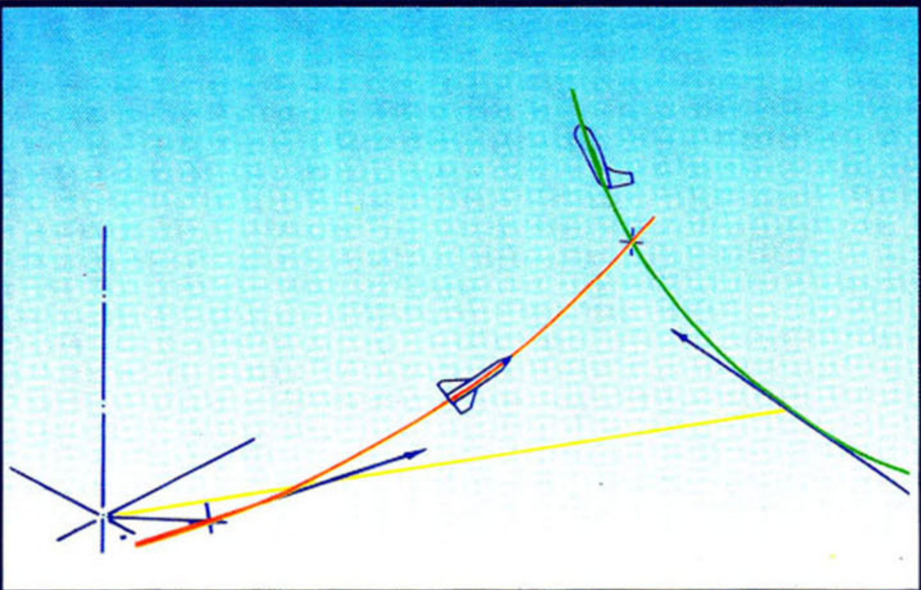
Guided Weapons System Design



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GUIDED WEAPONS SYSTEM DESIGN

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PREFACE

The genesis of this book has a long history. The story starts around December 1963, when the author was posted to the *Fourth Special Weapon's Course* at the *Institute of Armament Technology, Pune*. This was a course of studies on the design of guided weapons. One of the aspects of guided weapons that fascinated the author was the variety of configuration shapes and sizes that he noticed in every issue of *Jane's Weapons Systems*. How were these configuration shapes arrived at? What is the logic behind the choice of their shape? What were the design considerations for determining their shapes and sizes?

This fascination continued even after the author's transfer in 1965 to the Defence Research and Development Laboratory (DRDL) at Hyderabad. Those were the early days of development of guided weapons in India. Very little data for the design of guided weapons was available since most of the information pertaining to guided weapon systems was classified. The only set of declassified books pertaining to guided weapons that was freely available then, was the *Merril Series* of books on guided weapons. Naturally, this set of books formed the early source of information. However, as these books were based on the knowledge gained from the development of guided weapons during the Second World War, these books did not contain information on the later developments in this field. While, there were detailed discussions on the guidance policies and on the preliminary design of systems, they did not provide the logic for the choice of the configuration shape and size. The quest for finding answers to these questions therefore became the mission of the author, throughout his stay at DRDL.

The initial efforts at DRDL, during the first decade of its existence, were directed towards the design and development of a first generation, man-portable, wire-guided, anti-tank missile. Even though the system was a seemingly simple one, its design taught valuable lessons on the need for systems approach to weapon design. *This was a radical departure from the practices prevailing then.*

In the second decade of its establishment, DRDL set out to develop a long-range surface-to-air weapon system. Under this project, initially, the efforts were directed towards indigenous development of a foreign design. The technology of the electronics subsystems used in this foreign design was, however, no more current. The efforts involved in redesigning these subsystems using the state-of-art electronic devices was found to involve as high an effort as was needed to take on a new design altogether. It was soon realised, therefore, that this route was not worth pursuing.

At this stage, Government of India thought it essential to ascertain the capability of DRDL to take on *ab-initio* development of guided weapons. For this assessment, a committee headed by the late Dr Brahma Prakash visited the Laboratory. They had detailed interactions with scientists engaged in the development of each of the specialised subsystems of the guided weapons system.

During this period, the author was leading the Aerodynamics Division of the Aeronautics Group, which was then headed by Mr AV Ranga Rao, an eminent senior scientist. As part of the effort needed to prove our capabilities to take on *ab-initio* design, the systems study methodology for the design of the aerodynamic configuration for guided weapons was developed. This development was published in an internal report—*DRDL 031 100 6002 dated February 1975* — authored by AV Ranga Rao, R Balakrishnan and RN Agarwal. This report on *Aerodynamic Design* was the first serious attempt at DRDL for applying the systems study method to missile configuration design.

Soon thereafter, the author was made a specialist member of a study team formed at the Armament Research & Development Establishment (ARDE), Pune (one of the sister establishments under the DRDO) for the development of a *Kinetic Energy* gun-launched ammunition. As a member of this team, the author applied the systems study methodology for the design of the aerodynamic configuration for the *FSAPDS* ammunition. This approach enabled the author to identify the configuration characteristics that were essential for its design and to determine the admissible range in their values.

After the successful completion of this assignment, the author was nominated as a member of yet another study team at DRDL for the design of a low altitude, quick reaction time, short-range, surface-to-air guided weapon. The *French CROTALE* and the *British RAPIER* systems are two well-known representatives of this class of weapon.

As a member of this team, the author extended the systems study methodology to identify the essential *configuration characteristics* that were needed for its design, to meet the user's performance expectations in the weapon. The author was in for a pleasant surprise when he identified in the solution region thus found, the configuration characteristics of the CROTALE and the RAPIER systems also. The surprise was all the greater when one realised that CROTALE and RAPIER followed two different control philosophies. While CROTALE employed canard controls, the RAPIER system used a tail-controlled configuration. The systems study method was thus able to identify all the configuration solutions to the design problem. *The methodology could thus provide the key to the logic for the choice of the shape and size for the configuration.* The successes of the systems study methodology was thus an exhilarating experience for the author.

This finding formed subsequently the core of the author's doctoral thesis on the *Aerodynamic Configuration Design for Cruciform Missiles.* The Indian Institute of Technology at Madras, under their external registration scheme, in 1985 conferred on the author the *Doctorate* degree in *Aeronautical Engineering*, based on this thesis.

Before his retirement from DRDL in December 1993, the author completed yet another system study exercise on the design of a *shoulder fired missile*, aimed against low-flying targets. This study on the shoulder fired system was based on the application of the *proportional navigation policy* to guided weapon design. The earlier systems study exercise undertaken by the author to counter a low altitude threat was based on the application of the *Command Guided Policy* to missile design.

The successes of the systems study methodology for the design of guided weapon systems following two different guidance policies, indicated that the systems study method was the key to missile design. Further, it was soon realised that the applicability of the systems study method was not exclusive to guided weapon design alone but was applicable to almost all engineering designs. The author therefore felt that the utility of the systems study methodology to solve engineering design problems should be given wider publicity. With this in view, the author decided to engage himself in propagating this methodology, as part of his post-retirement plans.

At this juncture, three events occurred, almost in quick succession. The first was a request to the author from *DRDO*, in August 1994, to write a *Monograph on Guided Weapon Systems Design*. The second was an invitation in October 1994, from the Aerospace Department of the *Indian Institute of Science, Bangalore*, for delivering a series of six lectures on guided weapon design. There was yet another invitation from the Aerospace department of the *Indian Institute of Technology, Bombay*, to deliver a similar series of lectures on guided weapon design in February 1995. The author readily accepted all the three assignments, since the effort involved in these were complementing each other. He felt that the preparation for a lecture would be a welcome pre-requisite before one embarks on writing on the subject.

The author, therefore, set out to prepare the course material needed for the first series of lectures at the Indian Institute of Science. He then updated this material based on the feedback he received from the staff and the students of IISc. The revised notes formed the course material for the next series of lectures at the Indian Institute of Technology, Bombay. With further feedback from the staff and students of IIT, he revised the notes once again, and these formed the basis for this monograph. Subsequently, on completion of the first draft of the monograph, at the author's request, *Lt. General (Dr.) VJ Sundaram, Director, DRDL,* organised a review of the monograph by a team of scientists from DRDL. The review was chaired by *Mr Ranga Rao*, who is one of the Indian pioneers in the field of guided weapon design. The suggestions offered by the review team have been incorporated in the final monograph.

This monograph is, therefore, a record of almost all the efforts put in by the author in his quest to find the logic for the shape and size of the configurations for guided weapons.

The author would like to thank all the scientists with whom he had interacted at DRDL during his quest for the answer to the configuration design problem. In particular, the author would like to thank *Mr K Anandha Narayanan*, a young scientist of DRDL who developed the computer simulation programmes which are needed for validating the results presented in this monograph. The author would also like to thank all the students and staff of IISc Bangalore and IIT, Bombay, who helped him finalise the sequence of presentation. Last but by no mean the least, he wishes to thank *Lt. General Sundaram*, for organising the review of the draft monograph before it could be finalised. The author would like to thank, in particular, *Mr Ranga Rao* and the review team for the valuable comments they offered during the review.

The author wishes to thank *Dr APJ Abdul Kalam* who, as the head of the DRDO, encouraged him to write this monograph on systems study of guided weapons. The author would also like to thank him for writing the foreword for this monograph. He would like to thank *Director, DESIDOC* also, through whose office, the necessary support for this effort was canalised by DRDO.

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November 1996

CHAPTER 1

INTRODUCTION

One finds an amazing variety of missile configuration shapes listed in every issue of Janes Weapon System. While some are delta-wing configurations, others are either trapezoidal-wing configurations or rectangular-wing configurations. Some have cylindrical bodies with hemispherical noses, while others have either ogival or conical forebodies. Likewise, one finds variations in the type of control systems employed—canard-controlled configurations and tail-controlled configurations—while a few are just thrust vector-controlled configurations. Even in missiles of the same class, one finds variations both in their external shape and in the type of control system employed. Consider, for example, the class of low-altitude surface-to-air missile systems represented by the French CROTALE, the British RAPIER and the Euro-Missile Consortium's ROLAND. Where CROTALE uses canard controls, RAPIER employs tail controls and ROLAND is a thrust vector- controlled configuration. The configurations of these missiles have been drawn to the same diameter as reference, though their diameters differ in magnitude (Fig. 1.1). Seeing such a diversity in their configuration (though these are designed to meet an almost identical mission requirement), one wonders on what basis these configuration shapes have been arrived at. Surely, these have not been stumbled upon by chance! Is there a logic for arriving at these diverse configuration shapes to meet an identical mission requirement?

Missile design is a time-consuming and expensive venture. The user is also a very demanding customer who would like to be assured at every stage of its design, that the design was based on sound logic. There was, therefore, a very high probability of the design meeting his requirements. Considering such a premise, it is reasonable to presume that every configuration variation listed in Jane's must have been evolved after considerable deliberation and could not have been arrived at by chance. By the same token, it is logical to expect that there can be many other configuration solutions also that would have met the user's expectations equally well. If so, how can one identify these solutions and what are the reasons for discarding them in preference to those that are listed in Jane's?

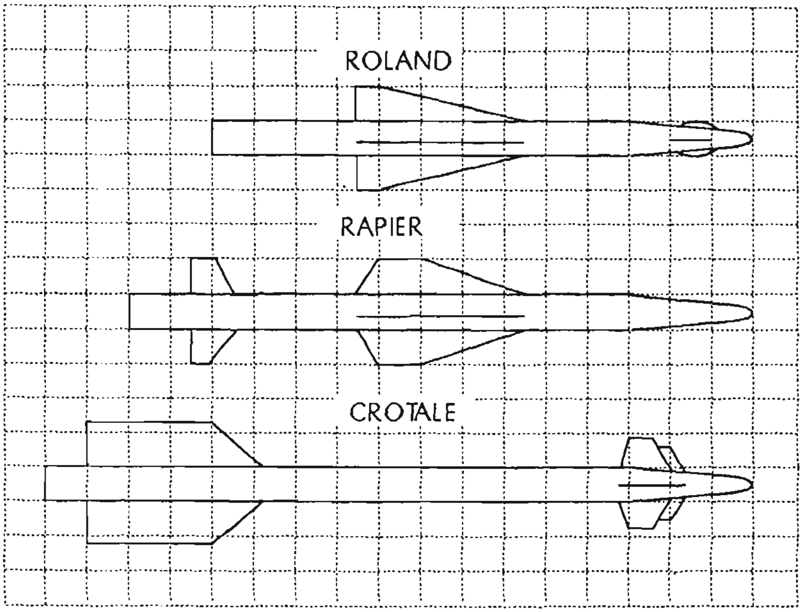

Figure 1-1. Comparison of CROTALE, RAPIER and ROLAND

Some of these questions are proposed to be answered in the subsequent chapters.

The author has not come across any reference in the published literature dealing with the methods for missile configuration design. At the same time, it is improbable that a vacuum exists in this area. Perhaps, the information on missile design is classified and, therefore, its availability could be severely restricted. What is presented in the following chapters, therefore, is a method developed by the author[1] after many years of patient search for the Rosetta Stone for unlocking the secret of missile design. Having developed the method, in hindsight, it appears that the method is not something peculiar to missile design alone, but is universally applicable to all engineering designs. Therefore, there is no need to be secretive about it at all, in the first place.

1.1 ENGINEERING DESIGN

According to Dixon[2], the objective of engineering design is to help one develop skill in applying what one has learnt in science and other engineering courses, for finding solutions to practical engineering problems. The objective of the courses in engineering design, therefore, is to help use purposefully and effectively what one has already learnt in the various branches of engineering.

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