Executive Summary

Abhishek
Associate Professor, Department of Aerospace Engineering, IIT Kanpur

1. Title of the Project: Prototype building and field trials and commercialization of the following: i) Rotary Wing UAV of 5 kg and 10 kg payload capacity, ii) High efficiency Vertical Axis Wind Turbine (VAWT) and (iii) Hybrid multirotor UAV
2. Date of Start of the Project: April 1, 2018
3. Aims and Objectives:

   The overall broad objective was to explore the various technologies being developed in the area of Unmanned Aerial Systems and VAWT wind turbine for commercialization and are being listed below:

   a. Rotary Wing Unmanned Aerial Vehicle (UAV) Ruggedization and field trials for commercialization
   b. Hybrid Multirotor Vertical Take-Off and Landing (VTOL) Unmanned Aerial System (UAS)
   c. Small wind turbines for standalone household application

4. Significant achievements (not more than 500 words to include List of patents, publications, prototype, deployment etc)

   Publications:

   - Chipade, V., Abhishek, Mangal, K. and Chaudhari, R., "Systematic design methodology for development and flight testing of a variable pitch quadrotor biplane VTOL UAV for payload delivery," Mechatronics, Vol. 55, Nov. 2018, pp. 94-114.
   - Swarnkar, S., Parwana, H., Kothari, M., and Abhishek" Biplane-Quadrotor Tail-Sitter UAV: Flight Dynamics and Control," Journal of Guidance, Control and Dynamics Vol. 41, No. 5, May 2018, pp. 1049-1067. doi: 10.2514/1.G003201.
   - Bhargavapuri, M., Sahoo, S. R., Kothari, M., and Abhishek, "Robust Attitude Tracking in the Presence of Parameter Uncertainty for a Variable Pitch

Quadrotor", Proceedings of 2018 American Control Conference, Milwaukee, USA, June 27–29, 2018.

- Setu, S., **Abhishek**, and Venkatesan, C., "Time-domain System Identification of Small Helicopters Using Nonlinear Acceleration and Jerk Prediction Model," Journal of Aircraft, Vol. 56, No. 3, May 2019. doi: 10.2514/1.C035273
- Bhargavapuri, M. T., Sahoo, S. R., Kothari, M., and **Abhishek**, "Robust Nonlinear Control of a Variable-Pitch Quadrotor with the Flip Maneuver", Control Engineering Practice, Vol. 87, June 2019, pp. 26-42. doi.: 10.1016/j.conengprac.2019.03.012.
- Dhiman, K. K., Kothari, M., and **Abhishek**, "Autonomous Load Control and Transportation Using Multiple Quadrotors", Journal of Aerospace Information Systems, Vol. 17, No. 8, August 2020. doi: 10.2514/1.I010787
- Raj, N., Banavar, R. N., **Abhishek**, and Kothari, M., "Attitude Control of a Novel Tailsitter: Swiveling Biplane-Quadrotor", Journal of Guidance Control and Dynamics, Vol. 43, No. 3, March 2020, doi.: 10.2514/1.G004697
- Raj, N., Simha, A., Kothari, M., **Abhishek** and Banavar, R. N., "Iterative Learning based feedforward control for Transition of a Biplane-Quadrotor Tailsitter UAS", accepted for presentation and publication in 2020 International Conference on Robotics and Automation (ICRA), May 31 - June 4, 2020, Paris, France.
- Raj, N., Banavar, R. N., **Abhishek**, and Kothari, M., "Robust Attitude Tracking Control of Aerobatic Helicopter: A Geometric Approach", in IEEE Transactions on Control Systems Technology, Vol. 29, No. 1, Jan. 2021, doi.: 10.1109/TCST.2020.2969124
- Dhiman, K. K., Abhishek and Kothari, M., "Flight Dynamics and Control of an Unmanned Helicopter with Underslung Double Pendulum," accepted in Journal of Aircraft.

Patents:

- Patent: Balaji, N. N., Kothari, M. and Abhishek, "System and Method for Estimation of Yaw Angle for Mobile Objects," Application No.: 201911048789, Dated: 28/11/2019
- Dalal, K. D., Abhishek and Venkatesh, K. S., "Real-time Spherical Omnidirectional Visual Gyroscope", Patent Application No.: 202011057504, Dated: 08/01/2020.

Prototype Development and Deployment:

- Development of Unmanned Helicopter with high endurance capability was completed and demonstrated to Indian Army during a trial at Mhow for possible application for surveillance with more than 15 km range of operation.
- Biplane Tailsitter drone with payload delivery capability was fully developed and "sold" to a private company (through startup) for mid mile delivery application.

5. Concluding remarks

The funding support through this fellowship has been a tremendous help in enabling completion of development of two products in UAV domain, namely Unmanned Helicopter and Biplane Tailsitter UAV. A startup with name EndureAir Systems Pvt. Ltd. has been established to market these products for wide range of civilian and defense applications.