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Rapid Development of Bespoke Unmanned Platforms for Atmospheric Science

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The effective deployment of airborne atmospheric science instruments often hinges on the development cycle time of a suitable platform, one that is capable of delivering them to the desired altitude range for a specified amount of time, along a pre-determined trajectory. This could be driven by the need to respond rapidly to sudden, unexpected events (e.g., volcano eruptions, nuclear fallout, etc.) or simply to accommodate the iterative design and flight test cycle of the instrument developer. A shorter development cycle time would also afford us the ability to quickly adapt the hardware and control logic in response to unexpected results during an experimental campaign.

We report on recent developments aimed at meeting this demand. As part of the Atmospheric Science Through Robotic Aircraft (ASTRA) initiative we have investigated the use of rapid prototyping technologies to this end, both on the 'airframe' of the platform itself and on the on-board systems. We show how fast multi-disciplinary design optimization techniques, coupled with computer-controlled additive manufacturing (3D printing) and laser cutting methods and electronic prototyping (using standard, modular, programmable building blocks) can lead to the delivery of a fully customized platform integrating a given instrument in a timescale of the order of ten days.

Specific examples include the design and testing of a balloon-launched glider sensorcraft and a stratospheric balloon system. The 'vehicle' for the latter was built on a 3D printer using a copolymer thermoplastic material and fitted with a sacrificial protective 'cage' laser-cut from an open-cell foam. The data logging, tracking, sensor integration and communications services of the platform were constructed using the .net Gadgeteer open source hardware kit. The flight planning and eventual post-flight recovery of the system is enabled by a generic, stochastic trajectory simulation tool, also developed as part of the ASTRA initiative. This also demonstrated the feasibility of retrieving instrument platforms after the observations are complete, either through self-recovery (in the case of the glider) or accurate pre-flight prediction and real-time tracking, in the case of the balloon platform.

We also review developments in progress, including a balloon-launched flock of sensorcraft designed for the effective mapping of aerosol concentrations or other atmospheric measurements across a target airspace block. At the heart of this effort lies the optimization of the (pre-programmed or dynamically re-designed) trajectories such that they combine to approximate space-filling curves that maximize sampling efficiency (a 3D 'travelling salesman'-type calculus of variations problem).