PDHonline Course G516 (4 PDH)

Drone Technology

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If we exclude missiles, there are three kinds of aircraft that fly without on-board pilots:

- Drones – very limited mission flexibility (e.g. target practice drones)
- Remotely piloted vehicles – piloted from a remotely located position. (The media and general public are also using the term "drone" for this type of aircraft)
- Unmanned vehicles – may carry out autonomous or preprogrammed missions

Unmanned aircraft systems (UAS) can be described in terms of the following six subsystems:

1. Air vehicle – This subsystem is the airborne part of the system. Although the payload is also airborne, it is usually treated as an independent subsystem. The airborne side of the communications data link is also part of the air vehicle. The air vehicle can be a rotary wing, fixed wing, lighter-than-air or a ducted fan vehicle. The air vehicle subsystem consists of the following components:

    - Airframe
    - Electric power system
    - Propulsion system
    - Flight controls

2. Mission control – This subsystem is the operational control center where video, telemetry and command data are processed and displayed. For small UASs this ground control station can be contained in a back pack. At the other extreme, these structures are located in permanent structures thousands of miles away from the air vehicle and using satellite links to communicate.
3. Launch and recovery – Depending on the type of air vehicle, a number of options exist as follows:

    - Vertical takeoff and descent using rotary or fan systems
    - Catapults using a rocket
    - A combination of pneumatic/hydraulic arrangements
    - Small UAVs are launched manually

4. Payloads – The payload is the reason for the existence of the air vehicle and is usually the most expensive subsystem often consisting of video cameras for surveillance. UAV payloads can also function as platforms for communications and data relays to extend the range and coverage of line-of-sight systems including the data links used to control and return data to the UAV users.

5. Communications link – The data link provides on-demand or continuous communication. An uplink provides flight path controls and commands to the payload. The downlink provides a low data rate channel for command acknowledgement and UMV status information. A high data rate downlink channel is used for sensor data such as video. The data link may also be used to measure the position of the UMV by determining its azimuth and range from the ground station antenna.
6. Ground support – Ground support requirements may include readily available spare parts and test equipment.

The next part of this course is a review of increasingly autonomous (IA) technology that is contained in the National Academies Press (NAP) report entitled, "Autonomy Research for Civil Aviation: Toward a New Era of Flight". A free copy of this report can be downloaded from the web by clicking here . Please read the first three sections of this report with titles as follows:

Autonomous Capabilities and Vision

See NAP report for content of this section.

Potential Benefits and Uses of Increased Autonomy

See NAP report for content of this section.

Barriers to Implementation

See NAP report for content of this section.

Autonomy Levels for Unmanned Systems

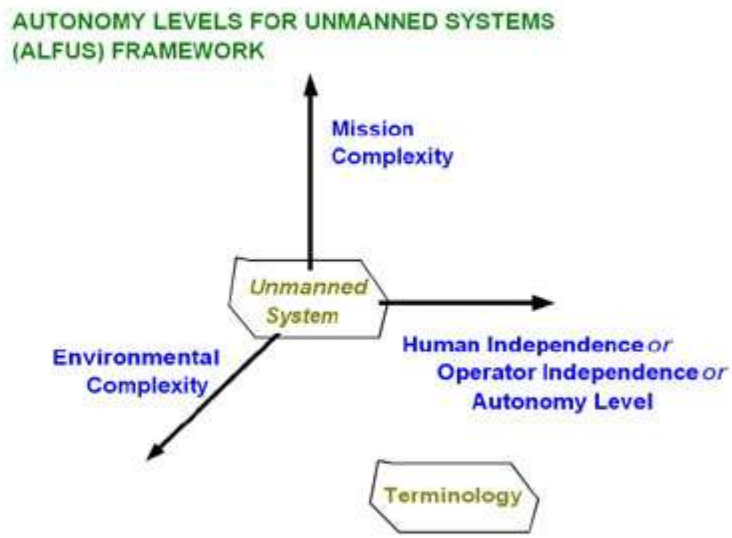
The National Institute of Standards and Technology (NIST) has been developing a framework for classifying Autonomy Levels For Unmanned Systems (ALFUS) since 2003 in collaboration with both the military and civilian organizations involved with the field of unmanned vehicles. ALFUS was intended to be a generalized framework, applicable not only to air vehicles but to other types such as ground and undersea as well. Major goals of ALFUS included providing standard definitions and terms for autonomous capabilities of unmanned systems and also the development of processes, metrics and tools for evaluating this autonomy.

Within the ALFUS framework autonomy is defined as follows:

"An unmanned system's own ability of integrated sensing, perceiving, analyzing, communicating, planning, decision-making, and acting/executing to achieve the goals assigned"

The level of autonomy of a system is evaluated within the context of three aspects:

- Mission complexity – the measure of the difficulty of the mission to be performed
- Environmental complexity – the measure of the difficulty of the environment within which the mission is being conducted.
- Human interaction – the measure of human interaction during the mission.



In practice, each of these three aspects is rarely treated independently thus presenting major difficulties in defining the level of autonomy and requiring metrics to be developed for each aspect on a test-by-test basis. Readers interested in more details about this topic can click here for the ALFUS report. A NIST working group called The Performance Measures Framework for Unmanned Systems (PerMFUS) has been formed to address the metrics challenge. A PerMFUS report is available here . The metrics issue is also being examined by The Society of Automotive Engineers Aerospace Systems Division (SAE AS-4) Unmanned Systems Technical Committee. The goal of SAE AS-4 is to address all facets of unmanned systems with a primary objective of developing open system standards and architectures for military, commercial and civil use. Information on the work of SAE AS-4 is located here .

Drone Applications and Business Opportunities

Novel applications of drone technology abound. Some have compared this stage of development with the early stages of the personal computer. Organizations interested in using drone technology have the option of owning and operating them or contracting with companies that have drone expertise. The following list describes examples of drone applications. Some are in early stages of development.

- Internet Infrastructure - Google purchased the company Titan Aerospace that is developing high altitude, lightweight Wi-Fi drones with the goal of bringing the Internet to remote locations around the world as an alternative to building on-the-ground telecommunications infrastructure. It is solar powered and can operate about

12 miles above ground. The Solara 50 is a fixed wing drone with a wingspan greater than a Boeing 767.

- Railroad Applications - Railroads are examining the use of drones in a variety of roles including bridge inspection and trouble detection by master conductors who normally have to walk alongside the train for significant distances. Another useful application could be helping to evaluate derailment scenes that are too dangerous to approach closely. Railfans will likely be increasingly attracted to the use of drones to obtain spectacular photos and videos from ideal aerial locations.
- Real Estate - The value of drones equipped with cameras is obvious. Dramatic photographs can be taken from locations not otherwise accessible for use in marketing properties.
- United States Border Surveillance - Drones can be a cost-effective way to monitor for illegal traffic across U.S. borders.
- Electric Power Utilities - According to the Electric Power Research Institute (EPRI), drones can be effectively used to assess storm damage on utility distribution systems and help utilities shorten their outage response times. .
- Crop Pollination - Currently promising research may produce tiny drones which can be used for crop pollination. This category of drones is bio-inspired with insects being one of the models being imitated. The flying dynamics are being studied using advanced imaging systems with cameras that can operate at 7,500 frames per second and in infrared light. For the first generation of these microdrones, significant engineering challenges remain with the major one being power. Microfabrication techniques, novel battery design, microfuel cells and wireless power transfer are all being investigated for this application. An example university research center working on these challenges is the Harvard Microrobotics Laboratory .
- Agricultural Crop Surveillance - The Association for Unmanned Vehicle Systems International predicts that 80% of the commercial market for drones will eventually be for agricultural purposes. Crop surveillance can significantly increase crop yields and corresponding reductions in the cost of walking the fields or airplane fly-over filming. Drones equipped with imaging systems can create composite video that describes the health of crops and facilitate precision agriculture, the tailored use of pesticides, herbicides, fertilizer and other applications based on how much is needed at a specific point in a field. An example drone system with advanced imaging capabilities is the Trimble UX5. RoboFlight is a company with drone expertise that specializes in agricultural applications.
- Pipeline Monitoring - Utilities can benefit from the use of drones for monitoring and maintaining gas, oil and water pipelines. Pipeline surveillance with drones is more environmentally friendly and quieter than helicopters.
- Construction automation - Drones and unmanned bulldozers and excavators can be used to automate much of the early foundation work on construction sites. Click here for more information.
- Law Enforcement - Police use of drones could help with search and rescue and crime scene viewing. It is believed that drones could revolutionize how crashes are

investigated by enabling accidents to be cleared quicker. Michigan State Police may be the first police agency in the U.S. to receive permission to fly drones as part of public safety programs. The first drone purchased was an Aeryon SkyRanger .

- Another example of UAV technology specifically designed to support law enforcement: Homeland Surveillance and Electronics, LLC .
- Nixie the Selfie Drone - A camera that comes with you everywhere and can fly. With a gesture, Nixie takes off, captures the moment and comes right back. Click here for more information.

The Dark Side of Drone Technology

As with any technology, there is always the possibility of criminal use. One of the first examples to emerge is the use of small drones to deliver drugs and cellphones over the walls of prisons. It is the high-tech version of smuggling a file into a prison in a birthday cake. Unlike pay phones in prisons, smartphones are not recorded or monitored, enabling gang leaders to freely operate their criminal activities from behind bars. Placing nets over every sensitive area in the United States to keep drones out is just not feasible. At the time of this writing the best way to control the problem seems to be "geofencing" software that is designed to prevent drones from flying over a specific location.

Selected Education and Research Opportunities in the UAS Field

- **University of North Dakota – the Center for Unmanned Aircraft Systems Research, Education and Training provides a conduit between private industry and UAS researchers, promoting commercialization of new UAS-related products and services.**

- **Georgia Tech – Georgia Tech Research Institute carries out innovative and advanced research for unmanned systems, spanning from basic research to advanced prototypes and test and evaluation.**

- **AUVSI Foundation – Each year the AUVSI Foundation offers a series of educational programs as well as robotics competitions that allow students to apply science, technology, and mathematics education outside the classroom.**

- **Embry-Riddle Aeronautical University – Embry-Riddle offers a Bachelor of Science in Unmanned Aircraft Systems Science degree that gives graduates the expertise needed for employment as operators, observers, sensor operators and operations administrators of unmanned aircraft systems. The curriculum also includes engineering aspects of these aircraft systems and the regulations governing their operation.**

- **K-State Salina – The Salina campus of Kansas State University offers a bachelor's degree in unmanned aircraft systems that allows students to participate in actual flight training missions.**

Technical Reference Books

Barnhart, Richard K., Stephen B. Hottman, Douglas M. Marshall and Eric Shappee, *An Introduction to Unmanned Aircraft Systems*, CRC Press, 2012.

Beard, Randal W. and Timothy W. McLain, *Small Unmanned Aircraft: Theory and Practice*, Princeton University Press, 2012.

Fahlstrom, Paul Gerin and Thomas James Gleason, *Introduction to UAV Systems*, Fourth Edition, Wiley, 2012.

Gundlach, Jay, *Designing Unmanned Aircraft Systems: A Comprehensive Approach, Second Edition (AIAA Education Series)*, American Institute of Aeronautics, 2nd Edition, 2014.

Website Resources

Federal Aviation Administration (FAA) – The FAA is responsible for the regulation of unmanned non-military aircraft since the passage of the FAA Reauthorization Act (Public Law 112-95), February 14, 2012. This is the place to find the latest developments in the evolving regulations for civilian unmanned aircraft.

International Aerial Robotics Competition (IARC) – The IARC is the longest running collegiate aerial robotics challenge in the world. Entering its third decade of advancing the state of the art in autonomous aerial robotic behavior, the competition continues to tackle challenges that are currently impossible for any flying robots owned by government or industry.

Journal of Unmanned Vehicle Systems – This quarterly journal covers developments in the rapidly emerging international field of unmanned vehicle systems and their sensors.

FAA Center of Excellence (COE) for Unmanned Aircraft Systems – the objective of the COE is to bring the best minds in the nation together to conduct research, educate, train and work with the FAA toward solutions for unmanned aircraft challenges. Some of these challenges include: technical issues critical to safe and successful integration of unmanned aircraft systems into the nation's airspace, detect-and-avoid technology, control and communications, compatibility with air traffic control operations and training and certification of unmanned aircraft system pilots.

International Conference on Unmanned Aircraft Systems Association (ICUAS) – The mission of the ICUAS Association is to advance knowledge, education, basic and applied research and development in unmanned systems by organizing annual conferences and short courses for scientists, engineers, researchers and practitioners who are interested in advancing their knowledge in this area.

Association for Unmanned Vehicle Systems International (AUVSI) – This Association is the world's largest non-profit organization devoted exclusively to advancing the unmanned systems and robotics community, serving government organizations, industry and academia.

Resources for Hobby Drones

Caution: Please read current information on FAA regulations here before planning to start a business that uses drones.

Books

Issod, Craig S., *Getting Started With Hobby Quadcopters and Drones*, Create Space Independent Publishing Platform, 2014.

LeMieux, Jerry, *Drone and UAV Entrepreneurship: 30 Businesses You Can Start*, Unmanned Vehicle University Press, 2013.

Protogerellis, Alex, *The Beginners Guide to FPV*, CLUEfox Publishing, 2013.

Glover, John, *Drone University*, KiloOhm.com, 2014

Websites

Drone Flyers Information Site – Quadcopter and other multirotor platform resource site.

Forums - RC Multirotor Groups - A forum that includes various categories and subsystems of multirotor flying platforms.

Do It Yourself (DIY) Drones – This site claims to be the largest community for amateur unmanned aerial vehicles (UAV).

Tom's RC Pro Reviews - The site of an individual who writes product reviews for helicopters, quads, transmitters, receivers, batteries and aftermarket parts.

AR Drone Forum 1

AR Drone Forum 2