Unmanned Aircraft Systems

A Global View

Defence Research &
Development Organisation
Ministry of Defence, India

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Preface

The book is specially meant for systems engineers who are required to have a global view of the unmanned aircraft vehicles (UAV) system top down so that they do not miss any requirement while defining the system.

Systems engineers are specialists engaged in the design and development of multidisciplinary and integrated systems (systems engineering). Assistance is taken from all disciplinary specialists in translating the needs of a system into a system definition that will meet the requirements. Hence, this book is thus designed to cover a wide spectrum of disciplines that need to be understood. I have read extensively and collected suitable literature on the subject and compiled what I felt a system engineer should know. I hope that it is also useful to several others who want to kow about UAS.

Comprising of 11 chapters, the monograph is segmented into four parts. Part I: General comprises four chapters that are generic in nature introducing Unmanned Aircraft Systems (UAS). The second part deals with Systems Engineering and UAVs. The third part deals with Knowledge Gained through Research and Development and fourth part focusing on the State-of-Art and Way Ahead.

Part I has four chapters. First chapter is an introduction to UAS. Second chapter is an attempt to compare the complexities of design and development of manned aircraft, missiles and unmanned aircraft systems. Third chapter looks at different UAV concepts. Fourth chapter discusses several UAV systems both Indian and foreign.

Part II has five chapters. This part covers important issues with UAV design and development. Chapter five is on the philosophy of certification of UAVs. Chapter six is about the operational issues of UAS. Chapter seven is about UAS, systems engineering and aircraft design education. Chapter eight discusses the life cycle of a UAV. Chapter nine is an attempt to apply systems engineering process to a UAS concept against a need statement.

Part III deals with lessons learnt. It is knowledge gained by Aeronautical Development Establishment, Bangaluru in the field of UAS. It is hoped that it will be immensely useful to other UAV designers and developers.

Part IV is a review of the state-of-the-art. This chapter should be useful to specific domain specialists also. It is meant to aid a domain specialist to learn about the state-of-art in other disciplines.

The monograph is supported by extensive references, which enables any reader to locate and retrieve the parent paper and gain more knowhow about the topic.

Bangaluru J Jayaraman

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It is not a single person's effort to write a book of this nature. Many have contributed to it through their work at Aeronautical Development Establishment (ADE), Bangaluru and elsewhere. I have read and compiled what I felt is important. First and foremost, I am grateful to ADE which gave me the opportunity to work on several projects. I am also grateful to the previous and the present Directors, Shri SK Jindal, Director, DESIDOC and Shri PS Krishnan, Director, ADE for having chosen me to write this book. It has kept me busy for the last 18 months. Apart from me, many others have also contributed in some form or the other and I place on record their support and contribution.

Dr KG Narayanan, the then Director in ADE gave me the opportunity to lead a fine team of scientists, engineers and technicians in Lakshya, Pilotless Target Aircraft project. I learnt a lot from him and the Lakshya team. He has given me considerable moral support and guidance while writing this book. Shri G Natarajan has gone through the complete manuscript and suggested several corrections and modifications to improve this book. Shri K Sundar Rajan of Knowledge Centre, a true information scientist who has provided me several papers I had required and suggested several more that he thought will be of use to me. Shri K Selvaraj supported by checking aerodynamic portions and suggesting improvements. Shri Sathya Moorthy performed FEM analysis. Shri Sateesh Kumar of NC Centre helped with the cost and time estimates for machining.

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I would be failing in my duties if I do not acknowledge the support of my family especially, Usha, my wife, Karthik my son, and Sakshi and Surabhi my grand daughters specially for allowing me use the laptop. They had to put up with my odd working hours. My son was my consultant for solving word processing problems. Shri SN Girish of Cocoon Creatives Ltd got more than 50 line sketches of flight vehicles made within a very short time at a very low cost.

Chapter 1

Global Unmanned Aircraft System

1.1 UNINHABITED AIR VEHICLE – A REVIEW

UAV stands for uninhabited air vehicle. The potential of UAVs was recognised by military and has been exploited over the years. Today, UAVs have become an essential arm of the Armed Forces all over the world. It is a force multiplier. In military terminology, it means that the powers of both the material and personnel are improved without increasing either. Synergy between the two increases the effectiveness of the system to be greater than the sum of its parts. When UAVs are added to a force, effectiveness of the force is increased considerably by a factor greater than one, which may be as high as 4 to 5, when compared to the effectiveness of the force without UAVs. Besides their military applications, UAVs have moved over to several useful civil applications and the field of education and research.

1.2 RATIONALE FOR THE USE OF UAVs IN MILITARY

Manned aircraft operations face highly lethal enemy air defences, thus they experience high attrition rates of both men and machines (losses in pilots and aircrafts because of enemy action). The cost of training the pilots and ground crew are exorbitant. The time required for training competent pilots is also very long. Pilots with combat experience have become a diminishing entity due to causalities during war. Causalities result in serious damage to sustaining the war effort. Manned fighters normally spend 95 per cent of their flight life in training sorties. It adds considerably to the training costs. Such problems are not faced by unmanned aircraft operations.

UAVs have the ability to loiter over a target for long periods of time to gather intelligence, surveillance, and reconnaissance (ISR) data. At the same time, they can use the opportunity to strike an enemy target. UAVs are fearless as the pilot is sitting in the comforts of his control station piloting the aircraft. Also, in the event of failure and crash, it does not leave any tell-tale evidence as the pilot cannot be captured as in the case of capture of Gary Powers during one of the U-2 reconnaissance flights over Russia, in May 1960. It is extremely suitable for dull, dirty, dangerous, demanding, and different missions.

- Dull missions are long endurance missions. These are very monotonous, for example; maritime reconnaissance sortie and oil pipe line surveying could last for 18–20 h.

- Dirty missions are those where threats of biological and chemical contaminations are too high for a manned aircraft flight.
- Dangerous missions are the combat missions. These could also be forest fire fighting, flying into hurricane, lightning, chasing tornadoes and gathering data, nuclear fallout sampling measurement, and gas leak mapping, e.g., Bhopal gas tragedy.
- Demanding missions place high demands, high endurance or high 'gs' on the crew.
- Different missions mean those missions that are not feasible for manned aircraft. Some of the mini and micro UAVs can be hand-launched. These can provide quick intelligence for soldiers on the battle field that is not feasible for manned aircraft. Some of the UAVs integrate 'find, fix, finish' sensor and strike capabilities into one platform.

1.3 GENERAL

UAVs have been in use, especially in military applications, for over four decades. Several non-military applications have also been demonstrated and used extensively during this period. Now, it could be said that UAV technology has reached some stage of maturity. But this technology is still evolving and making enormous strides to achieve higher capabilities. One is attempting to give it considerable onboard intelligence. During the periods of strikes by airline pilots, the joke floating around was 'civil airlines would have no pilots onboard, but to give confidence to the passengers, a person would be seated in the pilot's seat. A dog would be by his side. Its job would be to bite the person in the pilot's seat if one was to meddle with the controls of the aircraft'. Thus, unmanned civil passenger aircraft was seen to be a solution to get over the pilot's strike problem.

The following are the advantages of UAVs over manned aircraft:

- It has the ability to loiter over a target for long periods of time to gather intelligence, surveillance, and reconnaissance data.
- Space and weight savings result in reduced size and weight due to the absence of the pilot-onboard and related support equipment such as pilot seat, display systems, pilot control actuation system, airconditioning of the pilots cabins, etc. Thereby, a cost reduction also results.
- Design freedom results to locate airframe components without the constraint of pilot-specific equipment placement.
- Less expenditure is incurred due to operations and training, resulting in lower life cycle costs.
- Due to its smaller size, the vulnerability both in the air and on the ground is reduced.
- It is most suitable for Kamikaze (suicide) missions.
- It is suitable for very long endurance missions as the pilot is very comfortably seated at ground control station. Here, the duties of pilots can be rotated suitably to minimise fatigue and increase their effectiveness, whereas in long-endurance manned aircraft, the number of pilots onboard has to be limited and may not be more than two or three.
- Pilot is not lost in the event of a crash or an enemy hit.

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About the Book

This monograph provides a bird's-eye view of the complex technology of Unmanned Aerial Vehicles (UAVs). It is targeted towards a wider audience that includes, beginners who need an introduction to the subject; practicing specialist engineers who need to learn about other disciplines; and programme managers, bureaucrats, planners and policy makers who would like to get a holistic picture of the UAV technology. It provides an approach to the system engineering methodology for the initial sizing of an UAV.

A very informative chapter on the lesson learnt provides practicing engineers a glimpse of real life problems. The book discusses several issues relating to the operation of UAVs. An exhaustive compilation of references is provided with every chapter to explore the depth when desired.

About the Author

Shri J Jayaraman is a well-known engineer scientist from Aeronautical Development Establishment (ADE), Bangaluru. He has over four decades of work experience in the development of indigenous aeronautical systems. A mechanical engineer by training, Shri Jayaraman provided mechanical and airframe design support to several UAV projects as a lead mechanical designer. He led the Project team Lakshya culminating in successful Inter Services User Evaluation and subsequent induction into Indian Air Force. He was also the Group Director for all UAV projects of ADE. He is the fellow of Indian National Academy of Engineering, Institution of Engineers (India) and Aeronautical Society of India. He is a recipient of a number of awards including DRDO Performance Excellence Award for Development of PTA, DRDO Scientist of the Year and Dr Ghatge Design Award from Aeronautical Society of India. His current focus is on Systems Engineering.

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