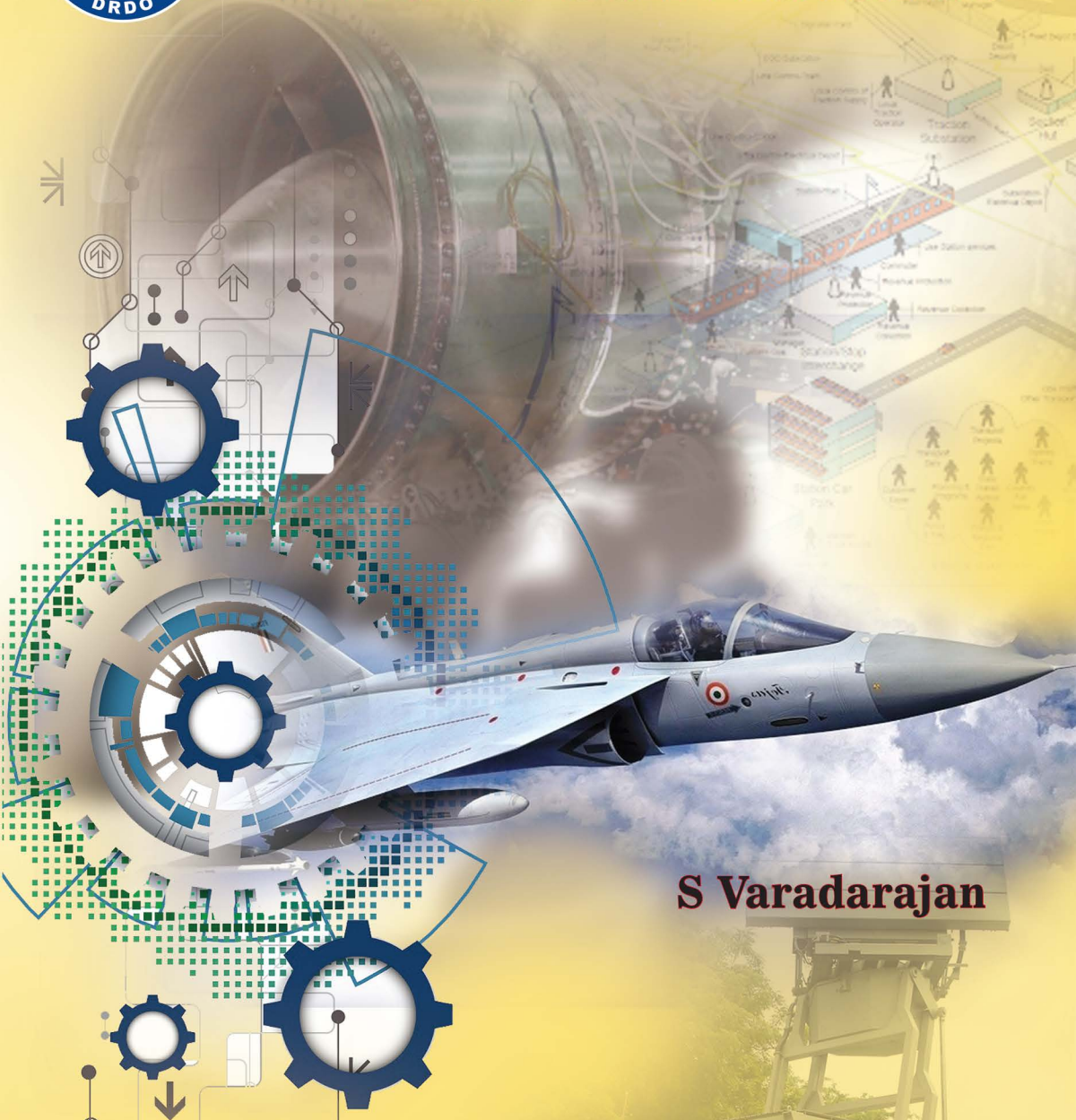
Systems Engineering Towards Self-Reliance



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Defence Research & Development Organisation
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2021

DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES

SYSTEMS ENGINEERING TOWARDS SELF-RELIANCE

Sengottaiyan Varadarajan

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Varadarajan, Sengottaiyan

Systems Engineering Towards Self-Reliance

DRDO Monographs/Special Publications Series

1. Defence Systems 2. System Engineering 3. Virtualizations
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I. Title II. Series

62-9:355/359

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ISBN 978-81-86514-77-1

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Cover Design	*Printing*	*Marketing*
Rajesh Kumar	SK Gupta	Tapesh Sinha

Published by Director, DESIDOC, Metcalfe House, Delhi – 110 054.

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Preface

It was indeed a pleasant surprise and a proud moment when I received the information from the DRDO Head Quarters to be the author of 'Systems Engineering' monograph. The surprise was that I had been handpicked to write on such a versatile topic overlooking many other stalwarts, who had proved their mettle in number of complex programs. It is a known fact, that my association all along had been withthe development of various indigenous radar systems. In addition, I had the fortune of getting associated with many DRDO programs where radars were the key system elements, through which I could learn many aspects of the systems engineering. Therefore, I had gracefully accepted to perform the task with due dignity and honour. I sincerely express my heartfelt thanks to the Chairman and members of the monographs committee of DRDO.

It is a well-accepted policy, that for attaining national prosperity by maintaining the territorial integrity and peace at the borders, the country must be militarily agile, strong and mighty in tune with the vision of the political leadership. It is worth to note that country shares large chunk of borders among most inhospitable terrains, including high altitude, mountainous and low temperature regions. Ours is the only country where critical border areas with primitive infrastructure, cover the coldest regions drawing special attention of the security planners. Hence, systems to be deployed in those difficult regions call for customised engineering features. For the country to be self-sufficient there is no alternative other than, indigenous design development and manufacture of military systems. Significant maturity and advancements attained in the areas such as information technology, modern manufacturing techniques, increased private entrepreneurship are some of the key enablers to achieve the dreams of indigenous realisation of contemporary defence systems.

Military system development through indigenous route had undergone tremendous changes especially during the last three decades. There had been steady increase of success stories, which are essentially due to the synergy between the customer, developer and the manufacturer. Increasing participation of the private entrepreneurs augurs well to meet the challenges of global level competition. Successive Defence Systems Procurement Policies (DPPs) framed by the Government increasingly prefer the 'make' over 'buy' options. Thus,the policies truly reflect the 'Make in India' commitment of the state. Thrust given to make the country 'self-reliant' in the critical areas of defence systems, augurs well with the increasing awareness of systems engineering practices.

The main cause of such transformation in new system development is through the 'institutional learning'. This is evidenced by the fact, all stake holders had learnt over the past, whether success or failure. In fact, a failure had delivered more impact than even a success. This monograph is perhaps an attempt to count on such experience to emphasise the importance of systems engineering applicable at various phases of system life cycle.

The case studies have been brought out, mainly from the radar development phases. In addition to the radar related programs, certain specific instances of the systems engineering applications have been brought out from apex programs such as AEW&C, IGMDP, LCA, etc. While the impact of system engineering practices which were adopted were discussed, certain issues which arose out of the lack of system engineering principles were also brought out. The idea is to drive home the impact of system engineering practices during system development.

The monograph unambiguously brings out the steps towards inviting bids either for acquisition or proposals for new system development. It dwells on the homework for justification of any new system and the acquisition mode. System acquisition process must be adequately supported by the systems engineering expertise. When technology intensive, complex defence systems are to be acquired, best practices of systems engineering, related to the concept exploration must be followed in letter and spirit.

The amount of initial system study, analysis pursued by assigned groups formed out of multiple agencies have paid rich dividends in arriving at the most appropriate system level requirements. Pre-sanction activities if systematically adhered can set the correct course and result into the appropriate and optimum project appraisals. Draft Systems Engineering

Management Plan (SEMP), carried out seriously at early stages, should convince the decision makers and all stake holders.

The monograph addresses the technology assessment and management which are essential to survive in any competitive environment. Risk management is also addressed then and there in a generic manner. Benefit of state-of-the art system realisation within the cost and schedule only can establish the much needed customer satisfaction. System integration, test and evaluation are another important stage for the systems engineering application. Upfront planning of personnel, training, establishmentof test infrastructure have taken centre stage during the development of complex systems. Formal systems oriented approach while planning and execution becomes essential for smooth progress. Commonly occurring time and cost overruns and schedule slippages can be addressed through these planned exercises.

Special emphasis has been given in the areas of software systems engineering and concurrent engineering, both of which advocate the integrated design approach. Since software contents in the defence systems are ever increasing, system-oriented software design and development attains importance to achieve optimum system performance. Abundantly available talent in the development of embedded real-time software within the country can enable the supply software controlled system elements which is essential for several mission critical systems. Similarly, concurrent engineering addresses the issues arising during manufacturing and post development phases, at the design phase itself. Therefore, rapidly advancing domestic infrastructure and availability of huge amount of trained human resources can help to make the country to be not only self-reliant but also the potential exporter of validated defence systems in future. To realise, world class defence systems at competitive cost, systems engineering will be playing the key role.

It is strongly believed that this monograph can be a capsule which can be prescribed to those engaged in the areas of defence system acquisition, design, development, production, evaluation, technical auditing, commissioning, operation and maintenance. It stresses more on the lateral thinking which is gaining importance. Those engaged in project management often face the challenge of adopting and management of emerging technology. The monograph attempts to formalise the solution. Close co-ordination between the project management and systems engineering is dwelt which

perhaps should clear the confusion on account theoverlapping roles. Proper understanding should bring in greater harmony amongst the Project management and systems engineering related personnel.

Finally, the monograph had greatly helped in 'unwinding' the author's experience lasting over nearly three and a half decades. It is strongly believed and expected that this monograph can perturb the minds of the younger generation towards seeking holistic and systematic process towards achieving self-reliance in defence systems.

Jai Hind!

July 24, 2020
Bengaluru

Sengottaiyan Varadarajan

Acknowledgements

I am ever grateful to Ms J Manjula, Director General, Electronics and Communication of DRDO who could patiently go through the entire monograph and offer valuable suggestions to improve the monograph quality. I thank her for her encouraging remarks while according the necessary clearance and approval for the publication.

I would like to thank Shri SS Nagaraj, Former Director and Shri P Radhakrishna, Director, Electronics and Radar Development Establishment (LRDE), DRDO, Bengaluru for extending the required help towards the preparation of the manuscript. I also acknowledge the help rendered by Dr A Vengadarajan, S/Shri Justin Sagayaraj and Vinod Alphonse, Scientists of LRDE, Bengaluru towards sharing the material on systems engineering tools.

I express my gratitude to Dr K Soundararajan, former Senior Scientist of Aeronautical Development Establishment, Bengaluru for offering suggestions and reference material. I am indebted to S/Shri Ramachandra Kuloor and KR Narayanaswamy who had reviewed the material and offered useful suggestions.

The material covered in the monograph along with the case studies relate to my three and half decade service at LRDE. I had the fortune of getting associated with large number of Scientists and staff and substantial portion relate to the systems engineering practices adopted at LRDE. I am ever indebted to my colleagues of LRDE from whom I learnt many lessons throughout my career. I express my sincere thanks to all those with whom I had pleasant interactions.

I thank Shri Chandra Sekaran of LRDE who helped me in formatting and adding figures in the manuscript.

I am thankful to my son VG Vidyashankar and wife Mrs Bhanumathy who constantly encouraged me towards completing the monograph.

I sincerely express my heartfelt thanks to the successive DESIDOC Directors, and Ms Alka Bansal and Ms Kavita with whom I had constant interactions and received their continued support leading to the successful completion of this monograph.

CHAPTER 1

Growing Importance of Systems Engineering

1.1 UNIQUENESS OF MODERN DEFENCE SYSTEMS

Modern Defence Systems are becoming more and more complex. Acquisition of Defence Systems has gone through massive transformation. The acquisition assumes greater significance in the fast changing global scenario. Armed forces have to plan meticulously and execute the process in a time bound manner. Threat perceptions are changing. Services are getting aware of customised solutions vis-a-vis ready made solutions. Aspirations to possess cutting edge, state of the art weapon systems is a genuine right of services. Defence systems at any point of time must address the agile requirements. Seamless integration, net centric operation, operation at hostile terrains, fast changing technology, changing geo-political situations in the neighborhood, etc., pose challenges in acquisitions, upgrading existing systems and phasing out of obsolete systems.

As per the global trend, defense spending as a fraction of the gross domestic product is gradually shrinking. Notwithstanding the security threat perceptions, the Government is compelled to cut funds for capital acquisitions. With the globalisation, the economic policies of the Government are under close scrutiny. These factors compel the acquisition of defence systems at affordable rates.

Hitherto acquisition of modern weapon systems often suffered huge time and cost overruns. Even in advanced nations, it has been reported that there is generally huge delays and budget constraints. Affordability has been a major factor in the defence acquisitions. Defence systems are something peculiar in the sense the customer is identified and unique. Quite often the requirements are not fully defined. Ill defined requirements, immature

technology, changing Government priorities, long phases involved in development and validation make the defence systems a distinct class of items needing special attention. Of late international collaborations have to be resorted to bridge the technological gap.

Operation of defence systems also often confronted with environmental related issues. Carbon emissions, climate change, sharing of precious resources such as electromagnetic spectrum are some of the constraints in which the systems will have to co-operate.

Defence systems generally assume complexity because of incomplete/ incompatible requirements, fast changing threat scenario and exploding technology. Clarity and priority amongst the operational requirements can be vague leading to misinterpretations by developers. Lack of required co-ordination amongst the stake holders, namely the customers,developer,sponsors and suppliers/vendors pose real challenges towards the 'right system' acquisition.

Modern day defence systems are expected to have life span extending a few decades. Classic examples are: fighter aircrafts, sensors, combat vehicles, airborne surveillance platforms, etc. System complexity gets further stretched for inter-operability, net-centric operation, and open system interconnect. They are required to have high degree of availability, with extremely low downtime. Interaction with humans and smart operation, agility with changing environments can be some of the formidable challenges.

System of systems is another emerging area. Quite often the systems need to be integrated with partially developed, yet to be developed group of autononomous but interdependent systems. Interoperability amongst systems of different origin, different vintage call for well thought out process for integration to get the maximum value. Acquisition process of such systems can be demanding and calls detailed analysis/simulation, etc.

Unlike the past civil applications of modern technology is fast expanding. In fact, adaption of civilian nurtured products and processes can greatly benefit military systems especially to have faster turnaround at affordable cost. Hence careful usage of Commercially Off the Shelf (COTS) technology is becoming more and more important. Similarly, reusable technology and products will reduce the acquisition time.

While the armed forces have their own mechanism of system study and analysis groups, quite often the teams are handicapped with the structured

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About the Monograph

This monograph describes the best systems engineering practices during the development of any complex system in general and defence system in particular. It addresses practical issues towards new product development leveraging contemporary technology. Staying competitive and satisfying the customer are the main themes. The case studies are brought out of real systems developed successfully for the Armed Forces. It stresses on the holistic view of any system in its totality, lateral thinking by the stake holders with wider perspective for the successful system acquisition. The simplified treatment should enable the user, acquisition, development, inspection, manufacturing and field deploying agencies to exploit the past experience and be successful in highly demanding circumstances. It is certain that the monograph can be a good companion to those young professionals dealing with the development and production of military systems.

About the Author

Shri Sengottaiyan Varadarajan holds BE(Honours) in Electronics and Communication from Madurai University and ME in Electrical Communication Engineering from the Indian Institute of Science, Bengaluru. He served nearly three and half decades as Radar Scientist at the Electronics and Radar Development Establishment (LRDE), Bengaluru. He played a key role towards the induction of the INDRA-II radar through which he learnt the mind of the customer. He then led the successful development of the man-portable Battlefield Surveillance Radar-Short Range (BFSR-SR). As Director of LRDE, several Radar systems such as the 3D Surveillance Radars (Rohini, Revathy, 3D TCR), Low Level Light Weight Radars (Bharani and Ashlesha), Electronically Scanned Phased Array Radars (Rajendra, Weapon Locating Radar/Swathi) have been successfully developed and delivered to the Armed Forces. He initiated Rotating Electronically Scanning Active Array Radars (Arudhra, Ashwini, AD TCR) with close interaction with the users. Adherence of systems engineering and concurrent engineering principles could yield total customer satisfaction resulting in repeat orders for most of the radar deliveries. Till date orders close to 10,000 crores have been placed by the three services. These radars, meeting more than the customer requirements have far excelled in performance than the imported ones.

The author is a fellow of the Indian National Academy of Engineering (INAE) and the Institution of Electronics and Telecommunication Engineering (IETE). He is recipient of several awards such as the DRDO Scientist of the Year, Technology Leadership award, Agni award for self reliance and IETE-IRSI (83) award. He served as advisor to M/s Bharat Electronics Ltd and is an adjunct faculty of the Defence Institute of Advanced Technology (DIAT), Pune.

978-81-86514-77-1

Price: INR ₹ 1700
US $ 45
UK £ 40

Defence Scientific Information & Documentation Centre
Defence Research & Development Organisation
Ministry of Defence, Metcalfe House, Delhi - 110 054, India