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REALTIME AERIAL VIDEO TRANSMISSION FROM A UAV PLATFORM TO A GROUND STATION

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Abstract: *The perspective of UAS in today's dynamic battlefield is briefly presented in this paper, followed by the description of a project that was conducted to illustrate the potential of a very cheap UAS. The main goal of this project was to successfully perform realtime video data transmission from a UAV platform to a ground station. This project represents a cheap possibility of acquiring Imagery Intelligence (IMINT) about an objective. If further developed, a number of improvements and upgrades could be implemented, that would extend the radius, payload and broaden the missions that this project can perform.*

Keywords: *UAS, video transmission, dynamic battlefield*

1. Introduction
The importance of using remotely controlled and unmanned systems in battle

1.1 Using remotely controlled and unmanned systems in battle

Ever since humans first started to wage wars against each other, there were certain aspects that they were considering: means of inflicting damage, means of protection from damage, and means of collecting intelligence. From spear and sword to bow, crossbow and rifle and from leather armor to steel breastplate, Kevlar vests and tanks, the devices of war were improved over the course of history. The next step in that improvement -- unmanned and remote controlled assets -- offers the perfect solution: a means to collect information and inflict damage while offering their user complete protection from the enemy capabilities of inflicting damage. The development of Unmanned Aerial Vehicles could revolutionize warfighting, since the full range of capabilities is still under research and testing. The military could be presented with the option of accomplishing certain missions more efficient at lower costs and with minimal risk to the fighting force. This paper will analyze the advantages and disadvantages of using unmanned and remote-controlled assets, and how their use might change the way war is waged.

Self preservation causes humans to distance themselves from potential damage: first, behind a layer of armor and shield, then inside a tank, on their way towards putting more and more distance between them and the damaging factor. The endpoint of that was creating a way to inflict damage while not being exposed(remotely). Remote controlled military robots were first used in World War II, such as German "Goliath Tracked Mines" – remote controlled demolition vehicles and Russian "Teletanks" – radio controlled tanks. Their main purpose was to inflict damage on the enemy while minimizing exposure to danger of friendly troops. The tracked mines were used to deliver an explosive payload without endangering personnel or scout a mined field. Teletanks were used in a similar way: a normal tank crew was using radio control to drive the teletank ahead, so that it would draw enemy fire and thus not endanger the tank crew using it. The technology used was rudimentary compared to what we have available today, with only a limited set of commands that could be relayed through the radio remote control. Since then, the technology changed, was improved and expanded, its usability was broadened, but its purpose remained the same: to avoid taking damage and gain the capability to inflict damage remotely.

Robots can accomplish a broad spectrum of missions and be potentially more successful, assuming proper supervision by a human agent, than the classic human approach to accomplishing that mission. Examples of such missions are protecting perimeters (sentry duty), collecting intelligence, clearing rooms and not ultimately, active implementation in inflicting damage on the enemy or his assets. As stated by "http://www.spectrum.ieee.org" one such use of a sentry robot will be implemented in South Korea on border protection. The SGR-A1 robot is capable of detecting human border violators using its sensors, and can, if required, relay a message to them (telling them to stop and wait to be arrested or be shot). Tests have shown that the robot is capable of very accurate shots. Should an order to shoot be given by a human supervisor, the sentry would stop anybody from trespassing into the defense perimeter. These robotic sentries can become a better alternative to the use of human guards, since it will present multiple advantages. The cost of protecting the border will be drastically reduced, since it would require fewer personnel, just some supervisors that would remotely be in contact with the sentries in order to provide human input. Also, in case of a potentially aggressive act, the personnel would not be put in any danger. Even though this seems like a wonderful solution, there are some potential vulnerabilities: energy dependence, and susceptibility to jamming and/or overriding. The technical aspects of logistics in this case should be taken into consideration: How will the robotic sentries be powered? Also, other important characteristics are the political and legal aspects. What happens if children walk in the area protected by the robot sentries and they get shot due to a glitch in the system? What happens if someone reprograms the targeting algorithms of a few sentries? All these are important consideration that could influence the success of employing robotic sentries to accomplish such a mission as border protection.

In order to broaden the array of missions that robotic assets can be used for, a new concept is developed in the area of robotics called "swarm system robotics". As per "http://www.guardian.co.uk" specific research is directed towards swarm system robotics – small to medium sized robots capable of performing a specific mission such as clearing a building or keeping an area under surveillance faster and with increased effectiveness. The increased redundancy due to the large number of robotic assets (swarm) ensures a higher mission success rate and also a higher mission execution quality. By having a swarm of robots scout an area or a building you avoid endangering putting personnel in a potential harmful situation (booby traps or snipers). Also, in dealing with today's unconventional warfare, this system might prove very useful in tracking down insurgents due to its increased capability of scouting large areas really fast. The current research in programming swarms of robots to interact and accomplish elaborate tasks is very complex and progress slowly, but there is untapped potential that could prove extremely useful in accomplishing today's missions.

The unmanned and remote-controlled assets that are most used today in both passive and active missions are UAVs. Technology advancements increased their feasibility through new sensor and propulsion systems as well as payload options. These advancements allow UAVs to have increased endurance, to become smaller, more reliable, and capable of carrying more ordinances. As described in "http://www.af.mil" there is still plenty of space for improvement regarding communication link between the UAV and the UAV pilot. Such errors (when the link is interrupted) are dealt with through specific autonomous programming that allows the UAV the remote pilot has lost contact with to fly a certain pattern until the link is re-established, or to return to base in case the link is not reestablished. This vulnerability could also be exploited by the enemy through jamming the signal, or even through remotely overriding it and potentially hijacking the UAV.

Another important aspect of using UAVs is their reach and high mobility. It is easier to dispatch a UAV to search a certain area for a target or to deal with a certain threat that it would be to dispatch personnel. The high endurance that UAVs are capable of simplify the logistical effort necessary to conduct such operations.

Using robotic assets might also have a strong political impact through increasing public support. Public support of a war decreases when there is a high number of US causalities or collateral damage that costs human lives (easily noticeable the campaign in Iraq and Afghanistan). Robotic assets would be more expendable, and if they were lost, it would not trigger important public reaction, since nobody would be losing members of their families to the war. Also, there would be less civilian causalities due to collateral damage, since robotic assets would be more capable of increased accuracy in delivering payload or lethal force. This can be seen through wars that as technology advanced, it allowed continuously increasing target discrimination, from the World War II indiscriminate carpet-bombing to smart bombs capable of taking out one specific room inside a building in order to eliminate an important target today.

Even though it seems that due to the continuous technological progress, there will be a time in which we will be able to conduct military operations without endangering humans, that could just as easily backfire and have consequences similar to the ones we tried to avoid in the first place. Any automatic or autonomous system could have bugs that went undiscovered throughout the entire testing process, or could simply be tricked by a potential enemy into mistaking the target and unleashing a lethal ordinance over civilians, or even friendly forces.

A state that relies mainly on technological assets has a high vulnerability to weapons capable of creating an Electro Magnetic Pulse. As stated in "http://www.globalsecurity.org" an electromagnetic pulse produces very high transient voltages on electrical equipment (such as radio and computer equipment, and electronics required to maintain an uplink to the remotely controlled robotic asset as well as electronics that are vital to the navigation system of the robotic asset). This irreversibly damages the said equipment and could potentially interdict the use of robotic assets. The most feasible way of creating such an electromagnetic pulse is a nuclear explosion. Even a small yield nuclear detonation would be enough to damage electronic equipment over an extended area. This vulnerability should not be seen as a certainty, since there are ways of shielding devices from an electromagnetic pulse. It is just another level of the fight to create a weapon and to create a defense against it, similar to World War II: bigger guns leads to thicker armor which leads to even bigger guns and so on. In any area of development, when referring to weapons, there is always a connection between a way to inflict a certain type of damage in a certain way and a way to defend against that type of damage.

1.2 Implementing unmanned aerial systems

The next step in the overall advancement of the military and the ways wars are fought today is large scale implementation of unmanned aerial systems. These new Unmanned Aerial Systems offer capabilities such as collecting intelligence, surveillance, reconnaissance and delivering payloads. If further research and development is pursued, new capabilities might be available for the Unmanned Aerial Systems, such as air supremacy, and counter-air. Due to the survivability, low cost and decreased risk to the operator we should make the transition from manned aircraft to unmanned aerial systems.

The survivability factor of the Unmanned Aerial Systems refers mainly to the crew survivability. When using an UAS, the operator is at a certain distance from the actual theater where the UAS is being used. That is minimizing the exposure to danger of the pilots, while preserving their experience in case they ever get shot down by enemy forces. If manned aircraft would have been used, then the pilot would either die in the crash, thus making us unable to use his experience, or eject, and then additional resources would have to be directed for his extraction. Also, I will add the possibility of his capture, and of critical information being extracted from him, increasing the risk of the entire operation.

Another factor in which Unmanned Aerial Systems excel when compared to the manned aircraft is endurance. The first limitation of manned aircraft is fuel flight time, and second is crew limitations. The crew limitations can be either in number of sorties that crew members can fly and be efficient, the G forces they can sustain, the altitude they can fly at. An UAS does not need a life support system for the pilot, thus increasing its endurance since removing the life support decreases the overall weight of the system. Also, not being limited by human resistance for the G forces, the turn radius and maneuverability can go up and be superior to any manned aircraft.

Some concerns have been voiced over the fact that the absence of a human element in the midst of things, with the UAS, overseeing the entire situation could have more complicated ramifications than it was initially thought. That is why the Unmanned Aerial Systems will be monitored from the main base by human operators, and important decisions, such as whether to drop ordinance over a target or not will be made by humans. To try to counter this, there is the question: What happens when the connection, either satellite, or radio or the specific connection to the UAS is broken. In that case, today's Unmanned Aerial Systems have autonomous programming that allows them to fly a pre-defined pattern until the connection is reestablished, or to return to base.The information security will have to be enhanced, in order to prevent our own UAS system from being hijacked by enemy forces. That can be accomplished by high-power encryption of the data transmitted to and from the UAS. Another danger, that can affect both unmanned and manned aerial systems, is the Electro Magnetic Pulse. This weapon is still in development at this time, but it needs to be taken into consideration, since it is a weapon that can be very effective against any system that contains any electronic part. The potential vulnerability against this weapon is equal in both the case of an unmanned aerial system or a manned one.

Secretary of Defense Robert M. Gates addressed the audience at the Air Force Association's 2009 Air and Space Conference and Technology Exposition in Washington, D.C., Sept. 16, 2009, and stated that:

"UAV potential based on today's systems to judging manned aircraft based on the Wright Brothers Flyer; Large numbers of increasingly capable UAVs - when integrated with our fifth-generation fighters -- potentially give the United States the ability to disrupt and overwhelm an adversary using mass and swarming tactics, adding a new dimension to the American way of war; In future years, these remotely-piloted aircraft will get more numerous and more advanced, with great range and the ability to fight as well as survive"(http://www.af.mil/news/story.asp?id=123168156)[5,6].

Regarding the same subject, but referring broadly to use of robots, Major Kenneth Rose of the US Army's Training and Doctrine Command made references to the advantages of using robots in the military: "Machines don't get tired. They don't close their eyes. They don't hide under trees when it rains and they don't talk to their buddies ... A human's attention to detail on guard duty drops dramatically in the first 30 minutes ... Machines know no fear." (http://news.bbc.co.uk) [7]

The transition to the Unmanned Aerial System is going to bring along important changes in the way a war will be waged, and the way the resources will be used to accomplish the mission. The combination between human ingenuity and creative thinking along with the advantages that the Unmanned Aerial Systems offer is going to optimize the warfighting capabilities and minimize the personnel causalities.

2. Realtime video data transmission from a UAV platform to a ground station

2.1Project description

The main goal of this project was to successfully perform realtime video data transmission from a UAV platform to a ground station. The military use for this project is the cheap possibility of acquiring imagery intelligence (IMINT) about a specific objective. For this project I used a radio controlled aeromodel. On this platform I mounted a wireless transmission camera (280C) and a 9 V battery as a power source for the camera. The camera and its power source were placed in specific load points in orded to maintain the stability of the aeromodel and ensure a fixed viewing angle for the camera.

I first performed a live video transmission on the ground to check if there are any signal interferences altering the video data signal. The test consisted of placing the wireless camera near the aeromodel's motor, establishing the video link between the camera and the ground station and starting the motor. The conclusions of this test were that there were no interferences and the transmission was uninterrupted.

I conducted three flight tests and tested the wireless data video transmission while airborne. After each test I operated small adjustments in order to improve specific aspects of the transmission.

The first test was performed at 1700 using a standard 9V battery. The battery measured voltage was 7.89 volts (due to the battery being a little old). The conclusions were as follows:

- Transmission radius was considerably reduced (radius was about 30 meters);
- Ambient light was too low (due to time being 1700 on wintertime) and the video was too dark;
- The realtime transmission had a 3-5 second delay due to a problem with the software used for video capture;
- There were no visible interferences due to the motor powering the aeromodel;

The second test was done at 1500, using a brand new 9V standard battery (the battery measured voltage was 9.87 V – bigger than the previous 7.89). The conclusions of this test were as follows:

- The transmission radius increased (to a radius of about 50 meters);
- Ambient light was very good – resulting in good quality video
- Realtime transmission was performed with no delays as a result of changing the video capture software;
- There were no visible interferences due to the motor powering the aeromodel;
- A brief loss of video signal during a barell roll – due to obstructing the transmission line between the emitting and the receiving antenna.

The third test was conducted at 1540, using a brand new 9V standard battery (battery measured voltage was 9.63V). The conclusions were as follows:

- the transmission radius remained at 50 meters;
- ambient light was good;
- good realtime transmission again, with no delays;
- no interferences;
- better viewing angle due to repositioning the camera to another location on the body of the aeromodel;
- the same brief signal loss when doing a barrel roll.

Fig.1 Picture taken from the first flight test

Fig.2Picture taken from the second flight test

Fig.3Picture taken from the second flight test

Fig.4Picture taken from the third flight test

2.2 Materials used for this project

Fig.5The aeromodel used for the project

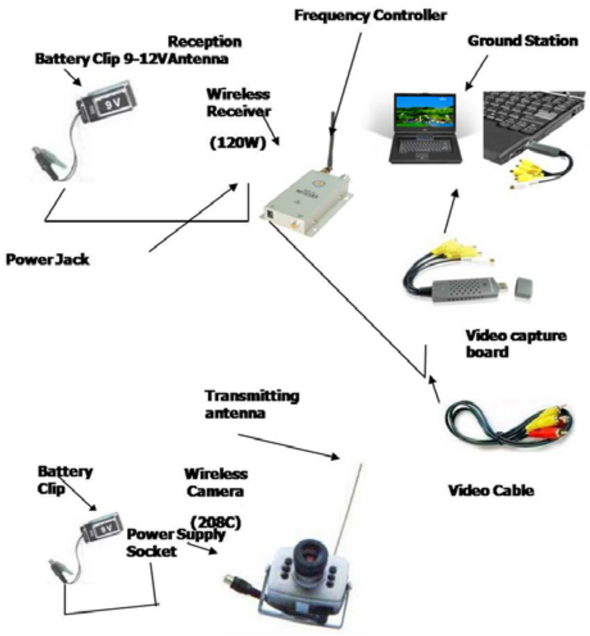
Fig.6 Remote control used for controlling the aeromodel

Wireless Video Camera 280C

Technical specifications:

The 280C CMOS Wireless camera offers a medium quality video transmission. The most important aspects of this wireless camera is that it has a decent transmission radius, it is very small and it has a low weigth and power consumption.

208C – 120W Connection



208C Video camera Specifications:

Receiving Radius	Up to 300m direct LOS
Resolution	380 lines
Scan Frequency	EIA: 60 Hz
Minimum lighting	2 LUX
TV system	NTSC
Output power	200 mW
Power supply	DC 8V, 9V/12V
Energy consumption	< 960 mW
Dimensions	25 mm x 33 mm x 33 mm

Receiver dimensions	59 mm x 115 m x 20 mm

Producer specifications for the video capture board:

- - 4 video inputs
  - 1 audio input
- Capture specifications:
  - Resolutions: 320x240, 352x288, 640x480
  - Framerate: custom from 1-30 fps
  - Compression: MPEG4
  - PAL, NTSC, SECAM
- Minimum system requirements:
  -OS: Windows 2000 or later
  -CPU: Intel Pentium 4 or Equivalent
  -HDD: 5 GB HDD Space
  -RAM: 512MB
  -Display: Windows with minimum resolution of 1024x768
- USB: 2.0 and USB powered

Any laptop or PC can become a ground station after the video capture board is connected and its drivers are installed. The software can be used for direct in-flight observation and it can also be used to record everything that the camera sees in a file on the HDD.

Costs:

Specific Part	Price (RON)
Kit Wireless Camera208C(camera + Receiver)	176
4 channel DVR USB 2.0 Easy Cap	116.76
Futaba FF-7 (T-7CP) 2.4 GHz F7029	1190

Specific Part	Price (RON)
TR 35-30C 1100kv Brushless Outrunner	57
Turnigy AE-25A Brushless ESC	33
Servo micro SG90, 9.6 g/1.3kgcm@4.8V (X2)	47
Rechargeable battery NiMH 9.6V/ 1100mAh KAN	72.5
Rechargeable batteryNiMH 4,8V/ 350mAh (KAN)	27
Materials and work for aeromodel body	100
TOTAL PRICE	1 819.26

This project was a success and it accomplished its goal – that of performing realtime video data transmission from an airborne UAV platform to a ground station. The tangible result is a tool that can be used in acquiring imagery intelligence. The following improvements and upgrades can be implemented in the further development of this project:

- *Lower the minimum speed and increase the payload through using another UAV platform (better geometry that offers better lift and stability)*
- *Increase its radius by using a more powerful emitter (sending data via satellite is an option)*
- *Increase the security through signal encryption*
- *Implementation of a GPS navigation module*
- *Improvement of the sensor by replacing the camera that was used with a better one having a bigger resolution and a larger field of view. Night vision and a zoom function are options.*
- *Adding new sensors to collect and transmit flight and vehicle information (such as attitude, airspeed,, altitude, battery power)*

3. Conclusions

This area of development is at its beginning; the same way many other areas were just a few decades ago. The Marechal Fardinand Foch, a french strategy professor at the "L'Ecole Superieure de Geurre" (The French Superior War College) said about airplanes that "Airplanes are interesting toys but of no military value."(www.permanent.com/quotes.htm) History proved him wrong. The submarine was first imagined by a science fiction writer, Jules Verne, and it proved to be a versatile weapon less than 30 years later. Nobody can claim they know exactly what direction will the warfare methods take, but the contemporary trends can be analyzed and conclusions regarding those trends can be drawn. The today's trends in warfighting methods tend to lean more and more towards the use of robotic assets, and significant improvements are made in those areas. It seems that combat methods evolve towards minimizing human losses, maximizing accuracy and precision, combined with an overall fine-tuning of those methods, in order to achieve maximum efficiency.

The UAVs acquire informations through sensors, they evaluate the information acquired and act in accordance with their programming. At the same time, the acquired information is relayed to the human operator, and he can relay back instructions in case of an unforseen situation not included in the programming.the means of communication, the means of generating power for the various subsystems, the sensors and the decision factors (microcontrollers and computers) have been improved and their size was reduced due to technological advancements in design and manufacturing. All these improvements contribute to the increase of the autonomy, the payload and the radius of the UAV. Research conducted in areas such as AI (Artificial Intelligence) and Neural Networks will lead in the near future to a further increase of the autonomy and the type of missions that the UAVs will be able to perform.

The integration of robotic assets into the armed forces should be seen as exactly what it is: integration, not some kind of replacement. In order to employ the robotic assets towards protecting human lives, we should strive toward balance: integrate the human assets with the robotic assets in such a way as to minimize human losses, and at the same time maintain control and close supervise the robotic assets that we have at our disposal. Too big a deviation towards either dismissing the robotic assets or towards overemphasizing them could lead away from the goal of minimizing causalities both military and civilian. A balanced combination between the human assets' ingenuity and potential along with the robotic assets' precision and accuracy would ensure the optimization of warfighting capabilities and minimization of personnel causalities.

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