contractor's manager's personal interest in the subject (particularly if he is by training a scientist or technician).

The consequences for both parties, in relation to these elements, are systematically set out in Table 11.6.

As far as incentives are concerned, the contractor's reactions will be typically as follows:

Cost incentive: Positive if cost uncertainty is high, negative if a considerable profit is expected (both due to sharing).

Performance incentive: In general negative; it will only represent an additional risk.

Delivery incentive: In general positive as time reduction will reduce fixed costs. As there will be a penalty scale anyway, the contractor can only win by it.

Award incentive: Basically negative, owing to subjectivity and the administrative burdens.
**TABLE 11.6  Consequences of decision criteria**

<table>
<thead>
<tr>
<th>EFFECT</th>
<th>CONTRACTOR'S ATTITUDE</th>
<th>CLIENT'S ATTITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost uncertainty high</td>
<td>-- Will not accept a fixed price</td>
<td>-- Will have no preference for fixed price</td>
</tr>
<tr>
<td></td>
<td>-- Will prefer cost (risk) sharing</td>
<td>-- Will prefer maximum inclusion of incentives</td>
</tr>
<tr>
<td></td>
<td>-- Will be reluctant to accept performance and schedule incentives</td>
<td></td>
</tr>
<tr>
<td>Cost uncertainty low</td>
<td>-- Will accept fixed price (if other elements are acceptable</td>
<td>-- Will be reluctant to accept cost-plus arrangement</td>
</tr>
<tr>
<td></td>
<td>-- Will prefer firm fixed price (this will lower his administrative costs)</td>
<td>-- Will try to include incentives, if interested in other elements</td>
</tr>
<tr>
<td>Technical uncertainty high</td>
<td>Will avoid:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-- fixed prices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-- performance incentive</td>
<td></td>
</tr>
<tr>
<td>Technical uncertainty low</td>
<td>Will consider:</td>
<td>Will propose performance incentive</td>
</tr>
<tr>
<td></td>
<td>-- Fixed price acceptable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-- Performance incentive sometimes interesting</td>
<td></td>
</tr>
<tr>
<td>Extra resources available</td>
<td>Will be more flexible towards accepting a compromise</td>
<td>Will in general not be known to him, so no major influence</td>
</tr>
<tr>
<td>No extra resources available</td>
<td>Will not accept compromises if other elements are critical</td>
<td>Will generally have no major influence</td>
</tr>
<tr>
<td>Schedule critical</td>
<td>Will be hesitant to accept a delivery incentive</td>
<td>Will in all cases propose delivery incentive</td>
</tr>
<tr>
<td>Schedule not critical</td>
<td>Will be more flexible towards accepting a compromise, such as incentives (lower cost risk)</td>
<td>Will not be interested in delivery incentive</td>
</tr>
<tr>
<td>Performance critical</td>
<td>Will be very cautious, as this can represent a major cost driver</td>
<td>Will try to introduce performance and cost incentive</td>
</tr>
<tr>
<td>Performance not critical</td>
<td>Will be more flexible, and will possibly accept fixed prices</td>
<td>Will insist on fixed price</td>
</tr>
<tr>
<td>Long-term motives exist</td>
<td>This will influence his final decision (to a limited extent) to to accept incentives</td>
<td>This will have no major influence (normally unknown)</td>
</tr>
<tr>
<td>No long-term motives</td>
<td>Will have greater reluctance to accept compromises such as incentives</td>
<td>This will have no major influence (normally unknown)</td>
</tr>
</tbody>
</table>
11.5 PROPOSED GENERAL MODEL FOR CONTRACT CHOICES

Both parties will meet at the negotiation table. The negotiation can be considered as a game with some rules. Our model will therefore reflect the rules of this game as follows:

(1) The final outcome has to be acceptable to both parties, taking into account the consequences set out in Table 11.6.

(2) All incentives comply with the submodels set out in previous chapters.

(3) Both parties have a general knowledge of the final outcome and consequences of the various types of contract.

(4) The client wishes to maintain an effective control during contract execution.

(5) Both parties have only a limited knowledge of the other party's desire to conclude the contract and of typical circumstances (e.g., the contractor's cash flow is considered to be unknown to the client).

(6) All conclusions are based upon systematic considerations. Exceptional circumstances cannot be reflected in this general model (e.g., top management decisions).

(7) A slightly 'dominant' position will be maintained by the client.

The consequences of this last element will work out as follows: Consider, per specific case, three possible attitudes in relation to a proposed type of contract (both for the contractor and the client):

- Preferred
- Acceptable
- Not acceptable.

First of all, in relation to the first 'rule' of our model, the contract type has to be preferred by, or at least acceptable to, both parties. Furthermore, in view of the slightly dominant position of the client, a solution which is preferable to the client but only acceptable to the contractor will dominate over a solution which is acceptable to the client, even if it is preferable to the contractor. This leads to the order of preference as set out in Table 11.7. Note again that elements containing one 'unacceptable' will not be retained.

<table>
<thead>
<tr>
<th>ORDER OF PREFERENCE</th>
<th>CLIENT</th>
<th>CONTRACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preferred</td>
<td>Preferred</td>
</tr>
<tr>
<td>2</td>
<td>Preferred</td>
<td>Acceptable</td>
</tr>
<tr>
<td>3</td>
<td>Acceptable</td>
<td>Preferred</td>
</tr>
<tr>
<td>4</td>
<td>Acceptable</td>
<td>Acceptable</td>
</tr>
</tbody>
</table>
In order to present the result of these considerations in a systematic way, we have chosen a decision network format. The following abbreviations are used in Figure 11.2:

1 = contractor
2 = client
C = cost incentive
D = delivery incentive
P = performance incentive
AF = award fee

Note that considerations on 'escalation formulas' are excluded, as they depend upon the duration of the contract and are relatively independent of the contract choice (i.e. they can be added to virtually any contract).

The decision network in Figure 11.2 can be used as follows:

In order to determine a suitable contract type for a specific case, a number of questions need to be answered with YES or NO. Following these answers, we find at the end of the network, per specific case:

- Which contract type would be respectively preferable, acceptable or unacceptable to both contractor and client.
- Which contract type is proposed for this specific case, on the basis of the principles outlined earlier in this chapter (i.e. in accordance with the rules given in Table 11.7).

The order in which the questions are put is only indicative, and reflects a relatively common order of decreasing importance. If the questions were arranged in a different order, the decision network would look different, but would give the same results for each specific case.

In principle, a questionnaire should be completed before the decision network can be applied. There are two possibilities: either both parties complete the questionnaire independently and try, afterwards, to find a consensus; or both parties complete the form jointly. Whatever the procedure followed, a questionnaire such as that set out in Figure 11.3 will have to be available and completed.

Note that the term 'questionnaire' should not be regarded too formally. It can easily be assumed that no paper form will be needed in some cases and that both parties work directly with the decision network.

The essential point to be remembered is that, systematically, questions of this type will have to be answered, one way or another.
### Relevant Contract Type

<table>
<thead>
<tr>
<th>Pref.</th>
<th>Accept</th>
<th>Not Accept</th>
<th>Proposed Contract Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ D)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ D)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>1 CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
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<tr>
<td>1 CPFF</td>
<td>CPFF</td>
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<td>CPFF</td>
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<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
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<td>1 CPFF</td>
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<tr>
<td>2 CPFF (+ P)</td>
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<tr>
<td>2 CPFF (+ P)</td>
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<td>1 CPFF</td>
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<td>2 CPFF (+ P)</td>
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<tr>
<td>2 CPFF (+ P)</td>
<td>CPFF</td>
<td>CPFF</td>
<td>CPFF</td>
</tr>
</tbody>
</table>

**Figure 11.2** Decision network for choice of type of contract.
Figure 11.2 Decision network for choice of type of contract (continued).
1. **COST UNCERTAINTY**  
(1.1) Are cost estimates considered to be less accurate than 20%,

or,

(1.2) Is the cost estimation considered to be accurate

2. **TECHNICAL UNCERTAINTY**  
(2.1) Are there technical elements in the requirements, with an important cost impact, for which the know-how or experience is not readily available,

or,

(2.2) Are such elements not identified or negligible

3. **ADDITIONAL RESOURCES**  
(3.1) Can additional qualified manpower and other resources (example areas, offices etc.) be called in, if needed, within a short time,

or,

(3.2) Are such resources not available at short notice

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

*Figure 11.3 Questionnaire (to be used in connection with contract choice model).*
### 4. SCHEDULE CRITICALITY

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

(4.1) Are there elements in the requirements which indicate that the schedule may become critical (such as linkage with other deliveries, defined launch window, scheduled flight etc.)

or,

(4.2) Is the project considered less time dependent

### 5. PERFORMANCE CRITICALITY

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

(5.1) Is a deviation from the specified performances completely unacceptable to the client,

or,

(5.2) Is it realistic to assume that reasonable deviations will be accepted by the client

### 6. LONG-TERM MOTIVES

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

(6.1) Are there elements for the contractor which make this particular contract very important (continuity, image, spin-off etc.)

or,

(6.2) Are such reasons not evident

*Figure 11.3 Questionnaire (continued).*
11.6 ILLUSTRATION

In order to illustrate how this decision network approach can be applied, we will develop an imaginary case. Let us consider a possible development contract for the study and prototype development of reliable so-called fuel cells. Europe wants to develop these cells, based upon \( \text{H}_2/\text{O}_2 \) recombination, as they are considered to be essential for future manned space flight. An important European consortium, with experience in energy and battery fields, is approached to execute this project.

Both parties realise that:

(A) **Cost uncertainties** are immense. It is practically impossible to estimate development time and effort.

(B) **Technical uncertainties** are also very great. On the one hand, the project is feasible, since basic development of the fuel cells has already taken place in the USA (although there are still important technical problems). On the other hand, know-how and technological background (apart from some preliminary laboratory experiments and general information in US publications) are not available in Europe.

(C) **Additional resources**, covering various disciplines, need to be largely available. It was for these specific reasons that the consortium, which has considerable resources, was chosen.

(D) **Schedule** is less critical. In fact, if necessary, it will probably be possible to fall back on commercially available fuel cells from US companies.

(E) **Performances** are critical. As we can only afford a limited number of such cells in the future spacecraft (mass constraints) such points as guaranteed performances and reliability are essential. Furthermore, important safety aspects are involved.

(F) **Long-term motives** clearly exist. These fuel cells cover a very large field of possible applications and subsequent markets (aircraft, automobiles, instrumentation etc.).

Suppose that both parties (the client and the potential contractor) have jointly agreed on these inputs and obtain the completed questionnaire shown in Figure 11.4. The inputs from this figure can now be used to choose the most appropriate contract type for this specific case. This turns out, as we can see from Figure 11.5, to be a Cost Plus Incentive Fee (CPIF) contract with a cost incentive.

This conclusion seems very acceptable, for the following reasons:

— The contractor cannot accept any form of fixed price; the client will, however, try to keep control over the costs by adding a cost incentive.
— A delivery incentive is obviously less interesting for the client.
— A performance incentive cannot be accepted by the contractor as performances are still rather vague, certainly in quantitative terms.

This illustrative example shows us that, in a real life environment, the decision network approach gives us a very useful tool, protecting the interests of both parties.

Specific advantages of the proposed technique are:

— The decision tree approach forces both parties to consider a number of essential questions.
— The systematic rationale behind the various points allows both parties to evaluate the consequences (e.g. by reconsidering the advantages/disadvantages proposed in the tables displayed earlier in this chapter).
— The results of this systematic approach give a certain guarantee of ‘objectivity’. This
'independent assessment' might be useful as a guideline (or support) during negotiations.
- The results obtained can increase confidence or give a warning sign, whenever a 'feeling'
  has to be checked.
- The decision network will definitely be useful for the less experienced contract negotiator.
- The decision network can be used as the basis for a training session (management game).
### 1. COST UNCERTAINTY

(1.1) Are cost estimates considered to be less accurate than 20%,

or,

(1.2) Is the cost estimation considered to be accurate

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

### 2. TECHNICAL UNCERTAINTY

(2.1) Are there technical elements in the requirements, with an important cost impact, for which the know-how or experience is not readily available,

or,

(2.2) Are such elements not identified or negligible

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<tbody>
<tr>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

### 3. ADDITIONAL RESOURCES

(3.1) Can additional qualified manpower and other resources (example areas, offices etc.) be called in, if needed, within a short time,

or,

(3.2) Are such resources not available at short notice

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<tbody>
<tr>
<td></td>
<td>x</td>
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</tbody>
</table>

(Cont'd)

*Figure 11.4 Case study: completed questionnaire.*
### 4. SCHEDULE CRITICALITY

(4.1) Are there elements in the requirements which indicate that the schedule may become critical (such as linkage with other deliveries, defined launch window, scheduled flight etc.)

or,

(4.2) Is the project considered less time dependent

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

### 5. PERFORMANCE CRITICALITY

(5.1) Is a deviation from the specified performances completely unacceptable to the client,

<p>| | |</p>
<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

or,

(5.2) Is it realistic to assume that reasonable deviations will be accepted by the client

### 6. LONG-TERM MOTIVES

(6.1) Are there elements for the contractor which make this particular contract very important (continuity, image, spin-off etc.)

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

or,

(6.2) Are such reasons not evident

<p>| | |</p>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case study: application of decision network

Figure 11.5

Start

Is cost uncertainty high?

Is technical uncertainty high?

Are extra resources available?

Is schedule critical?

Is performance critical?

Are long-term motives considered?
11.7 SUMMARY

A number of manuals and publications propose one single criterion on which to base a decision concerning the appropriate choice of contract type. Such a 'one-criterion' approach has proved to be inadequate to cope with certain specific circumstances. For this reason, a model is proposed, based upon the following inputs:

- Cost uncertainty
- Technical uncertainty
- Resource availability
- Schedule criticality
- Performance criticality
- Long-term motives

The order of importance of these inputs is only indicative and can vary per specific case; the model, however, is not influenced by this order.

The effect of these inputs on the client's and contractor's negotiation attitude is carefully examined and a set of rules is established that is to be followed during the negotiation cycle.

One of the most important rules is, undoubtedly, that the type of contract finally chosen has to be at least acceptable to both parties.

On the basis of these considerations, a decision network has been constructed that allows us to identify the most appropriate contract type for each specific case. As a means of facilitating the use of this decision network, a questionnaire is proposed that helps the user to evaluate the necessary inputs.

These new tools, developed to support an appropriate choice of contract type, are demonstrated with the aid of an example and prove to yield useful and workable results.

11.8 REFERENCES

CHAPTER 12
VALIDATION OF THE CONTRACT CHOICE MODEL

12.1 GENERAL

In the previous chapter, we have proposed a model with the intention to provide contract negotiators with a useful and practical tool. In an earlier publication [1], we have demonstrated that each model should only be considered to be ready for implementation if it has been validated in relation to four criteria:

(A) workability
(B) consistency
(C) sensitivity
(D) plausibility

The ‘fuel cell’ example (in the previous chapter) demonstrated step by step the workability of our model.

In order to make sure that the results are also consistent with reality, we shall simulate the average results theoretically obtained with our model and compare them with real data. The sensitivity of the model is another important element: small deviations in the inputs may not result in a completely different behaviour of the results. As for the plausibility of the model, we shall check some practical cases and correlate the results of practical and theoretical outcomes.

12.2 CONSISTENCY OF THE MODEL IN THE ESA ENVIRONMENT

Typically, the general decision criteria for the ESA environment will be:

- **Cost uncertainty**: in view of the development and hi-tech character of the pilot environment, costs are in general uncertain. Only for certain follow-on projects (such as telecommunication satellites) can a higher degree of accuracy can established.
- **Technical uncertainty**: this is, if possible, even higher. Even if a project strongly resembling a previous one is executed, requirements are in general more stringent and this can lead to unexpected technical surprises.
- **Extra resources**: typical ESA contractors belong to the large aerospace and military consortia. In general, therefore, they are able to deploy additional resources rapidly.
- **Schedule**: this is often important, especially in view of so-called ‘launch windows’.
- **Performance**: quality and related requirements are very stringent, mainly because of the practical impossibility of performing repairs in orbit.
• **Long-term motives:** these are generally very strong. The contractors wish to restrict the market and to maintain their position, particularly in view of the spin-off for their other (aerospace and military) activities, which they want to keep for themselves.

If we express these statements in probabilistic terms, we can consider all 'yes' statements as highly probable. As an assessment, we attribute 80% probability to the 'yes' statement. In other words, we assume that in 80% of the cases:

- cost uncertainty is high;
- technical uncertainty is high;
- additional resources are available;
- the schedule is critical;
- performance is critical;
- a number of long-term motives exist;

and that the opposite situation occurs, per case, with a 20% probability.*

Calculation of the decision network with these probabilistic factors has been performed as follows:

(a) For each end node of the decision network, the relative occurrence is calculated with the 80/20 assumption. This means that in each node the 'YES' branch is given a value of 0.8 and the 'NO' branch is given a value of 0.2.

*Example:* For our specific example of the fuel cells, where a CPIF contract resulted (see Fig. 11.5), this leads us to the following relative occurrence of this case:

<table>
<thead>
<tr>
<th>Cost uncertainty high</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical uncertainty high</td>
<td>0.8</td>
</tr>
<tr>
<td>Additional resources available</td>
<td>0.8</td>
</tr>
<tr>
<td>Schedule less critical</td>
<td>0.2</td>
</tr>
<tr>
<td>Performance critical</td>
<td>0.8</td>
</tr>
<tr>
<td>Long-term motives</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Overall occurrence 0.065 (6.5 %)

(b) If we add all cases where CPIF occurs (of which the example is only one), we obtain a total percentage of 58.50 % for CPIF contracts. The results of these calculations are given in Table 12.1, which gives us a theoretical distribution of contract types for our pilot environment.

This table gives us, in fact, the result of a simulation and shows us that the theoretical average distribution of our model will lead to:

* This distribution should not be taken too rigorously; it is merely a quantitative expression of the qualitative statements 'in most cases' (80 %) and 'exceptionally' (20%). In Section 12.3 we shall show that the sensitivity of the model is sufficiently moderate to allow such an assumption.
TABLE 12.1 Theoretical distribution of contract types

<table>
<thead>
<tr>
<th>CONTRACT TYPE</th>
<th>THEORETICAL PERCENTAGE OF OCCURRENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPIF (Cost Plus Incentive Fee)</td>
<td>58.50%</td>
</tr>
<tr>
<td>CPAF (Cost Plus Award Fee)</td>
<td>0 %</td>
</tr>
<tr>
<td>CPFF (Cost Plus Fixed Fee)</td>
<td>20.99%</td>
</tr>
<tr>
<td>FPI (Fixed Price with Incentive)</td>
<td>13.44%</td>
</tr>
<tr>
<td>FFP (Firm Fixed Price)</td>
<td>4.00%</td>
</tr>
<tr>
<td>No decision</td>
<td>3.07%</td>
</tr>
</tbody>
</table>

- an average cost-plus-reimbursement contract percentage of some 80% (CPIF + CPAF + CPFF)
- a theoretical percentage of incentive type of contracts (CPIF + CPAF + FPI) of some 72 - 74% (depending on the distribution of the 'NO DECISION' case).

As these incentive provisions are one of the major elements of this study, we consider it as a good proof of consistency. Indeed, a recent article in Defense Daily [2] tells us that incentive contracts represented 72 - 75% of all NASA contract awards in the period 1980 - 1984. (Equivalent European data are not available.) Although we cannot disregard the fact that two different UAI's are being compared here, the correlation is significant enough to permit the use of this type of proof.

12.3 SENSITIVITY OF THE MODEL

The consistency of the model was tested with a 80/20 probability distribution of each node. As we have already indicated, the choice of this assumed distribution was made rather arbitrarily. We shall therefore have to evaluate the consequences of deviations from it. In order to do so, we have repeated the simulation that has led to the results presented in Table 12.1 (i.e. using a 80/20 distribution), using 50/50, 60/40, 70/30 and 90/10 distributions. As in our previous explanation, a 50/50 distribution would mean that, for each node, the average of 'YES' statements would represent 50% of the cases. For the other distributions, such an average would be 60%, 70% and 90%, respectively.

The resulting sensitivity analysis is shown in Figure 12.1, where the various probability assumptions are plotted against the theoretical (simulated) percentual occurrence of incentive contracts.

If we take as an upper and lower bound of occurrence 75% and 65% incentive contracts (which, according to the view expressed in Reference [2], can be considered feasible), we can deduce from Figure 12.1 that this band can be related to a distribution of assumed probabilities between 66/34 and 82/18. This means that the model is not very sensitive, certainly not for the range where the quantitative expression for 'in most cases' is situated between 66% and 82%.

For our specific environment, the European space sector, such a range is acceptable for the
respective inputs. On the average, it can safely be assumed that in more than 66% of the cases, but in less than 82% of them:

- costs can be considered as uncertain,
- technical uncertainty is high,
- additional resources are available,
- the schedule is critical,
- the performance is critical, and
- a number of long-term motives exist.

As we can also deduce from Figure 12.1, the curve is nearly linear in the area considered and has a moderate slope. We can, therefore, conclude that our model is acceptable within the plausible range of assumptions and not very sensitive to small deviations.

12.4 PLAUSIBILITY OF THE MODEL

Of the four criteria (workability, consistency, sensitivity and plausibility) which we wish to evaluate, the last one is, in general, the most difficult. The general problem is to find an acceptable point of comparison, for which data are available. If the model represents an innovative technique, such comparable data are not always readily available. In our specific case, availability of objective data gave an additional limitation.

We shall use ESA project data for two reasons: first of all we have better access to additional information on these projects; but, secondly, we should not forget that our model used inputs from this European environment.
As a first step: for the projects summarised earlier in Table 3.3, we shall evaluate the type of contract used, with the aid of the decision network shown in Figure 11.2. This results in a theoretical appraisal for the most appropriate contract type per case. The following step is to compare this theoretical appraisal with the practical outcome of the respective contract.

Here, we are confronted with the measurement of 'objectivity'. Most publications are written by the Project Manager or Contracts Officer, closely involved with the specific project. It is evident that 'objectivity' in such cases is only relative: it is very difficult to admit afterwards that the wrong type of contract has been chosen, as this is a major issue of the managerial decision.

Data on overruns (both of cost and time) also have a low significance level: overruns can occur as a result of important mission changes made by the client, unforeseen events such as substantial changes in technological know-how, slippage of launch date due to conflicting priorities or even a complete reconfiguration due to an obligatory change of launcher.

We have also limited our data to those projects that have been described in publications. Verbal information on other projects is available, but objectivity is, in such cases, even worse. The publication and subsequent approval cycle gives at least some guarantee of objectivity. (In fact, overruns which have not been properly documented seem to have a tendency to diminish over the years...)

The practical criterion for 'success' which was applied has therefore been checked twofold: from those published projects which were described as having been completed successfully (first screening), the relevant responsible managers were asked whether, if they had to run the project again, they would choose the same type of contract or would prefer a different one. Only if both points were positive, was the contract type considered to have been 'successful'.

Whereas the transparency of these data was relatively evident in the case of ESA projects, some question marks have to be placed against the SPOT case. This remote-sensing satellite, financed by CNES (France), undoubtedly represents a success which is, according to the Project Manager, largely attributed to the well-balanced performance incentive.

As an illustration of these performances, images taken by SPOT have alarmed US military officials. The resolution of the picture is, indeed, so good that military bases are clearly identifiable.

Financing of the project, however, has followed different patterns (from those of the other, ESA-financed, projects) and it is difficult to discover whether the fixed price arrangements would have worked as well under more stringent conditions.

Results of the foregoing considerations are presented in Table 12.2 (in which some doubts are expressed with regard to the SPOT case).

Comparison of the results in Table 12.2 shows us that a good correlation exists between theoretical evaluations and practical outcomes.

Although the number of data is too small to give statistical confidence, the results of this comparison give a strong indication that plausibility of our model may be assumed.
TABLE 12.2 Testing of the contract choice model

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>CONTRACT TYPE USED</th>
<th>CONTRACT TYPE ACCORDING TO THEORETICAL APPRAISAL</th>
<th>SUCCESS</th>
<th>CORRELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEOS-1</td>
<td>CP (Multiple inc.)</td>
<td>Acceptable</td>
<td>Yes</td>
<td>+</td>
</tr>
<tr>
<td>ESRO-IV</td>
<td>FP (Multiple inc.)</td>
<td>Acceptable</td>
<td>Yes</td>
<td>+</td>
</tr>
<tr>
<td>OTS</td>
<td>CP (Multiple inc.)</td>
<td>Acceptable</td>
<td>Yes</td>
<td>+</td>
</tr>
<tr>
<td>SPACELAB</td>
<td>FP (Award fee)</td>
<td>Not acceptable</td>
<td>No</td>
<td>+</td>
</tr>
<tr>
<td>SPOT</td>
<td>FPI (P)</td>
<td>Not acceptable</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>IPS</td>
<td>FPI (P)</td>
<td>Not acceptable</td>
<td>No</td>
<td>+</td>
</tr>
</tbody>
</table>

12.5 CONCLUSION

Validation of a model is always a difficult issue. A real validation can only be fully conclusive after some years of application and relevant post-evaluation. Still, a number of points can be tested in advance. The main conclusions of the tests on our model are:

— it definitely represents a practical tool;
— results (using a form of 'simulation') are sufficiently consistent with real data;
— the sensitivity of the model is not extremely high; small deviations do not significantly change the results;
— the plausibility of the model seems good, but needs further confirmation.

We can, therefore, conclude in general that the model is sufficiently validated and ready for use in real-life applications.

12.6 REFERENCES

CHAPTER 13
CONCLUSION

Development contracts are relatively new and have recently undergone a transition. Whereas
the major contractual aspects were adopted from the traditional procurement contracts, a
number of aspects had to be adjusted to the specific needs of development contracts.

An historical review shows that this adjustment has been done very gradually, being based
mainly on feedback of experience.

One of the most striking aspects of these development contracts is the considerable number
of contract types. Evidently, during the above-mentioned transition period, a number of
heuristic contract types have been devised and these have now resulted in a considerable
number of existing variants.

Such variants mainly originated in US governmental procurements and have gradually found
their way to Europe. In Europe, ESA, the European Space Agency, has been the most important
propagandist of such innovative contract types.

The rapid influx of these ‘intermediate’ types of contract has given rise to some problems.
The purpose of this study was therefore twofold:

First, to give a systematic overview of these intermediate contract types, indicating their
appropriate use;

Secondly, to re-evaluate the characteristics of the various contract types, suggesting
several improvements.

In order to accomplish this purpose, a systematic modelling approach has been followed. The
contractor/client relationship is considered within a control framework, whereby the client
wishes to maintain an effective control over the contractual outcome, leaving the control during
the contract execution under the responsibility of the contractor.

The client wishes to obtain a product that gives him a well-balanced result between cost,
schedule and performance.

Taking into consideration the prerequisites for effective control, a model has been developed,
initially, for each of these aspects. Afterwards, the aspects have been combined into a single
overall model.

All these models have been illustrated with data taken from ESA, which was considered as
the pilot environment. In addition to these generalised models, a number of environmental
factors have been examined, viz:

- Management motivation,
- Cross-cultural differences,
- Administrative aspects,
- Changes, and
- Future developments.
The influence of these factors and their consequences have been evaluated. This systematic modelling approach has resulted in a good understanding of the various properties within the various contract types.

The following step was to analyse both contractors' and clients' attitudes towards these different opinions. On the basis of the assumption that the final contract type chosen has to be at least acceptable to both parties, a number of decisive criteria were selected, viz:

- Cost uncertainty,
- Technical uncertainty,
- Resource availability,
- Schedule criticality,
- Performance criticality, and
- Long-term motives.

These criteria are presented in the form of a questionnaire. The subsequent answers are, on their turn, presented in a decision network. This decision network, which is the core of the study, allows both parties to make an appropriate contract choice, based upon objective, systematic considerations.

The final model has been tested and proves to be a practical tool with acceptable sensitivity. Simulation with the model shows that the results are very plausible and qualify the model for practical implementation.

In the course of the study, a number of other disciplines were touched upon. A number of aspects, related to such disciplines, are considered to be worthwhile subjects for further study and have been annexed as 'suggestions for further study'.

The main purpose of the study has been fully accomplished, resulting in a systematic approach to the different contract types and presentation of a global decision network. This network eventually gives both parties an objective tool, making it possible to choose the most appropriate type of contract for each specific case or contract phase.

The various contractual techniques, such as cost, schedule, performance incentives and combinations of these, have been systematically analysed and improvements are suggested.

Formulas are proposed for the calculation of the cost-sharing factor, the delivery incentive and penalty scales, as well as qualitative rationales for performance and multiple incentive formulas.

In a broader sense, the use of systematic modelling techniques has proved to be a very versatile tool with which to tackle a wide variety of practical problems and further illustrates the usefulness of such an approach.

During development contract negotiations, close cooperation between legal/administrative staff and technical staff is essential.

This study has considered the contract from a technical point of view and, it is hoped, makes a contribution towards solving the problem of bridging the communication gap between two complementary disciplines: technical management and administrative management.
ANNEX 1
SUGGESTIONS FOR FURTHER STUDY

It has already been remarked that the subject under discussion has a number of aspects that are related to other study disciplines. We have mentioned that it was not our intention (and even, on occasion, not within our power, owing to a lack of specialised knowledge) to deal with such aspects in more detail. At certain points in the main text, reference has been made to such opportunities, but it would seem preferable to group them here more systematically.

(A) LEGAL

- It would be worthwhile to examine whether governmental procurement guidelines in Europe are compatible with the new developments in contractual aspects.

- A number of formulas proposed require that the client receive information from the contractor and that he have the right to inspect/audit such information. The extent to which the client is entitled to exercise this right might be worthwhile examining.

- A contract has to be concluded by mutual agreement on the basis of certain assumptions. Both parties could, however, in good faith misjudge a factor such as technical uncertainty. To what extent can such misjudgement be accepted as a basis for so-called hardship-claims.

- Claims and change orders have been the subject of many studies. The way in which changes and claims may influence incentives might be another area for investigation.

- The direct rewarding of a contractor’s staff, via incentives, will also definitely have legal consequences.

(B) ECONOMICAL

- The contract awarding process — particularly the aspect of how influence may be exerted by employing different types of contract — has not been dealt with.

- The question of how proposals may vary in response to different types of contract and how they may be compared is a substantial part of this awarding process.

- General influences of major changes in administrative directives (specifically on types of contract to be used) have an important macro-economic impact. It might be worthwhile to examine such influences, with the aid of general models.

- The way in which control and aspects of governmental management may be mutually interactive constitutes another aspect for further study (appropriate balance between exerting control and the cost of so doing).
(C) SOCIO-CULTURAL

• Motivation of the top hired manager is an important current issue. Can motivation of such staff be re-evaluated, in order to ensure better compliance with the firm's objectives or does one have to rely on full delegation of authority and sense of duty?

• The growing impact of information technology (e.g. ESA encourages computer-driven tendering) will influence social relations and might make negotiations less subject to interpersonal contacts. Will this effect diminish the influence of strong personalities?

• The negotiation of a contract is a game played by two parties, each having a limited amount of information concerning the other party. The influence of the environmental aspects are an interesting subject for further study.

• The results of the xenopsychological studies definitely deserve a wider field of application. In supranational environments, such cultural differences have an important impact on social, but also on business contacts.

(D) POST-EVALUATION OF THIS STUDY

One aspect closely related to the study is a post-evaluation exercise, needed to test the model. It is evident (as has already been mentioned in Chapter 12) that full validation of the model will take time. One would need, for this purpose, controlled inputs as well as controlled outcomes.

Proper documentation of the project is an essential prerequisite for such an evaluation. Ideally, one would need per project:

(a) The input questionnaire (as per Fig. 11.3);
(b) An update change order logbook (as per Fig. 10.1);

Post evaluation should certainly not disregard those elements that have changed the project so drastically that the inputs, after these changes, have also been completely changed. A typical example, for the contractor, is the need for additional resources that have become scarce when other, more important, orders have been obtained. From that moment on, the contractor may have a completely different interest in the project. Similar effects may become apparent if a contractor's motives change significantly (e.g. after a merger).

All these elements should be taken into account in a post-evaluation study. If we wish, moreover, to have a sample of data that is significantly large, it is evident that such post evaluation can only take place some five years after implementation of this model (taking into account average durations of important development contracts).
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# APPENDIX A
## GLOSSARY OF ABBREVIATIONS AND TERMS

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<tr>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>ASPR</td>
<td>(USA) Armed Services Procurement Regulations</td>
</tr>
<tr>
<td>AU</td>
<td>Accounting Unit, value approx. = 1 ECU (1000 AU = 1 KAU; 1000 KAU = 1 MAU)</td>
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<tr>
<td>Ceiling price</td>
<td>The maximum price that is paid to the contractor under FPI contract conditions</td>
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<tr>
<td>CNES</td>
<td>Centre Nationale d’Etudes Spatiales (French national space agency)</td>
</tr>
<tr>
<td>CPAF</td>
<td>Cost-plus-award-fee (contract)</td>
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<tr>
<td>CPIF</td>
<td>Cost-plus-incentive-fee (contract)</td>
</tr>
<tr>
<td>CPFF</td>
<td>Cost-plus-fixed-fee (contract)</td>
</tr>
<tr>
<td>CPPF</td>
<td>Cost-plus-percentage-fee (contract)</td>
</tr>
<tr>
<td>DFVLR</td>
<td>Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (German national aerospace agency)</td>
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<tr>
<td>DOD</td>
<td>Department of Defense (of the USA)</td>
</tr>
<tr>
<td>ELDO</td>
<td>European Launcher Development Organisation (1964 - 1974)</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency, in operation since 1975, taking over previous ELDO and ESRO activities</td>
</tr>
<tr>
<td>ESRO</td>
<td>European Space Research Organisation (1964 - 1975)</td>
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<tr>
<td>FFP</td>
<td>Firm-fixed-price (contract)</td>
</tr>
<tr>
<td>FPE</td>
<td>Fixed-price-with-escalation (contract)</td>
</tr>
<tr>
<td>FPI</td>
<td>Fixed-price-incentive (contract)</td>
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<tr>
<td>LCC</td>
<td>Life-cycle costing: costing parameter used to evaluate influences of product lifetime</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean time between failures (in hours): most commonly used yardstick of reliability</td>
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<tr>
<td>Multiple incentives</td>
<td>Incentive provisions relating to delivery and/or performance in addition to cost incentives</td>
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<tr>
<td>Abbreviation</td>
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<tr>
<td>NASA (P.R.)</td>
<td>National Aeronautics and Space Administration (Procurement Regulations)</td>
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<tr>
<td>NASDA</td>
<td>National Space Development Agency (of Japan)</td>
</tr>
<tr>
<td>NIVR</td>
<td>Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Dutch national aerospace agency)</td>
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<tr>
<td>PERT</td>
<td>Program evaluation and review technique: a planning method/management tool</td>
</tr>
<tr>
<td>PIIM</td>
<td>Planned interdependency incentive method: specific multiple incentive (used in Gemini project)</td>
</tr>
<tr>
<td>POESMIC</td>
<td>Program Office for Evaluation and Structuring Multiple Incentive Contracts (centralised USA/DOD office)</td>
</tr>
<tr>
<td>PTA</td>
<td>Point of total assumption: point in FPI where sharing stops</td>
</tr>
<tr>
<td>RIE</td>
<td>Range of incentive effectiveness: band of costs over which incentive provisions are operative</td>
</tr>
<tr>
<td>RIW</td>
<td>Reliability improvement warranty: under these conditions, the contractor basically has to bear all repair and maintenance costs</td>
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<td>Sharing ratio (or formula)</td>
<td>The expression (normally in percentage terms) of the client's and contractor's cost-sharing arrangements</td>
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<tr>
<td>Target cost</td>
<td>The estimated cost accepted by both parties as a basis for sharing excess costs and savings</td>
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<td>Target fee</td>
<td>The fee payable if actual cost equals target cost</td>
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<tr>
<td>UAI</td>
<td>Uncertainty avoidance index</td>
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