Remote Sensing from an Autonomous Tactical Reconnaissance Platform

This paper describes a new reconnaissance technology developed over the past three years by an interdisciplinary team of researchers from California State University at San Luis Obispo (Cal Poly). The initial developmental effort, funded by a grant through the Office of Naval Research, was inspired by rocket recovery research previously performed by the Aerospace Engineering department. The initial prototype work has now been completed and we are now searching for partners to help develop requirements specific application areas.

The Autonomous Tactical Reconnaissance Platform (ATRP) consists of a standard parafoil that carries instrumentation for autonomous flight and remote sensing capabilities. The ATRP is designed as a small, man-portable reconnaissance platform that is launched, deployed and performs its mission under a pre-selected program of autonomous flight maneuvers. Weighing less than 2 lbs., the ATRP is launched to an altitude of 350 to 700 meters. The launch and deployment altitude are governed by the mission and the launch mechanism employed. Onboard sensors collect and relay real time telemetry to the notebook sized ground station providing the user with a low altitude view of the surrounding terrain for reconnaissance and communications missions.

In recent years the U.S. military has begun to make extensive use of unmanned air vehicles (UAV), primarily in the role of reconnaissance. However there has been much less use of UAV's by individual soldiers in forward deployments, mainly due to issues of high cost, complexity and size. These drawbacks have limited the use of UAV's where a simple, real-time reconnaissance and communications capability could save lives. The ATRP as developed at Cal Poly is designed to fill the need for a real time reconnaissance and communications device that is man-portable, expendable, rapidly deployable and easy to use. The ATRP is particularly well suited for locating the source of incoming enemy mortar fire or performing a fast response reconnaissance of the next city block, mountain ridge or nearby jungle terrain.

Use of commercial off the shelf (COTS) components that are available from multiple sources make the platform inexpensive and helps to minimize production time and costs. The ATRP in its rocket launch configuration is man-portable, with set-up and launch operations achieved in a matter of seconds. A range of alternative launch mechanisms including compressed gas, artillery shell and aerial deployment are possible. The ATRP is intended to be an inexpensive, expendable device, however it is also re-usable as the application permits.

The ATRP is a parafoil designed to carry a payload that is instrumented for autonomous flight and remote sensing capabilities. A parafoil is a flying wing made of flexible material, supported by lines that maintain its shape as it is inflated by the air flowing over and through it. Advantages of the parafoil design are that it is lightweight, is easily compacted and deployed, and has a very tolerant flight envelope.

Potential military users of the ATRP would include frontline soldiers for scouting and communications and for the precise distribution of ground sensing devices. The reconnaissance capability of the ATRP, providing real-time telemetry data, would be extremely valuable in rugged or jungle terrain and during nighttime operations. An infrared and/or visual sensor aboard the ATRP would pinpoint enemy location and numbers during such exercises. Both civilian and military agencies could use this technology in order to provide the precision air-drop of emergency supplies and medical equipment.

The ATRP platform provides the technology for real-time, easily deployed reconnaissance and/or extended communications capability. It embodies a unique combination of features including ease of use, expendability, and portability not currently available. The addition of this capability to individuals in the field would save lives and enhance effectiveness in both military and civilian applications.

Unique advantages of the ATRP include:

- Reaction time or speed of deploy – The ATRP is packed and ready for deploy on the soldiers' back. There is no need to assemble any parts. The procedure is as simple as; select type of flight pattern, aim, and launch.

- Time to reach target – The ATRP is rocket propelled in its man-portable version. If a unit receives enemy fire from a distance or has an urgent need to know what is going on in the next block, flight time to target occurs in a matter of seconds for this rocket propelled device vs. an extended flight for helicopter or fixed wing devices. These last two points mean that the user gets their data much faster than is possible with any other type of device.

- Vertical launch capability – This is a distinct advantage for the ATRP since buildings, trees, or hills may make it difficult to launch other types of UAV devices. A soldier can remain in cover by a wall while launching the ATRP, whereas other devices my force them to expose themselves to enemy fire during launch.

- Ruggedness/durability – The ripstop nylon of the canopy and the robust electronics container make this device much more likely to survive any sort of collision, landing or enemy fire. Fixed wing and helicopter UAV's tend to have parts are easily damaged making them one shot devices.

- Flexibility in launch options – The current baseline launch method is similar to that of a short range shoulder launched missile. However we have demonstrated that we can launch from barrels such as an artillery piece or a tank gun with the capability to survive very high G force launch modes. Our device also could be deployed from a cruise missile prior to entering terminal dive in order to provide Battle Damage Assessment (BDA).

- Forgiving flight platform – The ATRP is much easier to control than a fixed wing device or a helicopter. This means that there is less demand for computing resources to fly the device which provides an opportunity to reduce the cost, devote more resources to data collection, or miniaturize the electronics vs. other types of devices.

- Software – It uses a unique type of flight algorithm, Soft Computing (SC) algorithm, that is extremely tolerant of imprecise and noisy input data. We have simplified the algorithm even more from traditional Soft Computing Control methods. Because of the robustness of the SC technique, there is no need to tailor the control constants for each production vehicle. The exact same software can be downloaded to each production vehicle without modification. This feature saves money due to reduced final testing tuning that would be required by other UAV's.

- System cost – The ATRP uses much cheaper flight electronics due to advantages in platform stability and robust flight control software. It can be re-used many times due to its rugged construction. The materials in the construction are cheap and readily available and manufacturing is a relatively simple process.

- Ease of use – The ATRP is completely autonomous, with the user pre-selecting the type of flight pattern desired, and then launch and receive data on the handheld tablet device. Data is stored for review and further scrutiny by the user. Ground coordinates are identified by GPS location coupled with viewing angle information collected by the device.

- Load carrying capacity – The ATRP is much more flexible than typical flyers in the amount of load that it is capable of carrying. Adding more weight to the payload causes the vehicle to have a faster sink rate but will also increase flight speed. These two effects tend to offset one another to allow the device to cover the same ground track. The software is flexible enough to adjust to varying load factors without requiring any reprogramming. This ability provides a great deal of flexibility in the make-up of the payload and allows for expansion in future development.

- Camera platform stability – The motions experienced by the ATRP during the descent phase are relatively low frequency perturbations. This type of motion is easily compensated for in the processing by the handheld device on the ground. Most modern video devices have motion compensation for handheld operation. Other UAV devices have much higher frequency vibration problems induced by motors, rotors and aerodynamic effects that are more difficult to filter out. Typically, in order to avoid blurring of the images they must employ sophisticated dampening structures and/or software processing.

The ATRP is typically limited to 5 minutes of loiter time over the intended target area. For the mission scenarios envisioned for the ATRP this is a sufficient amount of time to observe and transmit the required reconnaissance data. Typically, small reconnaissance devices burn up a significant amount of flight time just getting to and from the target, whereas the rocket propelled ATRP arrives within seconds of launch. The small number of moving parts gives the ATRP a much greater mean time between failure rate (MTBF) than competing technologies.

The concept of launching and flying a parafoil with radio control was first addressed in a project in which a high power rocket was designed and built to carry a modified paraglider instead of a conventional parachute as a high power rocket recovery device. The successful flights of this rocket and parafoil led to the idea for an autonomously controlled parafoil. Work on this idea began with a one-meter tall rocket carrying an autonomously controlled parafoil. Initial simulation results, bench top testing and flight demonstrations were very successful.

In addition to parafoil testing, a Fuzzy Logic Controller (FLC) system was developed. This control system provides robust handling of noisy and/or missing input data, is flexible and has an easily modified control architecture. The FLC memory storage requirement is made manageable by using a unique formulation, known as Combs method, to control a common FLC problem of 'exponential rule expansion'. The optimization is performed using a steady state genetic algorithm with a dynamic fitness function. The optimization process has been performed in the Matlab/Simulink software environment with the FLC modules developed in the Matlab Fuzzy Logic Toolbox. Hardware limitations in terms of memory, computational speed and cost were critical factors driving the need for this simple, yet robust control algorithm.

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