THE EVOLUTION OF UNMANNED AERIAL VEHICLES

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Abstract: *Unmmaned aerial vehicles offer the advantage of flexibility and modularity of constructive and use concepts in the context of modern airspace and specific regulations inadequately adapted to reality. Operational requirements and limitations cover the UAV's technological path from design to entry into service, taking into account both manufacturing technologies, costs and materials as well as flight safety and maintenance aspects. The article offers an overview of the evolution of unmanned aircraft with aspects regarding the Romanian civil and military market.*

Keywords: *Kattering Bug, D-21- ShunkWorks, RQ-1 Predator, Shadow 600*

Abbreviations

SAM	*- surface to air*	*BRAA*	*-Air Defense Recognition Bureau*
UCAV	*- unmanned combat aerial vehicles*	*UGV*	*-unamnned ground vehicles*
USV	*- unmanned surface vehicles*		

1. THE EVOLUTION OF UNMMANED AERIAL VEHICLES

1.1.First projects

The first UAV projects came up with the pilot flying. Using the radio waves, the so-called "Aerial Target," a model speculated as a Zeppelin reaction weapon, was manufactured in the UK. Subsequently, the remote piloting technique began to develop, so that Hewitt Sperry's automatic aircraft, nicknamed the "flying bomb", became representative due to the fact that its gyroscope was used in its control system (1917), [1, 2, 3]. The first unmanned aerial aircraft on board were used as "air torpedoes" during and immediately after World War I. Americans talk about inventor Charles Kettering with his invention of the "aerial torpedo" called the Kettering Bug (1918), see table 1. Being a premiere at the time, this unmanned airplane onboard was able to launch a bomb, see Figure 1, [2, 4, 5].

The construction of the British-based "Queen Bee" ended many unsuccessful attempts during the First World War. This version is an unmanned version of the De Havilland DH 82-th Tiger Moth (mainly used as a target aircraft). Radio-controlled, it was modernized, between 1934-1943 by the British Royal Navy [7], see figure 2.

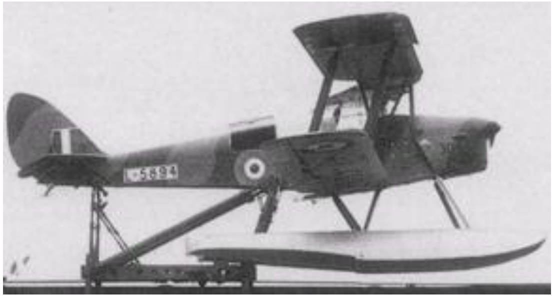
Also around this time, British actor Reginald Denny was the owner of a UAVs factory called "Radioplanes." This factory also produced unmanned airplanes for use as targets for troop training.

The OQ2 was equipped with two opposite-rotation propellers (to defeat the torque). Command control was done through radio waves, and the launch was done with a catapult, [2, 8]

Table 1. Kettering Bug, technical data, [27]

Data	Value	Data	Value
Span / Length / Height	4,5 / 3,8 / 2,3 m	Range	121 km
Cruise speed	80 km/h	Weight	240 kg
Powerplant 1x V4 piston engine		40 HP	

Fig. 1 The Kettering Bug



Fig, 2 De Havilland DH-82B [6]

German engineers from the Second World War worked intensively on this segment. They designed and developed the V-1 "Buzz Bomb" and V-2 (Figure 3). These systems used electronic equipment for the first time, being mainly used in theaters of operations in the UK with more psychological impact [7]. However, their operational results have prompted Allies to implement a large-scale air defense system. In addition, the Henschel HS 293, Fritz X and the *Enzian* missile were also used. The last two have been used very effectively in combat, especially in the Mediterranean theater of operations, see figure 4 and table 2.

Table 2. Henschel HS 293, technical data, [28]

Data	Value	Data	Value
Length	3,82 m	Range	2,2 …8,5 km
Speed	936 km/h	Weight	1045 kg
Power plant	Rocket engine	5,9 kN	

Fig. 3 V1 „Buzz Bomb", [7]

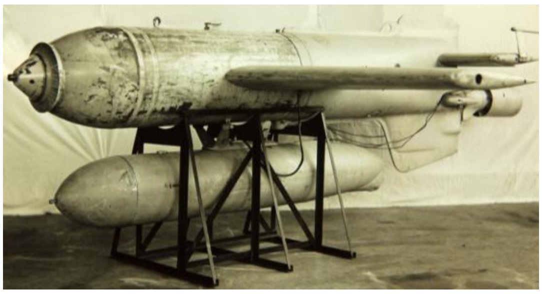


Fig. 4 Henschel HS 293 bomb, [14]

1.2. UAV evolution in postwar period

After the war, the Americans took over the project and developed it, imitating the "enemy targets", used both to prepare pilots for hunting and to prepare soldiers in antiaircraft artillery. Initially, in the Vietnam War, aerial research was carried out with the help of pilot airplanes on board.

They went after bombers and hunting aviation, many of them being shot down by Soviet-ground SAM missiles. As a result of these losses, the unmanned aircraft solution was imposed on board. Thus, on October 6, 1968, SB-12 flew to North Vietnam in reconnaissance missions. Thanks to the success, the range of missions made with this new model has increased, being used not only as a target, but also as a research aircraft. The airplane was powered, radio waves, with a rudimentary navigation system, with a first-generation onboard computer (controlling the camera). The airplane's recovery system was primitive (a pilot plane took the UAV from the flight at the time of parachute, and was then transported by air to an airbase using a helicopter). Due to lack of processing equipment, the film was sent to the US for development. This film trail, from the moment of the photos were executed and until they reached the table of the Pentagon commanders, lasted a few days, when the situation on the ground changed most of the time. This required the use of cameras and television systems. The monitoring point was in the C-130 plane fuselage (fly near the target to be monitored). The Ryan Firebee model was successful, resulting in the Ryan Model 147 Lightning Bug. And later on carried out research missions over North Vietnam, China and North Korea during 1960-1970, see Figure 5. The war in Vietnam has opened a new stage in the use of these systems. There have been 3.435 missions over enemy territory, shooting missions, electronic reconnaissance, passive jamming, communications and launching of manifests. With their help, the SA-2 missile routing signals were received and passive and active protection measures could be taken.

Fig. 5 Lighning Bug

Fig. 6 D-21- ShunkWorks, [10]

Technological advances in these devices declined after the withdrawal of US troops from Vietnam for nearly a decade, even if the espionage missions of the following years occurred in Russian and Cuban airspace. Thus, the CIA has boosted the field study by inviting Lockheed Martin to produce new types of research systems. The technological experience gained from the use of the SR-71 aircraft has led to the design and development of the D-21 "ShunkWorks" unpiloted model. Launched from the SR-71 platform, it has greatly enhanced technical-tactical performance. The model was used in espionage missions over China, (see Figure 6), and table 3.

Table 3. D-21- ShunkWorks, technical data, [29]

Data	Value	Data	Value
Span / Length / Height	5,79 / 12,8 / 2,14 m	Range	5550 km
Speed	3,35 mach	Service ceiling	29000 m
Engine	Marquardt RJ43-MA-20S4 ramjet		6,67 kN

Electronic image transmission technology was not developed at the time, so data was not transmitted in real time. The photo film followed the same awkward tracking and recovery route used in Vietnam.

As a result, the accuracy of recovery of the collected information material was deficient, which caused many problems in the planning and execution of the missions. Moreover, D-21's navigation system did not provide accurate data. Due to these conditions and accidents occurred in July of 1966 (when the UAV collided with a SR-71 in flight), the entire development program was canceled.

"The concepts of use have evolved both in terms of operating techniques and technological development (propulsion mode, flight duration and height, on-board research or on-board electronic warfare technology, navigation systems, transmission ground or satellite data, invisible structure by radar and / or IR, launch and recovery mode)"[9].

Due to the conflict, the Middle East area has been the area where acceleration has been accelerated. Israel's decision-makers have very well understood the role of UAVs in air operations in missions prior to piloted aviation. UAVs were mainly used to inform the battlefield, focusing on target recognition and evaluation of the results of the attacks. This fact was also recognized by Americans.

In early 1970, Israel used the American model "BQM-74" as”bait" (simulating combat aircraft flight) for Arab rocket troops (see Figure 7). Some UAVs have been knocked down, but the Israeli hunting-bombing aircraft has succeeded, with the support of these systems, to annihilate the launch ramps of the enemy pretty soon. The tactic was later used in the first Gulf conflict, more precisely at the Kuwait border with Saudi Arabia.

The UAV battle technique has been concentrated in groups of three flight vectors. Launched at short intervals, many lives and a lot of destruction techniques were saved in the initial hostile triggering phase.

Fig, 7 BQM-74, [15]

With all initial mistrust, Pioneer airplanes have provided real-time video images to senior allied commanders (over 700 hours in the pre-flight period and over 1,000 hours during the conflict). This tactical advantage triggered a change in the optician's use of these systems, ultimately in the thinking of military strategists. With the help of the Pioneer system, shipbuilding craft corrections were made in the US Naval Fleet, resulting in very effective target accuracy and, moreover, a novel fact "was the first time in history when the man surrendered to a machine ... the Iraqi they waved white flags when they noticed a UAV ".

We can assert with certainty that the Pioneer system has psychologically influenced the Iraqi army by the fact that, upon its appearance or only the noise produced by it, the soldiers gave up fighting; knowing very well that following the flight there will be intense shooting of artillery or allied missiles in the deployment area, [19, 20].

"The lessons learned from this conflict have generated the major directions that will be taken into account in the design of future UAV models" [9]. The development program continued after the first Gulf conflict when General Atomics Aeronautical Corporation designed the Predator at El Mirage, California.

The new generation UAV has a much broader range of radios, delivering real-time video from virtually anywhere in the world. Given the complexity of the system, the initial production was one copy per month.

The model was exploited in combat missions in the Yugoslav conflict as part of the IFOR (NATO) component of the Air Force Commands.

The notoriety of this system has led the US to establish the first UAV squadron "Squadron 11 Scouts". The Photographic Recognition Section of the US Pentagon and Department of Defense was named the Air Defense Recognition Bureau (BRAA). Gender. Maj. Kenneth R. Israel - USAir Force said in a film interview that BRAA's main theme was extensive recognition so that it could provide the military with "clear, timely, timely information when the fighter requested it at any time of the day, at all times.

"The Predator system was also used in non-military missions, but the focus was mainly on military missions. Two appliances were lost in Bosnia, but social implications were non-existent (cost: 1/6 of the price of an F-16).

1.3. The evolution of UAV's in modern age

The real battle UAVs only came to their end at the end of the 20th century and the beginning of the 21st century, when for the first time on the world, on 16.02.2002, a rocket launched from a UAV (RQ- 1 Predator), see figure 8. As Eric Adams also said "then it was the unmanned combat air vehicle" (UCAV). After the campaign it became clear that unmanned aerial vehicles on board are the weapon of the future.

The experience of the conflict in Bosnia and Afghanistan has not been limited here, so the famed Global Hawk product of Teledyne Ryan has been designed. This model uses the most advanced technology in the industry. This also led to an astronomical increase in the delivery price (a full US $ 35 to $ 50 million), thus achieving "equality" in terms of delivery prices for human-on-board airplanes. The model was later perfected by Americans and Europeans, resulting in the "EUROHAWK" model.

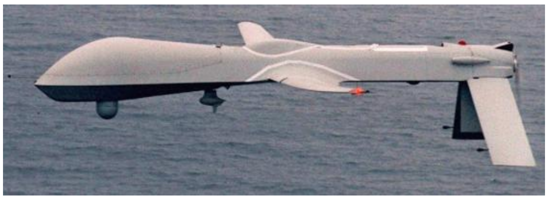


Fig. 8 RQ-1 Predator, [11]

Fig. 9 Air Target [12]

2. ASPECTS REGARDING THE DEVELOPMENT OF UAV'S IN ROMANIA

According to [12], the first uses of unmanned aircraft are dated from 1981 as aerial targets (Figure 9), and table 4, being equipped with only a remote radio control system, and between 1986 and 1997 a VR- 3 Reis, Soviet production, see Figure 9.

Table 4. ATM 1, technical data, [30].

Data	Value	Data	Value
Span / Length / Height	2,6 / 1,75 / 0,58 m	Range	3000 m
Min / max speed	35 / 190 km/h	Service ceiling	2800 m
Weight	8 kg	Automomy	0,75 h
Power engine	26 cmc	1,7 HP	

The first concrete actions on modern, unmanned aircraft in Romania were undertaken in 1997 when negotiations on the acquisition of Shadow 600 (see Figure 10), worth USD 20 million, were negotiated. There are currently systems in place, replacing URSS-type VR-3 models [12], see Figures 10 and 11.

Fig. 10 VR-3 Reis, [13]

Fig. 11 Shadow 600 [16]

Although no official data has been published, some analysts believe that UAV- was used during the events of December 1989 in Romania. According to [17], the evolution of the number of unmanned aircraft is highlighted in the chart in Figure 12, Romania being advanced and experienced in the use of UAVs and making efforts to align national legislation with the European one.

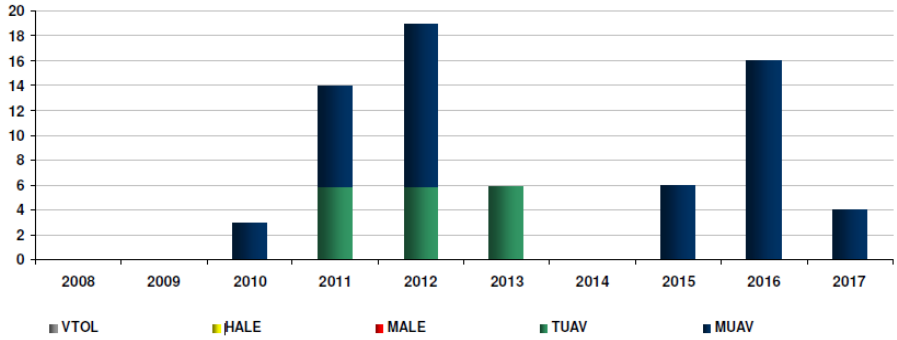


Fig. 12 Romanian UAV market evolution, [17]

Currently, the civilian market still offers moderate opportunities for UAV use, although concerns can be noted in the research area and uses for monitoring areas and events of interest, mainly using multicopter drones, see Figure 13, and table 5, [21, 22].

a b

Fig.13 Comercial multi-copter type: a. DJI Phantom 4 Pro [21], b. DJI Inspire 2 [22]

Table 5. DJI Inspire 2, technical data, [31].

Data	**Value**	**Data**	**Value**
Max speed	108 km/h	Service ceiling	2500 m
Weight	4 kg	Power	4 x electrical
Misions	Image aquisitions	Autonomy	0,5 h

Unscheduled aircraft research projects are finalized or under way at civilian and military research institutes such as: INCAS Bucharest [24, 33], see figure 14a and table 6, IMSAR Bucharest, ACTTM Bucharest or civilian and military higher education institutions: *Politehnica* University of Bucharest [26] see Figure 14b, The *Henri Coandă* Air Force Academy in Braşov [23], these institutions having the role of coordinator or partner in projects.

Table 6. IAR+T, technical data, [32, 33]

Data	Value	Data	Value
Max speed	180 km/h	Range	10 km
Weight	20 kg	Power engine	4,1 HP
Autonomy	0,5 h		
Misions	Image aquisitions, airborne laboratory, military training		


a

b

Fig.14. a. IAR-T (INCAS), [24, 33], b.UAV-DUAV (Poltehnica Bucureşti), [26].

3. CONCLUSIONS AND FUTURE DEVELOPMENT DIRECTIONS

Future development directions for unmanned aircraft are marked both by a number of operational requirements and limitations, as well as by national and European legislative coherence [17]. Operational requirements and limitations cover the UAV's technological path from design to entry into service, taking into account both manufacturing technologies, costs and materials as well as flight safety and maintenance aspects [18]. According to [20], unmanned aircraft have a number of attributes (persistence, penetrability, versatility) that give them far more exploited advantages, which is why we can notice a series of trends in the development of unmanned aircraft, the most important being: (UAV-UAV, UGV-UAV, USV-UAV) with the concept of *"smart sensor"* and *"sense and avoid"*.

We can conclude that unmanned aircraft offer the advantages of the flexibility and modularity of constructive and use concepts in modern airspace and specific regulations not sufficiently adapted to reality.

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