High Endurance, Micro Aerial Surveillance and Reconnaisance Robot

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***Abstract*— Remotely Piloted Vehicles (RPVs) or Drones have been the De facto terminology to describe Unmanned Aerial Vehicles (UAVs) used for Intelligence, Surveillance and Reconnaissance (ISR) operations for defense services. However their limitations are spotlighted by the fact that today's UAVs/RPVs are not capable of long-endurance operations for "closed-quarter" ISR. Their size and dynamics constraints limit their application to high altitude, fixed-wing flight based operations. On the other hand, rapid growth in the research and development of Micro Aerial Vehicles (MAVs) with VTOL / hovering capabilities have gained significant importance in ISR operations in urban/unstructured environments. Nonetheless, present day hover capable MAVs have not overcome their impediment of energy deficiency in design and actuation, resulting in very short and unproductive flight times. Flapping wings offer the most potential for miniaturization and maneuverability, but are currently far inferior to fixed wing and rotary wing MAVs. As we go smaller in size, the limitations of fixed and rotary wing technologies become apparent; the Reynolds number decreases with smaller wing surfaces resulting in decrease in efficiency and eventual aerodynamic failure. However at low Reynolds numbers, insects and birds have shown promising results. The paper presents the conception, design and development road map towards a Quad Winged Biologically Inspired Robotic Aerial Surveillance System. The strength of the system lies in its unique design and actuation mechanisms tailored towards higher endurance flight missions requiring hovering and VTOL capabilities in Micro Aerial Robots.**

OBJECTIVE of the Work: This paper spotlights our efforts in the direction of high-endurance, energy-efficient MAVs to address the flight time limitations of present day Micro flyers. We present the design, actuation, control, aerodynamics and avionics geared towards the development of an energy-efficient, Micro Robotic Aerial Surveillance System. The core objective is to engineer mechanical, electrical and aerodynamic systems to enable long flight times on Micro Robotic Aerial Vehicles (MiRAVs). The potential applications for such a high endurance vehicle are numerous, including air-deployable mass surveillance in cluster and swarm formations. The disposability of the vehicle would help in battlefield deployment as well, where such a MAV would be made available to soldiers for proximity sensing and threat level assessment. Other applications would include search and rescue operations and civilian law-enforcement.

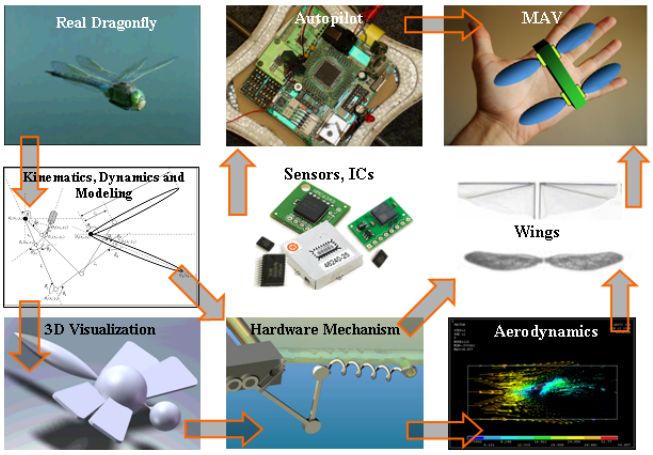

Fig. 1. Program Objective and Implementation Flowchart

RESULTS and their Significance: The MAV developmental plan includes parallel research and development of various software/hardware modules (Fig. 1). We present the results and significance of each of those modules towards improving flight endurance and mission deployment of MAVs:

1. We illustrate how a Quad Winged MAV (QV) design is capable of producing 6DoF Flight Maneuvers using four identical actuators employing the same controller for each; conventionally 6DoF flight has been obtained through the use of diverse actuators with varying control signals for each. Additionally, we illustrate Energy-Savings of a four-winged QV design over a two-winged conventional MAV.

2. Further, we unveil Fixed Frequency, Variable Amplitude (FiFVA) actuation mechanisms utilizing passive elastic elements to produce resonant flapping of wings. The use of elastic elements is demonstrated to produce significant energy savings in actuation. In particular, two novel FiFVA actuation mechanisms have been presented to meet the resonant flapping goal for the QV system.

3. MAVs operate in a very sensitive Reynolds number regime; wherein aerodynamic flow physics exhibits strong variance from conventional steady aerodynamics effects seen over the wings of fixed and rotary wing MAVs. The aerodynamics performance of custom wing designs is demonstrated. The indigenous wings demonstrate unique flapping and feathering characteristics towards improving both lift production and aerodynamic efficiency.

4. The complete avionics suite, architectured towards Surveillance and Reconnaisance operations, has been devel-

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oped for the QV. We describe the individual components which have been customized for small form-factor and low power operation during flight. Some of the avionics subsystems include: Multi-Core Processing, Long-Range Wireless Telemetry & Video-Imaging and Multi-Sensor & Multi-Memory Interconnect architectures.

How the paper fits the CONFERENCE THEME: The design of an efficient, long-flight / high-endurance capable MiRAVs presents a paradigm shift from the State-of-the-Art. It presents the opportunity to break the barriers of Flight-Endurance and High-Potency onboard Surveillance adequacy. The successful development of a micro robotic flyer will present the opportunity for MAVs to be actively involved in Military and Civilian security applications. The design of new actuation modalities utilizing FiFVA actuation can be utilized in other applications involving reciprocating systems, with the end goal of reducing energy consumption. The compact form factor of the onboard sensing, processing and navigational suite is adaptable across platforms and can be migrated to other MAV/UAV configurations. The low powered wireless telemetry, video-imaging capabilities will endow significant sensing and navigational improvements over conventional MAVs.

In conclusion, this paper elucidates our Robotic Quad Winged MAV (QV) design and showcases its unique actuation, sensing, control, aerodynamics and teleoperation/remote-imaging capabilities; thus making the Micro Flying Robot a worthy candidate for further research and development towards eventual incorporation into ISR operations by defense services and civilian security applications.