An Aerobot Ecology

Greg Pisanich
QSS Group Inc. gp@email.arc.nasa.gov
NASA Information Sciences Division

Larry A. Young
layoung@mail.arc.nasa.gov
NASA/Army Rotorcraft Division

NASA Ames Research Center
Moffett Field, CA

Extended Abstract

Introduction

NASA Ames has been involved in many leading edge projects whose goal is to extend the capabilities of Unmanned Aerial Vehicles (UAVs). These include the Autonomous Rotorcraft Project [ref.], BEES for Mars Plice, Pisanich, Lau, Young, In publication, March 2003], and ACAT (Autonomous Cargo Amphibious Transport) [Pisanich and Morris, 2002].

For the most part, current NASA aeronautics/UAV research is focused on defining/developing the integration of uninhabited aerial vehicles (UAVs) in the National Aerospace. Counter to that perspective is that aerial robotic vehicles (aerobots) (and other automaton) may ultimately become so pervasive in our society that the airspace management concepts currently being promulgated by NASA and the FAA will be woefully inadequate for even a tiny fraction of the aerobots likely to exist [Aiken, Ormiston, and Young, 2000]. Therein lies the power of the Robosphere concept as applied to Aerobots: a completely new paradigm to cooperatively operate these robotic aerial vehicles, as compared to conventional concepts of airspace management.

Also at this time many researchers see robotic aerial vehicles as performing essentially more or less the same missions as the inhabited aerial vehicles they are replacing. In reality, what will happen is that wholly new applications will be developed and aerobots will be thought of not as autonomous aerial vehicles, but robot systems that can fly. The Personal Satellite Assistant (PSA), [], being developed at Ames, is an example of one of these new concepts.

Finally, if, as we project, that radically new applications will be developed for aerobots, then automation must/will drive aeronautical and mechanical system design innovation. I.E., only a small fraction of Aerobots will look like (scaled-down or otherwise) inhabited aircraft but will, in fact, look nothing at all like conventional aerial vehicles.

Aerobot Applications

Aerobots may rarely operate in isolation. We will ultimately need them to interact with each other, with ground and space-based robots, and human beings. There will be a whole host of Aerobots that will have to be multi-mode in operation and include cooperative/social in behaviors.

Applications to Society:

- Active delivery aerobots that could replace bicycle delivery services and Fedex boxes.
- Medical emergency systems that could perch in strategic areas and apply first aid and transport injured people directly to the operating room;
- Search and rescue aerobots that could cover large areas in a group 27/7, while also being able to loiter in an area looking for movement.

Military:

- Checking the life signs of injured soldiers and applying medicine in advance of rescue.
- Active munitions that can be deployed in a group and called back when necessary
- Camouflaged to allow loitering or perching in unconventional places (rocks, trees, buildings)

Planetary Exploration

- Long-range search and sample return from a central port.
- Short range sample return and sensing from a larger mobile rover.
- As an adjunct to manned exploration providing services from transfer to Medivac.

Aerobot Characteristics:

New Flight Profiles: Without the limitations of humans, aerobots may be able to fly faster and more aggressive flight profiles than are currently

New Abilities: The ability to perch, loiter, pickup, deliver, and refuel autonomously.

New Sensors and Effectors: Effectors that are also landing gear. Landing gear that can also enable recharging. The need to balance the aerobot on wires or treelimbs.

Seamless communication and interaction: with humans and other robotic and conventional automation.

Aerobot Configurations:

Aerobots probably won't look anything at all like conventional aerial vehicles. Hybrid vehicles will be the norm. See for example Figure 1 below.

This robotic helicopter with a robotic arm could be used for exploration (soil/rock sampling), it could be used to recharge itself (self-emplacement of the power plug) to enable flight without any human intervention. It could be used for environmental monitoring, to install a covert surveillance device, or to could be used to apply a medical sensor device on fallen soldiers on the field, etc.)

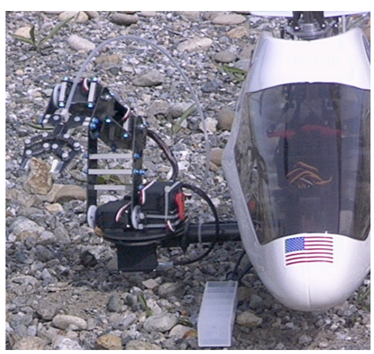

Fig.1 – Rotary-Wings & Opposable Thumbs

Other configurations could include hybrid or tethered blimps, dirigibles, Tilt Rotor, or VSTOL aircraft. Figure 2 shows a hybrid blimp system that exhibits some characteristics of a rotorcraft.

(a)

(b)

Fig. 2 – Proof-of-Concept Hybrid Airship Aerobot (a) front view, in flight in the laboratory, and (b) side view

Research Areas

The Robosphere project should allow us to generate new concepts on how flying vehicles would be designed delivered and interact with the other robotic vehicles and the world. Many of these are common problems to all systems and would need to be resolved.

Manufacturing and Distribution/Delivery: How would pre-built vehicles be delivered? Would they be pre-built such that they could be used right out of the box, would they need to be built on site and used, or would they be transferred in some way from another site?

Expendable/ Rebuildable: Some vehicles would probably be designed, either in whole or in part as expendable, never to be used again. Their material though might be recyclable for other tasks. Most vehicles would have to be repaired or rebuilt.

Design: New design criteria would need to be set up to make the systems rebuildable or fixable by other robotic vehicles. This might involve simpler designs with automatic connections. Information knowledge about how equipment could be damaged would be used to design those parts (like wings or tail parts) so that they would not transfer damage to other assemblies (thus bringing a whole new meaning to “design evolution.”).

Common Systems: Commonality of autonomy systems, propulsion systems, busses, sensors, etc., both between airborne systems and ground systems would save on energy expended and repair needs. Easy interchange would allow more systems to be repaired and put into use, including field damage repair.

Common Communications: Airborne and ground systems should share a common communications “language” and protocol. Sharing Messages, data, and frequency use should allow for common systems and also for the management of these systems.

Propulsion: The design of Robosphere would determine what propulsion systems would be usable with these vehicles. Solar, Nuclear, Liquid, or Solid Fuels may be a possibility. Propulsion system using materials on site (for example, hydrogen) may need to be designed. Other innovative uses of prior technology (such as steam, or air propulsion) may need to be examined. Small, pervasive, aerobots will most likely use electric propulsion with some ability to recharge (from automated ground stations or self-recharging from small solar arrays while resting on the ground).

Safety: How to operate aerobots safely close to human beings, valuable property, and each other. How to operate safely in several different modes: close interaction with human operators all the way to the other extreme where Aerobots operate with no active human intervention for extended periods of time (days, months, and years).

Acceptance: As aerobots become more pervasive in our society – and perhaps in and about our personal living space – and acquire more and more bio-inspired behaviors/attributes, it is a serious question to ask how to gain acceptance of aerobots as an integral part of human society.

Realization of the Vision: Prototyping Aerobot Robotic Colonies.

We can begin to understand the requirements and challenges associated with fielding initial aerobot colonies through the use of simulation and low cost demonstrations. The following are proposed applications that could help push the technology.

An Airship Colony: Low-cost hobbyist airships along with ground-based controllers could be used to simulate a “lighter than air” robotic colony. The semi-buoyant aerobots would include a grasping mechanism, simple image recognition, and sound generating capabilities. These aerobots would be designed to be able to move between ground and the highest aeries in the environment. They could be programmed with behaviors such as hunger, aggressiveness, and signing. They could recharge themselves simply by sitting or a perch, or could be trained to do certain tasks in order to gain power.

AeroCompanions for Planetary Robotics: An alternative approach would be to develop and add 1-2 small aerobots companions to a conventional planetary robot. These aerobots could be inexpensively prototyped using an electric rotorcraft enhanced with sensors and a grasping mechanism. They could recharge themselves automatically through the power of the ground system. These companions could be commanded by the primary robot to provide remote sensing and material gathering. The aerobots could also work as a team to provide wide stereo imaging or to lift material heavier than one alone could lift.

An Aerobot Search Team: A mixed team of fixed wing and rotorcraft UAVs could be used to perform a cooperative search within a limited area, for example, the Moffett Field Runway area. The goal would be to find and return an object given an area of search.

References:

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