RF-LINKS.COM
WIRELESS AUDIO/VIDEO LINKS

SMALLEST WIRELESS FLYING SYSTEMS

Unmanned Aerial Vehicles (UAVs)

Unmanned Aerial Vehicles (UAVs) are remotely piloted or self-piloted aircraft that can carry cameras, sensors, communications equipment or other payloads. They have been used in a reconnaissance and intelligence-gathering role since the 1950s, and more challenging roles are envisioned, including combat missions. Since 1964 the Defense Department has developed 11 different UAVs, though due to acquisition and development problems only 3 entered production. The US Navy has studyied the feasibility of operating VTOL UAVs since the early 1960s, the QH-50 Gyrodyne torpedo-delivery drone being an early example. However, high cost and technological immaturity have precluded acquiring and fielding operational VTOL UAV systems.

By the early 1990s DOD sought UAVs to satisfy surveillance requirements in Close Range, Short Range or Endurance categories. Close Range was defined to be within 50 kilometers, Short Range was defined as within 200 kilometers and Endurance as anything beyond. By the late 1990s, the Close and Short Range categories were combined, and a separate Shipboard category emerged. The current classes of these vehicles are the Tactical UAV and the Endurance category.

Pioneer: Procured beginning in 1985 as an interim UAV capability to provide imagery intelligence for tactical commanders on land and see at ranges out to 185 kilometers. No longer in the Army inventory (returned to the US Navy in 1995).

Tactical UAV : Designed to support tactical commanders with near-real-time imagery intelligence at ranges up to 200 kilometers. Outrider Advanced Concept Technology Demonstration (ACTD) program terminated. Material solution for TUAV requirements is being pursued through a competive acquisition process with goal of contract award in DEC 99.

Joint Tactical UAV (Hunter): Developed to provide ground and maritime forces with near-real-time imagery intelligence at ranges up to 200 kilometers; extensible to 300+ kilometers by using another Hunter UAV as an airborne relay. Training base located at Fort Huachuca, with additional baseline at Fort Polk to support JRTC rotations. Operational assets based at Fort Hood (currently supporting the KFOR in Kosovo).

Medium Altitude Endurance UAV (Predator): Advanced Concept Technology Demonstration now transitioned to Low-Rate Initial Production (LRIP). Provides imagery intelligence to satisfy Joint Task Force and Theater Commanders at ranges out to 500 nautical miles. No longer in the Army inventory (transferred to the US Air Force in 1996).

High Altitude Endurance UAV (Global Hawk): Intended for missions requiring long-range deployment and wide-area surveillance (EO/IR and SAR) or long sensor dwell over the target area. Directly deployable from CONUS to the theater of operations. Advanced Concept Technology Demonstration (ACTD) managed by the US Air Force.

What is a Micro Air Vehicle?

The term, Micro Air Vehicle, may be somewhat misleading if interpreted too literally. We tend to think of flying model aircraft as "miniature", so the term "micro" now alludes to a class of significantly smaller vehicles. But MAVs are not small versions of larger aircraft. They are affordable, fully functional, militarily capable, small flight vehicles in a class of their own. The definition employed in DARPA's program limits these craft to a size less than 15 cm (about 6 inches) in length, width or height. This physical size puts this class of vehicle at least an order of magnitude smaller than any missionized UAV developed to date.

MAVs should be thought of as aerial robots, as six-degree-of-freedom machines whose mobility can deploy a useful micro payload to a remote or otherwise hazardous location where it may perform any of a variety of missions, including reconnaissance and surveillance, targeting, tagging and bio-chemical sensing.

Although the 15 cm limitation may appear somewhat arbitrary, it derives from both physics and technology considerations. To fully appreciate the scale implications, we can compare this class of vehicle with other familiar systems, as in Figure 1. This is a plot of vehicle gross weight vs Reynolds number. The Reynolds number (a measure of size multiplied by speed) is perhaps the most useful single parameter for characterizing the flight environment. The smallest current missionized UAV is the "Sender", developed and operated by the Naval Research Laboratory. Sender boasts a 4 foot wing span and weighs only 10 pounds - impressive specifications for its near 100 mile range capability. MAVs are an order of magnitude smaller and may display a wide variety of configurations, depending on specific mission requirements.

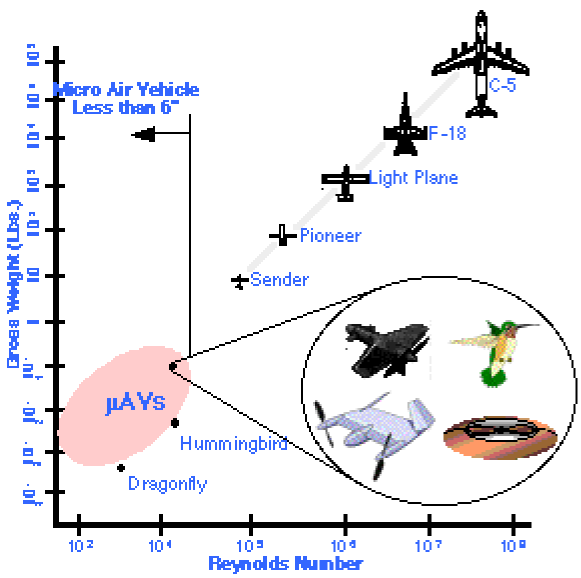
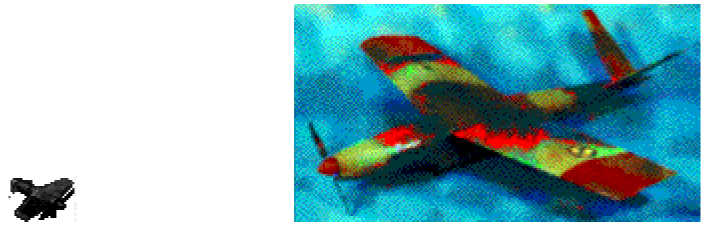


Figure 1. The Micro Air Vehicle Flight Regime Compared to Existing Flight Vehicles

The low Reynolds number regime is significant in that it projects a fundamental shift in physical behavior at MAV scales and speeds - an environment more common to the smallest birds and the largest insects. While naturalists have seriously studied bird and insect flight for more than half a century, our basic understanding of the aerodynamics encountered here is very limited. Neither the range - payload performance of bees and wasps nor the agility of the dragonfly is predictable with more familiar high Reynolds number aerodynamics traditionally used in UAV design. And if our understanding of low Reynolds number effects is limited, our ability to mechanize flight under these conditions has been even more elusive.

With the small size of the MAV comes high surface-to-volume ratios and severely constrained weight and volume limitations. The technology challenge to develop and integrate all the physical elements and components necessary to sustain this new dimension in flight will require an unprecedented level of multifunctionality among the system components. The traditional "stuffing the shell" paradigm of conventional aircraft design is not likely to be workable for MAVs.

Yet to be developed, Micro Air Vehicles will be roughly one-tenth the scale of the Sender, and the weight of a six-inch, fixed-wing MAV may be only 50 grams or so, just one one-hundredth the weight of the Sender. Figure 2 illustrates the difference in size. Yet MAVs must be capable of staying aloft for perhaps 20 to 60 minutes while carrying a payload of 20 grams or less to a distance of perhaps 10 km. Finding high density sources of propulsion and power is a pivotal challenge. And while the Sender is a conventional, moderate aspect-ratio, fixed-wing aircraft, MAVs may require more unusual configurations and approaches ranging from low aspect-ratio fixed wings to rotary wings, or even more radical notions like flapping wings.



Maximum-Sized (15 cm) Micro Air Vehicle Sender

Maximum-Sized (15 cm) Micro Air Vehicle Sender

Figure 2. Size Comparison Between an MAV Concept Vehicle and a Small UAV

Why Micro Air Vehicles?

Why "micro"? Why not something larger? The answer lies in the applications envisioned for MAVs. Studies like the Defense Science Board's 1996 Summer Study on "Tactics and Technologies for 21st Century Warfighting" emphasize keeping personnel out of harms way by providing unprecedented situational awareness right down to the platoon level. In contrast to higher-level reconnaissance assets like satellites and high altitude UAVs, MAVs will be operated by and for the individual soldier in the field as a platoon-level asset, providing local reconnaissance or other sensor information on demand, where and when it is needed. MAVs may also be used for tagging, targeting, and communications, and may eventually find application as weapons, as well.

The reconnaissance application is a primary driver behind the first generation of MAVs. Micro sensors like those mentioned earlier suggest the possibility of reduced latency and greatly enhanced situational awareness for the small unit or individual soldier. This is partly attributed to the direct connectivity envisioned between these systems and the "user" in emerging operational concepts. Direct connectivity means the user has to carry it. So the MAV must trade favorably with other soldier assets - like water and ammunition. The system must also be affordable. It must have a vanishingly small logistics tail, and for many missions it must be intrinsically covert. All this points to a highly compact, small system.

Additionally, the MAV's ability to operate in constrained environments like urban canyons and, eventually, even the interior of buildings, gives these systems a level of uniqueness unmatched by other concepts. MAVs are not replacements for previously manned air vehicle missions; because of their size, they will be capable of completely new missions not possible with any existing systems.

More on Missions

Micro Air Vehicles will be capable of a wide range of useful military missions. The one most often identified by users is the textbook, "over the hill" reconnaissance mission illustrated in Figure 3A. The current concept suggests that reconnaissance MAVs need to range out to perhaps 10 km, remain aloft for up to an hour, reach speeds of 10 to 20 m/s (22 to 45 mph), and be capable of real time day/night imagery. In contrast, some surveillance applications may require less range - payload performance. In these instances, the MAV would relocate to a suitable vantage point and serve as a fixed, unattended surface sensor with capabilities ranging from imagery to seismic detection.

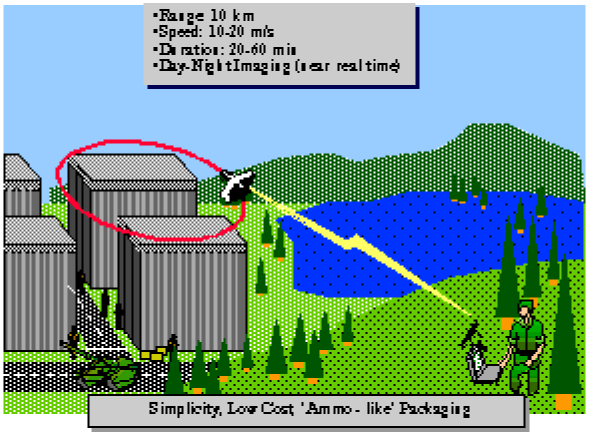


Figure 3A. The "O6er-The-Hill Reconnaissance" Mission for the MAV

At the same time, MAVs must be launched and operated relatively simply with an easy-to-operate ground station. Ground stations may employ directional antennas to -aintain contact with the MAV at long range.

In urban operations (see Figure 3B), MAVs, acting in small, cooperativ% groups¬ wiìl enablå reconnaissance and surveillance of inn¥r city areas, and may serve as communication relays. They may also enable observations through windows, and sensor placement on vertical and elevated surfaces. Their application to building interiors is the most demanding envisioned. The capability to navigate complex shaped passageways, avoid obstacles and relay information will require yet another level of technology.

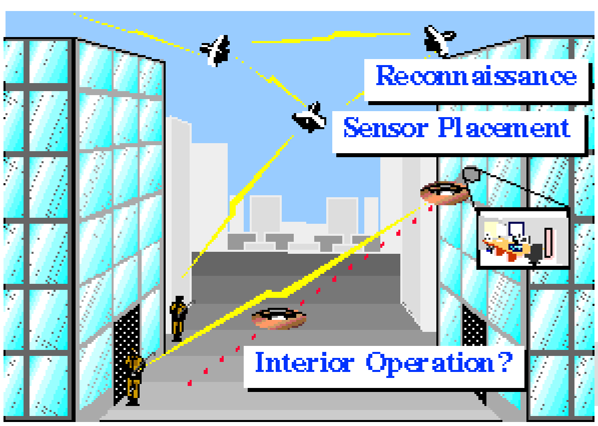


Figure 3B. Urban Operations Missions for the MAV

Biochemical sensing, illustrated in Figure 3C is another potential mission for MAVs. With gradient sensors and flight control feedback, MAVs will be able to map the size and shape of hazardous clouds and provide real time tracking of their location.

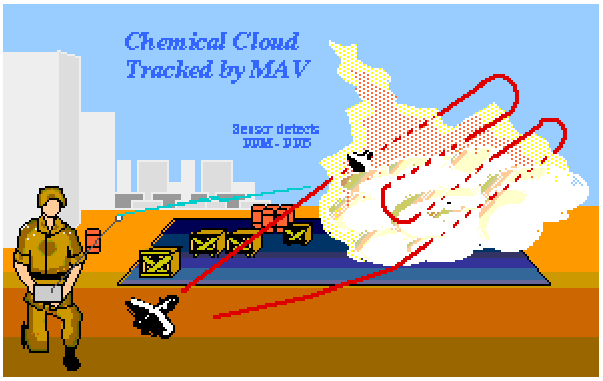


Figure 3C. The MAV as a Mobile Immersion Sensor

MAVs may also find application in search and rescue operations. An MAV could be packed into the ejection seat mechanism on fighter aircraft. If the pilot has to "punch out", the MAV is released from the ejection seat and lingers in the air for up to an hour, providing the downed pilot with reconnaissance information, or sending a signal to rescue vehicles.

While the challenge of developing self-propelled MAVs capable of achieving all the requirements alluded to previously is daunting, a more near-term application may be possible using assisted propulsion. Unpropelled MAVs could be launched from overhead flight vehicles or from barrel-launched munitions. Upon release above a target area, MAVs could provide targeting information and battle damage assessment back to the operator.

A large number of potential commercial applications also exist. These include traffic monitoring, border surveillance, fire and rescue operations, forestry, wildlife surveys, power-line inspection and real-estate aerial photography, to name a few.

The Technical Challenge

The development and fielding of militarily useful MAVs will require overcoming a host of significant technology and operational obstacles.

....Putting it Together

The physical integration challenge is believed to be the most difficult problem, the degree of which increases dramatically with decreasing vehicle size or increasing functional complexity. At and below the 15 cm scale size, the concept of "stuffing" an airframe with subsystems - our conventional approach to hardware integration - becomes extremely difficult. An examination of the range of system elements illustrates the problem (Figure 4).

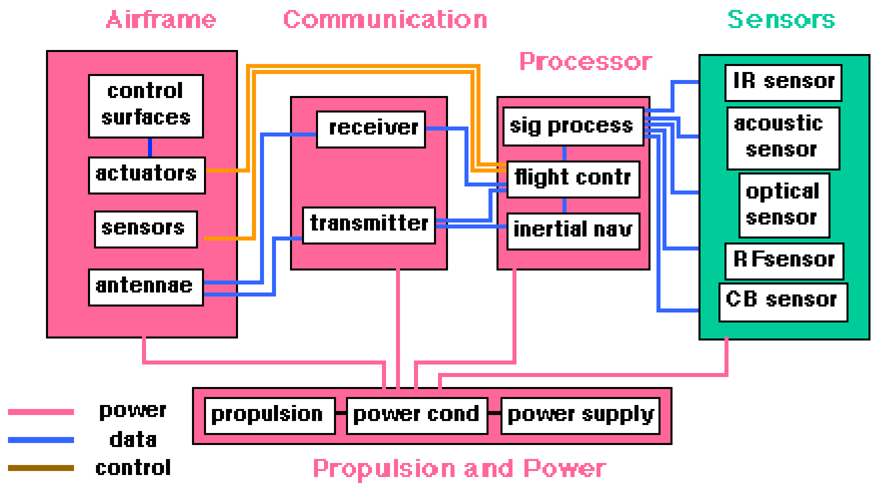


Figure 4. MAV System Integration

Many of the system functions depicted will be provided by microelectronics or MEMS-based components. Even so, separate modules for each function would consume more volume than may be available. From an electronics perspective, the on-board processor and communications electronics form the core of the vehicle. They provide critical links between the sensor systems and the ground station, and they are vital to the flight and propulsion control systems. In the scheme depicted in Figure 4, Power generation and propulsion subsystems support critical electronics and flight control functions in addition to flight propulsion power. The multifunctionality required by the MAV weight and power budgets may be achieved only by a highly integrated design, with physical components serving multiple purposes, or accomplishing multiple and often diverse functions. For example, the wings may also serve as antennae or as sensor apertures. The power source may be integrated with the fuselage structure, and so on. The degree of design 'synergy' required has never been achieved in a flight vehicle design.

....Achieving Stable Controlled Flight

Flight control is the single technological area which harbors the largest numbers of unknowns for the MAV designer. Relatively large forces and moments can be produced by the laminar-flow-dominated flight environment, and they are difficult to predict under all but the most benign flight conditions. Unsteady flow effects arising from atmospheric gusting or even vehicle maneuvering are far more pronounced on small scale MAVs where inertia is almost nonexistent, that is, where wing loading is very light. Platform stabilization and guidance will require rapid, highly autonomous control systems.

One common trend in aircraft and in nature is that smaller flyers travel slower and tend to have a higher ratio of wing area to vehicle weight. Given the limited wingspan available, MAVs may have to achieve high relative wing areas by having larger chords, i.e. by using configurations with low aspect ratio (wingspan divided by chord), more like flying wings, or butterflies. So MAVs may have to cope with fully three-dimensional aerodynamics. Here, there are even less low-Reynolds number data available than there are for two-dimensional airfoils. To make matters worse, MAVs will experience highly unsteady flows due to the natural gustiness (turbulence) of the atmosphere. Interestingly, natureÌs flyers of the same scale use another source of unsteady aerodynamics, flapping wings, to create both lift and propulsive thrust. For some applications, MAVs may ultimately have to do the same.

These low Reynolds number effects will have to be mastered using highly integrated flight control systems, with autonomous stabilization. In confined areas like urban canyons and interior spaces, autonomous collision avoidance systems will also be required.

.... Getting From Here to There

Small-scale propulsion systems will have to satisfy extraordinary requirements for high energy density and high power density. Acoustically quiet systems will also have to be developed to assure covertness.

To better understand some of the propulsion issues, consider the power equation for a propeller driven aircraft as shown in Figure 5. This relationship provides insight into ways to reduce the power required for propulsion. First, we need good aerodynamics (high lift to drag ratio). But low Reynolds number wings may only have 1/3 to 1/4 the lift to drag ratio of conventional aircraft. Propeller aerodynamics must also be efficient, but propellers below about 3 inches in diameter have poor efficiency, on the order of 50 percent less. So low Reynolds numbers affect propulsion in two ways: Poor lift to drag ratios increase the power required, and propeller efficiencies are low.

The power required can be reduced considerably by having low wing loading, achieved in MAVs by having large wing areas and lightweight vehicles. The Gossamer Albatross had a huge wing area (and low weight) so that it could be powered by a very weak engine (human power). But this was done with huge wing spans. In contrast, the 15 cm limitation means MAVs may have to maximize area by increasing the wing chord, leading to low aspect ratio configurations.

Finally, still in reference to the power equation, three is nothing more effective than low weight to reduce power requirements. Technologies like MEMS, low power electronics, and component multifunctionality will help. High energy density (i.e. light-weight) power sources are essential. Battery-based systems will likely power the first generation MAVs, but more exotic technologies like fuel cells are being developed for follow-on systems.

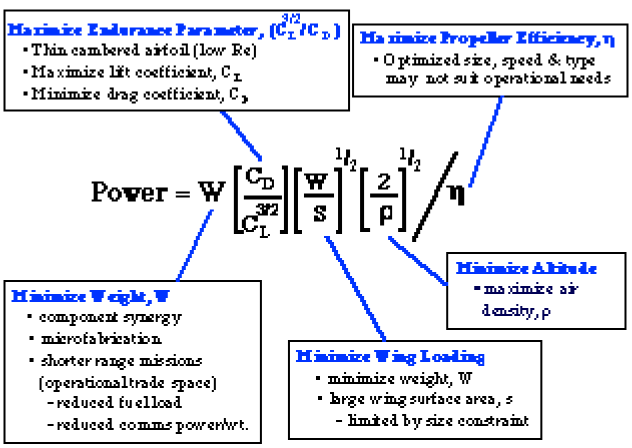


Figure 5. Minimization of MAV Propulsive Power

If the power and propulsion problems appear daunting, the issue of navigation may be even more so. Large reaches of open air environments may render this problem doable with in-hand technology, but the more demanding environments to which the MAV is uniquely suited are another matter. GPS would be a near-ideal solution, but current systems are much too heavy and too power-intensive for MAV applications. Inertial navigation for MAVs awaits the development of low-drift micro gyros and accelerometers. Constricted corridors of complex geometry, multiple obstacles - and some of them moving -must all be reckoned with if the MAV is to become useful to the warfighter. Real time human interaction to provide vehicle stabilization and guidance is being considered for early designs, but performance or other mission constraints may render this solution impractical in some of the more demanding applications. For example, necessary vehicle agility (or gust response) may well surpass a human operatorÌs ability to cope with it, and real-time human controls may not be possible except in the simplest of scenarios. Clearly, significant advances in miniature navigation, guidance and control systems are needed.

....In Touch with the Users

Success in any MAV mission rests with ability to establish a successful, robust communications link between the MAV and its user/operator. Figure 6 illustrates some of the factors influencing the communication systems design.

Communication problems relate primarily to the small vehicle size, hence small antenna size, and to the limited power available to support the bandwidth required (2-4 megabits per second) for image transmission. Control functions demand much lower bandwidth capabilities, in the 10's of kilobits range, at most. Image compression helps reduce the bandwidth requirement, but this increases on-board processing and hence power requirements. The limited power budget means the omni-directional signal will be quite weak. So directional ground antennas may be required to track the vehicle, using line-of-sight transmissions. But limitations to line-of-sight would be severely restrictive for urban operations, so other approaches will have to be found. One approach is to explore cellular communication architectures.

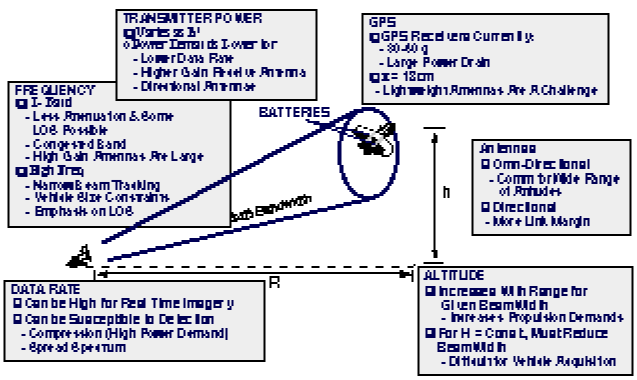


Figure 6. Issues Influencing MAV Communications

<u>....MAV Payloads</u>

The first generation MAVs will be equipped with sensor packages to accomplish various reconnaissance or surveillance tasks. A variety of sensors will have to be adapted and integrated into MAV systems. These may include optical, IR, acoustic, bio-chemical, nuclear, and others.

A visible imaging system is perhaps the most sought after payload for initial MAV applications and it fortunately employs the most mature of the micro sensor technologies. Figure 7 depicts a tiny video camera system envisioned by Lincoln Laboratory. The camera would weigh only 1 gram and occupy roughly one cubic centimeter, as shown in comparison to a deer fly. The camera would have 1000x1000 pixels and require as little as 25 milliwatts of power. The Lincoln Laboratory study suggests that this concept is feasible with emerging technology in about two years.

To add more substance to the discussion, consider the use of this payload in a compatible MAV design (Figure 8). This 8 cm (3 inch) concept vehicle was also studied by Lincoln Laboratory investigators. The overall weight of the vehicle is only 10 grams, and the total power required is 1 watt. Note that propulsion would require 90 percent of the available power and 70 percent of the total weight. This vehicle concept envisions a video systems that operates at only one frame every two seconds. The video system is forward mounted, and looks down at 45 degrees to the direction of flight. Higher frame rates will increase the demand for high-power and high-energy-density sources. Additional power would be required for on-board image compression and for higher data rate communications.

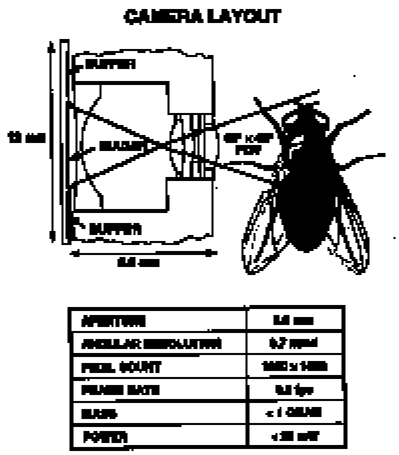


Figure 7. MAV Camera Concept (Source - MIT Lincoln Laboratory)

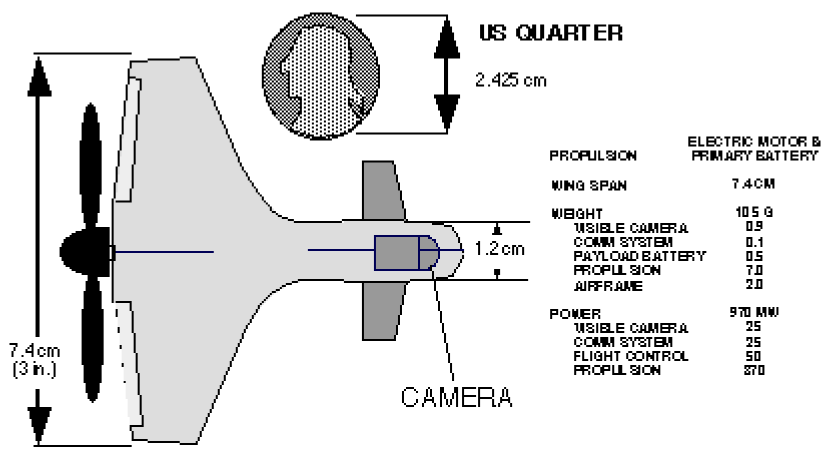


Figure 8. MIT Lincoln Laboratory MAV Concept.

It is more likely that in the near term fixed wing MAVs will be closer to 6 inches in length, weigh on the order of 50 grams and require 8-10 watts of power. Here too, the propulsion systems will consume nearly 90 percent of all available power, leaving only 10 percent for avionics systems, including communications.

.... Soldier Proofing

Building a Micro Air Vehicle that can fly and perform a useful function is indeed a significant challenge. But fielding a system that can survive in a range of nasty, treacherous military environments increases the challenge by at least another order of magnitude. External flight issues such as ambient temperatures, winds, moisture, and salt spray are only a fraction of the problem.

MAVs must be designed to be safe and simple to operate, preferably by an individual soldier. The launch system must accommodate possible severe initial conditions, such as being launched at speed or at an extreme angle. Electronic connectivity must be rapid and secure. And control interfaces must involve minimal concentration, freeing the operator to perform other duties.

The MAV must have a simple logistic tail. It must either be expendable or it must be easy to repair under field conditions. It must easily integrate into the combatant's field pack, and must be well-protected from hazards, including shock, until it is operated.

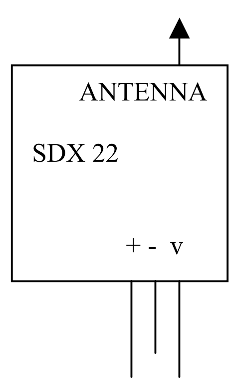
Finally, the MAV must be affordable. Affordability is, to some extent, dictated by the complexity and importance of the mission. But MAVs will not be fielded in large numbers if their cost is prohibitive. For many of the routine missions being considered, an expendable MAV must cost no more that an anti-tank round.

A Final Note

Despite the significant challenges facing the MAV developer, all indications are that these systems can be developed with today's emerging electronic and related technologies. Recognize that this statement permits an evolution of capability over time that will begin with the simplest of systems and missions. While small scale poses enormous technical challenges, it offers major advantages, not just in terms of enabling new missions, but also in terms of potentially short fabrication and testing time scales. These "small" time scales may help insure brief "gestation periods" (development cycle times) for each generation of capability. If this is so, we may optimistically anticipate a rapid evolution of MAVs to militarily useful and flexible systems in the not-too-distant future.

RECOMMENDED WIRELESS SYSTEMS

Wireless system such as SDX 22 smallest 2.4 GHz video transmitter is one of the best smallest units recommended for Micro AIR vehicles. In order to get the best results and longest possible range, this transmitter has to be used in combination with Receiver VRX 24 L (or any from VRX series). Why this receiver? The receiver is a very important part of wireless systems. Our receivers have excellent sensitivity and great selectivity. VRX 24 L receiver has RF end that contains Ga-As transistors. This is very important for the best performances. It is easy to obtain a range over 3 km with SDX 22 video sender, receiver VRX 24 L, amplifier for the receiver AMP-18 VM and high gain antenna on the receiving end.
For the best results batteries on the plane must be sufficient for supplying the camera along with the transmitter. Recommended DC power is 7.5 V – 9 V for SDX 22 with a current 68 mA, or 4.75 V for SDX 21 LP model with a current 35 mA. Complete video system model CMDX 22 needs 7.5 V – 9 V DC power for the best results with a current 80 mA.
More power and greater range will give model LUV 200 (over 250 mW RF power, Fig. 1); this transmitter will send a signal over 5 km from the AIR. The range for small wireless systems above is determine by line-of-sight, usually they are not bale to send a signal for that distance if used on earth. Some other systems are not able to obtain the longer range even from the AIR for a simple reason that receiver isn't sensitive enough to receive the signal.
SDX 22 small video transmitter in combination with color video camera is excellent wireless system. The unit is easy to hook-up (Fig.2). There are three wires. The first wire from the picture (brown color) is Positive (DC power), the middle one (shown red) is common (negative) and the orange wire is video input (in combination with common from the camera of course). The camera is connected directly to the transmitter (Fig.2). Transmitting antenna must be in vertical position exposed out of the plane's body. This is very important especially if plane made from the metal. There is a small potentiometer on the transmitter board to adjust desired video level (brightness). Transmitters are polarity protected but in any case do not change the polarity.



SDX 22 video transmitter

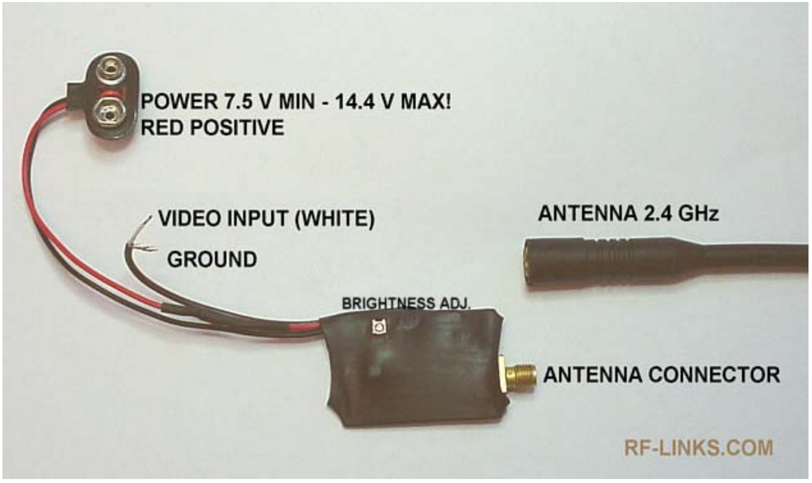


FIG.1

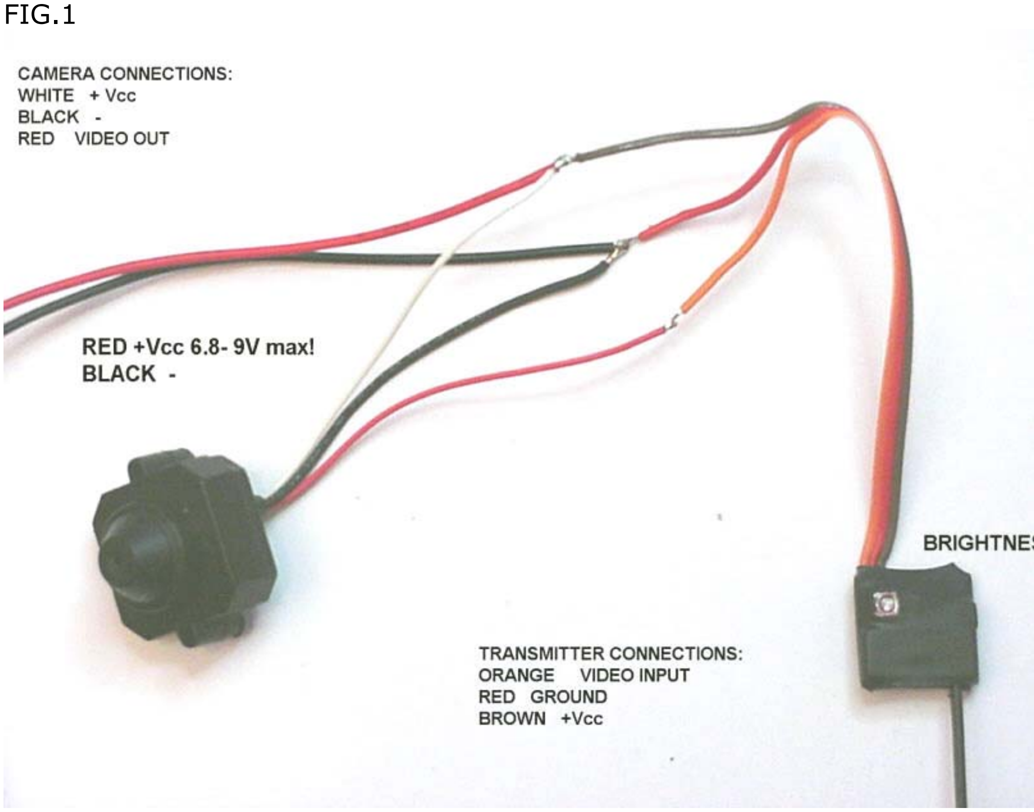


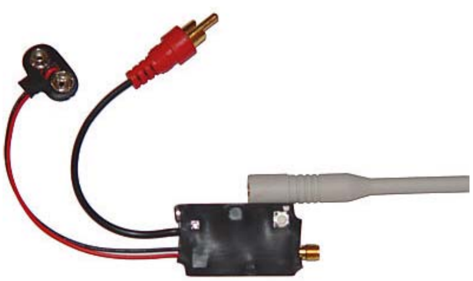
FIG.2

LUV 200 M RATING

Please make sure that your unit has enough supply DC power. The unit requires 150 mA current from the battery 7.5 V (absolute minimum required) to 14.4 V (max. Voltage allowed!) Maximum RF power is 280 mW / 12 V! Do not change polarity! RED WIRE positive +, BLACK negative -
Never connect unit to power without the antenna! This transmitter accepts any video signal (PAL or NTSC) even CMOS cameras without modification.

WARRANTY VOID IF HEAT SHRINK OPENED!

MX 3000 AUDIO/VIDEO TRANSMITTER



Specifications:

- 8 agile channels
- Microphone input
- Video control adjusting
- SMA connector
- Video input 1 V
- 7.5 V – 14.4 V DC supply
- 150 mA current
- 80 mW rf power output/12 V
- FCC approved