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Why Unmanned Aircraft Systems Failed for a Century?

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Abstract— Unmanned Aircraft Systems (UAS) will be the dominating force multiplier of the future air power. When the background of the technology and concept is researched, it can be seen historical systems complying with modern description of UAS started almost at same years with manned aircraft. UAS used in different operational functions such as intelligence reconnaissance surveillance (ISR), air to ground attack, electronic warfare, suppression of enemy air defense (SEAD) etc. in history and never followed an uninterrupted development line. UAS world today seems to be reinventing these concepts. This paper is trying to analyze the reasons of failures of many projects of the history. Determining the factors preventing the success of historical UAS, may provide a different point of view to planners, decision makers, UAS industry and scholars for current UAS development and procurement phases.

Index Terms— Aviation History; Remotely Piloted Aircraft (RPA); Remotely Piloted Aircraft; Unmanned Aircraft Systems (UAS); Unmanned Air Vehicles (UAV); Defense Projects

1 INTRODUCTION

FOR the engine driven, heavier than air and controlled first flight, either considered as realized by Gustave Whitehead in 1901 [1,2], or realized by Wright Brothers in 1903 [3], manned flight and unmanned flight started almost at the same time.

However, it was only in 2000's that UAS considered as a force multiplier, determined as an operational requirement which leads to procurement or research & development projects widespread. Popular subjects for scientific studies on UAS are mostly emphasizing future operating environment or possible civilian applications in the future. Contrarily, this study is an attempt to find the reasons of the failure (not becoming widespread, lacking behind at development/concept, cancelled projects etc.) of UAS flight that started together with aviation history.

"The rapid, at times almost chaotic, development of UAS over the last 10 years has led to a range of terminology appearing in both military and civilian environments. As a result, some legacy terminology has become obsolete, while differing national viewpoints have made it difficult to achieve standardization on new terms." [4]. In order to prevent misunderstandings, meaning of some basic terms of UAS and what they represent within the frame of this study handled briefly in Part II.

Part III, determines the criteria to choose if they can be admitted as UAS in accordance with the definitions summarized at Part II and eliminates amongst a list of historical aircrafts. Today's UAS are not part of this study, only addressed to compare or inform if needed.

Continuing parts examined the picked UAS in more detail to find out the reasons of failures. Reasons of the failure of historical UAS, arranged as main and sub factors. Those factors and their effect on whole system explained from technical, structural and operational points of views.

As a result, it was interesting to find out that many of the so called "new concepts" for UAS such as, arming the platforms, manned-unmanned cooperation and even air-to-air attack were operationally tried and abandoned many years ago. The method

and approach for analyzing the historical UAS used during this research can be suggested as an alternative tool for planners and decision makers for analyzing current systems' incapability, to predict the operating environment of future.

2 UAS TERMINOLOGY

In addition to the UAS term used by Federal Aviation Agency (FAA), US Department of Defense (DOD) and Turkish Air Force, literature contains other terms such as Unmanned Air Vehicle (UAV), Remotely Piloted Aircraft (RPA), Unmanned Air Vehicle Systems (UAVS), drone etc.

Although terms used to define UAS have similar meanings, it should be noticed that they give clues about the approach towards the system. For example the word "drone" refers to an approach considering UAS as expandable and considers them as a weapon similar to cruise missiles. Another term "RPA" started to be used by United States Air Force indicates an approach of accepting UAS same as manned aircraft with the exception of being the pilot out of the aircraft.

The term "UAS" used by many authorities including FAA emphasizes a systematic approach and giving importance not only to platform (aircraft) but also to main subsystems like Ground Control Station (GCS), data link and communication structure, payloads etc.

An analyze of the terms used in chronological order proves the idea of term-approach correlation in both civilian and military literature. For example, Eurocontrol used the word

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UAV in a document called "Use Of Military Unmanned Aerial Vehicles (UAV) As Operational Air Traffic (OAT) Outside Segregated Airspace Specification" in July 26th. 2007 however in 2012 a document dealing with same subject switches to the term RPA as the name of the publication becomes "Eurocontrol Specifications for the Use of Military Remotely Piloted Aircraft as Operational Air Traffic Outside Segregated Airspace".

2.1 General

In this study, following FAA and Turkish Air Force term UAS is chosen to indicate the whole system. It seemed more proper to handle each unit and their relations with a systematic way of thinking. This usage and the idea behind it is to take all main subsystems and man power as indispensable parts of a whole UAS. FAA defines UAS as "A UAS is the unmanned aircraft (UA) and all of the associated support equipment, control station, data links, telemetry, communications and navigation equipment, etc., necessary to operate the unmanned aircraft." [5]

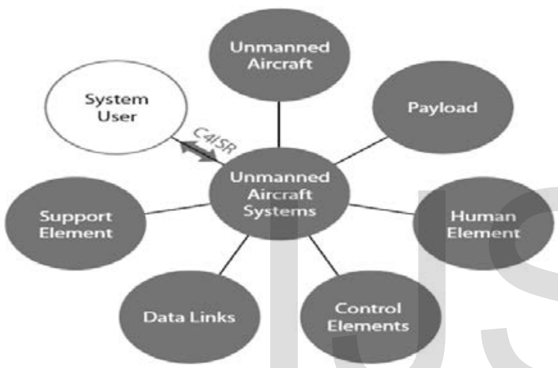

Fig.1. UAS components [6]

Fig.1 shows a general description of UAS. Similar figures can be seen in other sources with minor changes. Shown sub systems will be explained briefly below.

2.2 Unmanned Aircraft (UA)

"An Unmanned Aircraft (sometimes abbreviated to UA) is defined as an aircraft that does not carry a human operator, is operated remotely using varying levels of automated functions, is normally recoverable, and can carry a lethal or non-lethal payload." [4]

Various terms can be encountered to describe UA all referring the platform that actually flies, carries the payload and other equipment necessary for flight and mission.

2.3 Payload

"The total mass that can be carried or delivered by the specified rocket system or unmanned aerial vehicle (UAV) system that is not used to maintain flight." [7]

What is got from payload is the aim of the whole system. Once a reliable set of sub systems like unmanned aircraft, data link etc. acquired all the difference brought to mission quality depends on the sensor suite's quality.

2.4 Human Element

System is called unmanned, however, the most important sub system of an UAS is the human element. Crew necessary to operate an UAS depends on the operational concept and autonomy level, complexity, mission type of the design.

Attempts and studies to standardize and determine the licensing of UAS crew still continues.

2.5 Control Elements

Control interfaces and complexity, auto pilot capabilities and software hardware combination to help or self sufficiently operating the system has vital importance for UAS.

UAS's are categorized according to autonomy levels as human operated, human delegated, human supervised, full autonomous. [8] Such a categorization shouldn't be understood as the permanent operating concept of an UAS. It might be more proper to accept it as a capability. A full autonomous UAS does not necessarily execute mission without pilot intervention for example. Sometimes different levels of autonomy is necessary. In a loss of link situation for example an UAS that has higher autonomy level should recover more safely without or with minimum life and prosperity risk.

2.6 Data Links

Pilots flight command to flight surfaces or throttle are conducted via wires, hydraulic systems and other means of physically attached structures. A UAS pilots commands are send to UA by means of a data link. UAS data links almost always two sided ground to aircraft (commands, navigation data etc.) and aircraft to ground (telemetry, payload products etc.).

Data links of an UAS can be line of sight (LOS), beyond line of sight (BLOS) such as satellite communications (SATCOM) or both at same time.

2.7 Support Element

"Support element includes all of the prerequisite equipment to deploy, transport, maintain, launch, and recover the UA, and enable communications."[9]

Support element includes devices or systems varying from system to system. Generators, power systems, video disseminations systems, maintenance systems like flight line testers, ground equipment for take-off and landing are some of those equipments. Some UAS have image exploitation systems as part of the support element.

3. CHOOSING UAS TO ANALYZE

Since the early days of aviation. there has been hundreds of unmanned flight attempts and projects. This study does not claim to analyze all those studies and as many examples as possible that enough technical data can be retrieved are taken into consideration.

Many aircrafts, missiles or lighter than air vehicles can be categorized as UAS. In order to avoid such a mistake and determine the frame of the study, criteria implied to 74 different UAS listed below:

3.1 No Human On Board

Certainly the first criteria is having no human on board of aircraft. Any air vehicle that has a pilot or technician actually flying in it, is out of the scope of this study. However, convertible or optionally manned/unmanned vehicles are accepted as UAS.

3.2 Heavier Than Air and Rigid

Early manned, unmanned aircrafts and lighter than air vehicles were widely subject to scientific studies at the beginning of the 20th. century. Lighter than air vehicles, zeppelins, balloons either manned or unmanned are not subject of this study. This leads to the elimination of lighter than air vehicles. UAS that have a rigid structure are picked to analyze further.

3.3 Controlled Flight

Since the early stages of aviation controlling the aircraft became a major problem area. Researches to control the aircraft and designing control surfaces led to major development at aerodynamics, stability and material areas. This study takes only an UAS controllable into account. Controllability should be in all stages of the flight might exclude autonomous emergency procedures. UAS pilot should be able to control (controlling can be at different levels) and navigate the unmanned aircraft. An autonomy level of executing preplanned routes or predefined actions are also admitted as a kind of control.

3.4 Enough Data to Analyze

One the challenges encountered during the research phase of the study was obtaining the necessary technical specifications of the systems. Especially, data related to early unmanned systems were missing, controversial or even no technical data could be retrieved for certain systems. The study was planned the focus on technical details, operational concepts and the reasons of failure in past UAS. Historical debates and detailed research was out of the frame of this study so historical unmanned systems, technical data related to which are not sufficient had to be excluded from the study.

3.5 Propulsion System

An UAS should have a self sufficient propulsion system. Term self sufficient indicates that hand launched systems fly with hand launched engineless vehicles, early attempts like kites, primitive steam filled systems and gliders are not included to analyzes.

3.6 Not Expandable System

Flight profile of the unmanned vehicle should contain a controlled take off, controlled flight or navigation and a controlled landing. Systems that has an operational concept without landing phase and destructing itself like hitting a target, self destructing or free falling after mission execution are eliminated. UAS considered to be able to complete take off, execute mission or make a controlled flight and landing phases. This criteria eliminates cruise missiles and other expandable systems.

3.7 Aircraft Versions Meeting Criteria

Some UAS types are produced in series with minor design changes. All types produced in series are not included if version change does not contain a major change, especially related to criteria mentioned in this section. For example: AQM-37 Jayhawk is not chosen to analyze but the same UAS's 1000-1002 versions are chosen for being able to land.

3.8 Fixed Wing Aircraft

Rotary wing unmanned systems such as QH-50 are not included into analyzes.

3.9 Pre-1990 UAS

I. The First Gulf War (1990) can be admitted as the beginning of unmanned era of aviation, as unmanned aircraft began to be researched, invested and highly operated. Study will not cover the UAS of 1990's and later.

24 UAS from 74 UAS, met the criteria and used for further analyses.

4 PRE 1950 ERA

4.1 Curtis Aerial Torpedo N-9

Nicola Tesla's invention of radio control and Elmer Sperry's gyroscope made the unmanned aircraft a possible concept. Glenn Curtis an aircraft designer was involved in the project since the early stages. During the First World War, United States (US) Navy interested in the researches and the project started.

Operational concept of the system did not contain the landing phase but hitting at the target to destroy like a missile. There was also at least one flight including landing phase. "The Sperry team persevered and finally on March 6, 1918, the Curtis prototype successfully launched unmanned, flew its 1000-yard course in stable flight and dived on its target at the intended time and place, recovered, and landed, and thus the world's first true "drone." Thus, the unmanned aircraft system was born." [10]

Navy never got those UAS into service and US Army ran a similar project with Charles Kettering. Although a number of the system was purchased by army, they never became fully operational, either.

According the Stephen J. Zaloga main reason of the failure of the project was immature technology. "By 1918, it was evident that the technology of the day was not adequate to create a viable guided weapon, and the programs petered out." [11]

A more detailed analyze is "First, the experimenters had trouble launching the unmanned aircraft into the air. Second, the manufacturers found it extremely difficult to build a stable aircraft that flew well without a pilot. Limited aerodynamic knowledge, inadequate testing, and hasty construction of the machines caused basic aerodynamic problems with these early, unmanned flying machines. Third, technical problems plagued components such as guidance systems and engines, and this hindered program development. Fourth, the machines were fragile because they were built for one-way missions. Consequently, they were usually destroyed after a crash and

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this rapidly exhausted the supply for testing. Furthermore, these crashes provided little data for analysis to determine why the crashes occurred." [12]

It must be noted that project set up was too complex to be conducted for manned aircraft too within the level of the era flights conducted. Requirements were: designing an aircraft, using brand new technology of radio control to fly it, carry about 500 kilograms ammunition and try to destroy an armed military ship. Considering that Predator UAS payload capacity is "204 kilograms" [13] gives an idea about the complexity of the requirement.

One other reason for the failure of the project was reliability. In fact, all aircrafts were having safety and reliability problems in that early period of the aviation naturally.

4.2 Airspeed AS 30 Queen Wasp

Queen Wasp was designed to meet the requirements of British Defense Ministry for an aerial target UAS. It had conventional take-off and land version for Royal Air Force and floating version for Navy. Having 31 ft wingspan, 170 Mph maximum speed, 3500 lb. maximum take-off weight and 20.000 feet service ceiling, system performed first flight in 1937. Initial plan was to order 100 UA however resulted with 5 production only. Reasons for failure of the project were limited power and improper floating characteristics. [14]

Besides those reasons it can be evaluated that immature technology of radio controlled flight in that era combined with a complex data link architecture was not suitable for precise handling to land on sea. Without having adequate experience running two different projects simultaneously might be challenging for the company. Projects could be prioritized to focus the efforts on one requirement (Air Force or Navy). It seems that company did not last long afterwards, however in such an early time funding the company could be profitable in longer term.

4.3 Argus AS-292 (1939 version)

Argus AS-292 also started as a target drone project and performed first flight in 1939. Flights were uncontrolled. After some upgrades such as remote control capability and aerial photography payload integration a reconnaissance UAS produced obtained.

After about 100 of the systems delivered between 1942-1943 developments seem to be halted. AS-292 was a small aircraft that has maximum speed of 100 km/h and 30 minutes endurance. [15]

Even those specifications show the need for further developments since it has a low speed and very short endurance. Reconnaissance aircraft naturally expected to have either long endurance or higher speed to have a longer mission distance certainly.

Considering the primary design concept being a target drone probably material quality was not excellent. It can be assumed reliability was poor. Size and weight of the aircraft shows that it was weak versus adverse weather conditions.

4.4 Argus FZG-43 (Fernfeuer)

Argus FZG-43 was designed as target drone It was able to carry 1000 kilograms bomb for ground target. [11] The product became something much more developed than a target drone. AS-292 was a new concept of using UAS. A UAS that can take off, attack and land and proves to be exactly what we call Unmanned Combat Vehicle (UCAV). However, that concept did not appeal so much interest amongst defense industry and military.

Fernfeuer has another important concept it would be controlled by a manned version of the same aircraft. Probably, data link range limitations led designer to that idea. In 2012 same concept realized by an Apache helicopter controlling an MQ-1C Gray Eagle.

5 1950-1970 ERA

5.1 SM-62 Snark

Snark program started unofficially as a cruise missile and achieved to get a contract from US Air Force. Design had characteristics of both UAS and cruise missiles at same time. It was a model that can fly up 50 kilometers approximately with high subsonic speed and land if not hit target.[16] However, there were many difficulties facing the project.

Some of the major drawbacks of the program were design issues: control surfaces were not designed to perform the planned mission and aircraft was not stabile enough.

There was an intuitional resistance of pilots for an unmanned aircraft. Questions rising towards system seems not very sound for today's comprehension certainly. USAF was concerned about the vulnerability of the launch and control site of the system.

Circular Error Probable (CEP) value demanded was changed. Some other changes for requirements declared time to time. [16] Changes related to design parameters can delay the programs even now. Demanded specifications were not easy to succeed especially when the navigation and positioning systems available that time considered.

It is obvious that through all these problems. Abandoning the N-25 version and beginning a bigger and more complex version N-69 was not beneficial.

5.2 Lavochkin LA 17

The first Soviet drone to reach operational service was the Lavochkin LA-17, work on the LA-17 was initiated in 1950 and flight tests began in 1953. [16] There are a few versions of the aircraft such as LA-17 MM, LA-17 R. There were changes about take-off such as: air launch (abandoned cause of cost) catapult, rocket aided take off) or radio control and automatic control addition etc.

Designs continuing parallel with idea of having a target drone for pilots and anti-aircraft air defense systems and other usage concept was having a reconnaissance UAS. It was a jet engine UAS and had EO-IR camera, wide are films as part of sensor suit. When the imaging technology of its era considered, a jet engine aircraft that has "17.000 meter ceiling, 40-60 minutes endurance" [17] may not provide satisfying images.

LA-17 was even exported to Syria and China. It can be evaluated that concept and operational requirements were not very clear and despite successful missions and trials UAS was not developed and upgraded. Accumulation of knowledge could not be directed towards different concepts or designs efficiently.

5.3 North American Navaho

X-10 was the first step of a three step developing program based on the German V-2 cruise missile design. Navaho was expected to have 5000 miles operational range.

Canard, V-tail, wings added to original airframe and propulsion system upgraded. Radio control and landing gear made landing possible. First flight performed in 1953. Afterwards, 27 successful flights done. 2.05 mach speed was reached. [16]

Second phase was not very successful. Propulsion system, remote control, landing caused some problems. Although 78.000 feet ceiling and maximum speed above 3 mach acquired, project fall behind the schedule and reliability was a major problem. Project cancelled eventually. Reasons of for project's failure according to:

1. Insufficient technology to meet over ambitious requirements
2. Manufacturer's failure to manage the situation
3. Over optimistic estimates
4. Loose management
5. Inability to recognize technological defects early and respond
6. Air force commanders approach to unmanned systems [16]

5.4 Beachcraft MQM-61 A Cardinal

MQM-61 A was designed to tow banners, targets and was carrying a scoring device as payload. After making its first flight 2.200 of the UAS sold to different units: most to US and some minor numbers to US Navy, US Marine Corps and Spain. [18]

This UAS served well to accomplish what it was designed for. It had simple but proper airframe and enough capability to take off, execute mission and land.

Probably, the biggest loose of the aviation was that, company did not spend great afford to collect data from the concept, show afford to improve it and enlarge the capabilities of UAS they produce. Probably it did not fit the commercial vision of the company. Flying an UAS in 1955 could be a good source of know-how.

5.5 MQM-57 Falconer (SD-1)

MQM-57 Falconer was first produced by Radioplane Company which was later bought by Northrop Grumman Company. First Falconer flew in 1955 and served as surveillance UAS till 1970's. Rocket assisted launch and parachute landing could be performed. It could carry still picture camera, flare injectors and radar beacon payloads. Endurance of the UA was 40 minutes. About 1500 of them were sold. [19]

Very little information could be found related to operational experience of Falconer. However, since it server for a long time, it can be assumed it served as a good background like other Radioplane Company products for today's Northrop Grumman designs. One of the biggest weaknesses of that UAS seems to be endurance time, which is too short for a piston engine, slow speed reconnaissance aircraft. Since the company's claim was to build cheap systems, probably reliability problems had occurred.

5.6 MQM-58 Overseer (SD-2)

After SD-1, models that have higher speed and higher ceiling produced. MQM-58 Overseer (SD-2) made it first flight in 1958. Project began as a reconnaissance UAS, however capability to spray biological or chemical agents added later. It could be equipped with a side looking airborne radar. Mobility seems to be an advantage for this UAS as it can be carried by two trucks. 35 MQM-58 were built and none of them entered the service. In 1966 project cancelled because of navigation problems. [20]

5.7 BQM-34A Firebee I

Studies of Ryan Company on Firebee series began in 1948. First flight of the series called Model 124 was in 1958. It was designed as an aerial target. It is the UAS that has served for longest time in aviation history with some modifications through life cycle such as integrating GPS aided navigation in 1990s. Firebee design and the experience gained with the project led to other variants of the UAS for missions such as reconnaissance and signal intelligence. [21]

Firebee I fulfilled the assignment it was built for but could do more. A jet engine, maneuverable aircraft that can fly 0.95 Mach speed with 60.000 feet ceiling have been used only as a target drone. Its variants tried to expand the scope of operational usage of the systems.

5.8 Ryan 147A AQM-91 Fire Fly

In 1962, the contract to convert the Firebee to a reconnaissance UAS signed and flight tests began only two months later. Three steps of the test were: mission profile execution, aerial photography quality and survivability of the UAS. After the

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completion of the first two steps, 5 F-106 tried to intercept the Fire Fly UAS, each firing four air to air missile and all failed to shoot. [22]

The success of the program slowly diminished mostly because of the resist from Air Force. Lack of confidence to UAS and fear of being replaced were listed in [22] as reasons of the resist.

Fire Fly UAS had an operational range of 1200 nautical miles and ceiling of 55000 feet. It had high subsonic speed. Main payload was a camera to take photographs same as the ones used at U-2.

The Cuba crisis could be a turning point for the systems if the mission was not cancelled just while mother ship DC-130 which is carrying the UAS for air launch was taxiing on runway. Reason of the cancel was to keep the highly valuable system secret. [23] Dilemma was labeling the projects as top secret and very important for future operational needs, however cancelling same project in a few years.

5.9 Ryan 147B AQM-34 Lightening Bug

Lightening Bug project was a variant of Fire Fly series. They were used operationally to gather information about Chinese military and nuclear activities. Lightening Bug had a ceiling about 62.500 feet. They were successful at penetrating the Chinese Air Defense System. Even if they were shot down, political and public effects would be minimal. [24]

Aircraft was air launching from a DC-130 aircraft and performing a parachute landing. There were different versions of the system to fly high or low altitudes. Some different type of payloads such as infrared camera, electronic counter measure (ECM) pods, Hycon-338 camera that a mission would come up with a strip image of 780 NM x 22 NM. [25]

According to [24] major problem areas were mishaps during landing, administration problems, and coordination issues between company and military personnel, insufficient navigation accuracy.

Landing mishaps caused by high wind indicates either limitations of the UAS or sensitive meteorological forecast were not available at that time.

5.10 Ryan 147 AQM-34 Buffalo Hunter

Modified versions of BQM-34A Firebee, AQM-34's were used during Vietnam War. "Buffalo Hunter is a combat-tested unmanned system which has functioned effectively in a combat environment." [26]

System was designed to make an air launch from DC-130 aircraft and land by using a parachute. A CH-3 helicopter would catch the aircraft and carry it to land. SC variant of Ryan 147 series was designed for low altitude aerial photography. Resolution was approximately was 15 centimeters from 1000 feet above ground level and 30 centimeters from 1500 feet. Fairchild 415Y was the payload used for missions. [26]

Lightening Bug has two other types else than AQM-34 SC, which are AQM-34 H and AQM-34 L which are for high altitude missions. Besides, Electronic Counter Measures (ECM) pod, protective maneuver equipment, they were carrying Hycon-338 camera. Camera was photographing an area of 780 NM x 22 NM with three to six feet resolution. Operational range was 2400 NM.

Low level mission execution caused to help to obtain high resolution values like 15-30 centimeters. When the mission description would most likely be to find the location of surface to air missiles, buildings, large troop and convoy activity image quality is sufficient. [27] defines what can be seen with 6 inches resolution as "details that are visible at this resolution include individual small trees and plants, individual vines and other crops, vehicle types, power poles and other infrastructure details, road markings and lettering." However, there is a drawback for such high resolution acquired by low altitude flight: navigation should be precise. For that era accurate navigation and positioning was a major problem. "The navigation system in the Model 147SC was subject to error of about 3 percent of the distance traveled by the drone." [28] Technology related to positioning and navigation was not mature in those times.

There were other deficiencies of the UAS related to technology and operational set up. Namely:

1. Airborne Recovery Control Officer who was flying in DC-130 and functioned like an UAS pilot. However, telemetry related to aircraft was not very healthy and sometimes spurious. [29]

2. Intelligence-request and assignment of the Buffalo Hunter UAS was too complex and flow was through high posts such as Pacific Command Commander In Chief. That was causing delays especially for time-sensitive and urgent targets. Later, it was modified. However, even the new flow chart procedure requires the mission assignment 36 hours before takeoff and 6 hours in urgent demands. [30] That time flow is too slow for today's concept however it can be evaluated as satisfying for its era. It can be seen that the major problem was the inflexibility of the system. The planned route was very time consuming to change before take-off and to load a new mission was not very possible to inject easily.

3. Life time of the aircrafts was too short. It can be seen that it increases each year it was used. "Prior to Buffalo Hunter, drones averaged about four sorties before being lost. In 1970, however, they averaged 7.5 sorties and their lifetime increased to 9.5 sorties in 1971, then to 9.6 in 1972." [31]

5.11 AQM-91A Compass Arrow Model 154

Compass Arrow program started to design an UAS to perform reconnaissance missions over China. Although Bloom [32] accepts Compass Arrow and Fire Fly as same aircraft, this paper distinguishes them as different projects and aircrafts.

First flight of Compass Arrow was in 1968. Mission scenario and the requests were challenging. Project began with 100 orders and then number of orders decreased to 20. Estimated cost was 35 million US dollars and delivery would be in 18 months. However, it costed 250 million US dollars for 20 unmanned aircraft, which means 1.8 billion US dollars if converted to FY 2010 currency and delivery was five years after the contract. That makes Compass Arrow one of the most expensive UAS of all times. [33]

Delay of the delivery had two other major results. One of them was political: the improving Chinese-US relations and the other were technological: developments in satellite technology.

Commanders and politicians could not foresee a future for Compass Arrow UAS, which flew 80.000 feet and had a maximum speed of 0.8 Mach, plus had some stealth features. [34] Today there are no operational unmanned platforms with such capabilities yet.

Satellites were rivals of the unmanned technology at that time and won another round. KH-9 Hexagon and KH-11 Kennan with additional capabilities of digital imaging sensors and real time data transmission became more suitable for reconnaissance missions. [34] Mission requirement also aided to that conclusion. US Armed Forces were not interested in time sensitive targets but stable targets such as air bases and nuclear plants of China and Russia.

There were other drawbacks of the projects. The need for a DC-130 mother ship to take off and helicopter to retrieve the aircraft descending with a parachute were the main difficulties of operating the UAS. Those difficulties combined with concerns about the reliability of such a complex UAS, lacking the vision, concept or a roadmap for UAS led to the failure of the project.

5.12 AQM-37 Jayhawk Model 1100-1101

AQM-37 was designed to meet the requirements of US Army and Navy's requirements for a supersonic and expandable aerial targets. Since the requirement definition was expandable the system can't be called as UAS. However, 1100 and 1101 series which are variant of these targets were designed with the capability to make a parachute landing. All though variants have some different capabilities, missile like aerodynamic design helped these systems reach to speeds above 4.0 Mach with service ceiling 100.000 feet. That kind of ballistic missile type design had drawbacks of having short endurance (about 5 minutes) and total weight of the platform was only 280 kilograms. [35]

Endurance was not enough for intelligence missions and limited weight was making any payload or munitions of that era impossible to be integrated to system. 1100 and 1101 variants were produces in very little numbers and afterwards contacts continued for expandable designs. It can be assumed that lowering the speed somehow (may be bigger wing area) should contribute to endurance and a bigger airframe could contribute intelligence gathering or destruction of enemy defense systems capability. Even deception of enemy radars or defense systems could contribute as different operational usages. However, AQM-37 remained as target drone till recent years.

6 1970-1990 ERA

6.1 QU-22B Pave Eagle

QU-22B was derived from the manned Beechcraft Bonanza Model A36. That UAS served as a communication relay aircraft. It was optionally manned. It was usually flown with a pilot on board to ensure safe take off and landing. However, being unable to reach proper reliability values was the main reason of cancelling the program. [36]

When specifications given at [36] analyzed it can be seen that unmanned configuration can fly higher and longer. No programs to overcome the reliability problems found in literature.

QU-22 Pave Eagle entered service in 1970 according to [36] and in 1971 according to [37]. Both sources agree that program abandoned in 1972. Even today's technology it is not easy to mature an aircraft in a few years. It can be observed that even a slight change in a commercially of the shelf (COTS) aviation product, adds 2-3 years to delivery date.

6.2 Martin Marietta Model 845A

Optionally manned Model 845A was the competitor of XQM-93A for Compass Dwell project. It was converted from SGS 1-34 airframe. In order to meet 40.000 feet ceiling and 28 hours endurance requirement a turbocharged piston engine used. Endurance of 28 hours was demonstrated in July 1972. [38]

Reasons of Compass Dwell's cancellation are discussed in XQM-93A section below.

6.3 XQM-93A

Started as a competitor of Model 845 for Compass Dwell program XQM-93A (civilian name L450F) was also an optionally manned aircraft. XQM-93A was derived from SGS 2-32 sailplane by installing a turboprop engine. Aircraft flew with a man on board in 1970. Payload capacity was 450 kilograms and endurance was 21 hours. [38]

Eventually design couldn't fulfill both 40 thousand feet and 28 hours flight requirements at same time. In 1973, only one year after the test flight, project cancelled.

For the cancelation, available sources don't mention the reasons specific to the XQM-93A but for Compass Dwell project as a whole.

1. "Anti-aircraft threats drove altitude requirements higher so that neither Compass Dwell aircraft was selected for production." [38]
2. "More than any other impediment, the lack of European airspace clearance led to Compass Dwell's demise." [39]
3. Strategic Air Command resisted for airfield launch and recovery UAS. [40]
4. "Air Force viewed Compass Dwell as a speculative technology demonstrator rather than a legitimate candidate for adoption." [39]
5. [32] considers the main reason for cancelling the project was budget limitations.

When we consider modern ISR UAS, Predator is not even in this category. Only Reaper, Global Hawk and Heron-TP can reach to design requirements of 1970s and all these modern UAS became operational in last decade. It can be evaluated that planners did not arrive to see the possible benefits of acquiring an UAS with the specifications of XQM-93A and Model 845A.

Budget limitation to cancel Compass Dwell doesn't sound a realistic approach. Because a more ambitious program called was going on contemporarily.

6.4 Boeing YQM-94 Gull

YQM-94 and YQM-98A were designed for Compass Cope project of US Air Force. Compass Cope was aiming for a High Altitude Long Endurance (HALE) class UAS. "Compass Cope requirements were to carry a 320 kg payload" [38], to have 55.000 ft. ceiling, 24 hours endurance and to perform ISR and communications relay. [41]

"By 1974, TAC requirements list for Compass Cope expanded to include over-the-horizon drone control, tactical weather monitoring, and laser designation, among others." [42] Two other requirements of payload were Precision Emitter Location Strike System (PELSS) and communication relay.

There were two variants of the YQM-94 series: A and B, the latter produced after winning the competition versus YQM-98 which was heavier and had longer endurance time while having more payload capacity.

First flight of YQM-94A was in 1973. It had 5900 kg gross weight with 90 ft. wing span and turbofan engine. It had an endurance of 17 hours at altitudes above 52.000 ft. [43]. Additionally, there were some important features of the system: automatic take-off and landing (ATOL) and satellite communication (SATCOM) [44]

After a close competition Boeing's design is chosen for project, however procurement never occurred. It can be evaluated that both UAS had flight envelops as good as modern UAS. Major reasons of projects failure were:

1. Lack of vision for foreseeing the operational usage
2. Too complex sensor suit requirement
3. Too high performance requirements
4. Unable to get necessary permissions for civilian aerospace control units of Europe [44]
5. Idea to continue to conduct missions by manned aircraft. [43]

Amongst the given reasons number 4 is still subject to many arguments today. At that time declaration of being the reliability of this UAS adequate for flight in non-segregated airspace under positive control and for uncontrolled airspace required see and avoid capability or a manned chase aircraft [42] are significant.

6.5 Ryan YQM-98 (Model 235)

In the beginning of Compass Cope project Boeing was the sole contractor. However, one year later Ryan was included as a competitor. [44]

YQM-98 was derived from Model 154. Aircraft had some advanced specifications. Turbofan engine, 500 Nm/h speed, 70.000 ft. ceiling were some important features even in today's standards.[45] A very important milestone in UAS history was the endurance record of more than 28 hours in 1974, which wasn't excessed until Global Hawk's flight 26 years later in 2000. [43]

In 1976 Boeing was announced as winner and Ryan challenged it. Eventually in 1977 project was cancelled totally. [45]

Successful flights of YQM-94 and YQM-98 was not enough to come up with a procurement contract. During the debates over systems UAS were not without supporters however they weren't enough to change the outcome. For example, "Not only RPV's cheaper, since they don't need the life support equipment of a manned plane, but they can maneuver better and stay up longer. Teledyne Ryan's new Compass Cope reconnaissance aircraft can stay in the air for over 24 hour. [46]"

Literature does not mention specific reasons of cancelling the program. Shadowing the success of trials was probably the lack of necessary vision.

6.6 Tupolev TU-141 Strizh (VR-2)

Russian Experimental Design Bureau (opytno konstrooktorskoye byuro-OKB) which had somehow similar function to German Luftwaffe or US Skunk Works was in charge of the designing Tupolev TU-141.

TU-141 made its first flight 1974. It had one turbojet engine, take off was from a launcher and landing with an on board parachute system. TU-141 had operational range of 620 miles and ceiling was 20.000 ft. Its cruise speed was 683 Nm/h. It had a panoramic camera, a nose mounted imager (optic and IR) including prototypes 154 of them were built. Most were stationed at Soviet Union's west border.[47]

Easily deployable configuration, mobile launch & recovery systems, mobile maintenance system shows the intend to use it without runway or complex logistic support.

TU-141 concept can be evaluated as a reconnaissance system concept. Its range and speed gives a rough idea about short endurance time which makes the system improper for surveillance missions. Main payload is not a video but a film camera and UAS system doesn't include a data link for real time intelligence.

Another major drawback of the system was that its autopilot was dependent on a pre-programmed route. Considering the short endurance time, inflexibility of the mission planning might have caused missions to be repeated with a new sortie. Ability to control the planned route and mission adjustments could be beneficial.

6.7 IAI Scout

The rising interest of two Israel companies Tadiran and Israel Aviation Industries (IAI) resulted with two similar tactical UAS. IAI Scout demonstrated its operational capability in 1977. Made of mainly aluminum Scout UAS had 4 meters wingspan and maximum weight of 320 lb. [48] Ceiling of the Scout was 15.000 ft., maximum speed 109 Nm/h and endurance 7 hours 30 minutes. [49]

Scout had a lightweight camera and was able to provide real time streaming video intelligence. "This concept was first demonstrated in 1981 when the South African Army used the IAI Scout during Operation Protea in Angola." In 1982 Lebanon war Scout was used. During Bekaa Valley War Scout UASs

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were used effectively to locate the Surface to Air Missiles (SAM) sites of Syria. [50]

Unlike many UAS analyzed previously, Scout remained in service for a long time and inspired for the widely known and used systems of IAI.

6.8 Tadiran Mastiff

Tadiran Mastiff was an UAS designed and built contemporarily with IAI Scout. Later on, two companies merged for Pioneer project for a sale to United States. [51]

Mastiff had seven hours endurance, payload capacity of 30 kg. and 100 knots maximum speed. It could land with the help of a net or to a runway. [52]

Tadiran was a private company and its designs remained operational until 1990s. IAI, a state company, later on became one of the leading UAS manufacturer. Tadiran diverted from airframe production to data link sector of the UAS industry.

6.9 Amber B-45

Amber was a project to design two different concepts. A-45 was a cruise missile type of platform and is out of the scope of this study. Amber B-45 was to be used for photographic reconnaissance, electronic intelligence (ELINT) missions. Leading Systems Incorporation (LSI) was the contractor. Initial flight was in 1986. It had 28 feet wingspan and 350 kilograms take-off weight. 7 Amber B-45s were built. However, impatience of US Department of Defense to finalize the project and the effort to avoid duplications of similar projects caused project and the company die. [53]

Amber was a good test bed. 36 hours endurance with some good intelligence gathering capabilities opened path to Predator series of UAS. LSI was later bought by General Atomics. Emerging need for ISR assets during Gulf War caused Gnat and I-Gnat series (followers of Amber) evolve to become one of the most effective weapon systems of war history: Predators. It can be assumed that if Amber was not cancelled current UAS technology could be a few years ahead.

6.10 Boeing Condor

Condor UAS was a system that integrated some cutting-edge technologies to unmanned world. It had two 6 cylinder piston engines and performed first flight in 9 October 1988. During test flights it had reached to an altitude of 67.038 feet. It had flown about 60 hours in a single sortie.[51]

Project was cancelled in 1990. Although it was the groundwork for some follow on projects it never became operational. Boeing expresses the that there was no customer for the UAS. It was not suitable for military customers because:

1. Too long wingspan (~200 feet)
2. Slow speed (cruise speed 230 mph)
3. Lack of stealth
4. Being too vulnerable

It was not appealing for civilian customers because of being too expensive for civilian agencies at that time. Considering atmospheric research as the primary potential usage area for civilian applications.

6.11 Ryan Model 324 Scarab

Ryan Model 324 was designed for Egyptian Air Force. It was a low altitude photo reconnaissance UAS. "The aerial vehicle measured 20 feet in length, had a 12-foot wingspan and weighed 2500 pounds, including fuel. It had a designed payload capability of 250 pounds. Payload options were an airborne reconnaissance camera, TV camera or infrared laser system. had advances specifications such as 0.8 Mach top speed, 45.000 feet ceiling, 2300 kilometers operating range. 56 platforms were delivered starting from 1988 and in 2005, 50 were still operational." [52]

There is not much information available about the operational experience and lessons learned about the system. Although systems had INS and GPS capability for accurate navigation and autonomous mission execution features, Model 324 did not have real time intelligence capability and it was not designed for effective in-flight change of the planned mission.

As far as known, Egypt did not continue to upgrade or enhance its UAS. It can be assumed that potential of the UAS was not well understood and there were no indigenous UAS programs concluded successfully afterwards.

7 Helpful Hints

This study does not aim to be a catalogue of historical UAS. All of the UAS developed are not included but main purpose of the research was to identify the main reasons of the delay of unavoidable era of unmanned aviation.

Trying to figure out the deficits of systems, administration blunders or project set up mistakes may contribute us to avoid repeating those failures. Table-1 shows reasons of project failures in percentage value for UAS explained in previous sections of the study. 5 major factors discussed briefly below.

TABLE-1
REASONS OF PROJECT FAILURES (%)

Results indicate that during the long history of UAS, the basic reason for project failures was lack of vision. Authorities, companies, armed forces were not successful to foresee the potential and could not be able to form the true concept for UAS usage.

Unable to determine achievable, realistic specifications was the second highest factor for project failures. This factor is another indicator of how important capability and force structure studies for an armed force.

Reliability is a key factor for aviation. UAS have been forced to have higher capabilities for less cost. That dilemma caused the sacrifice of reliability and safety in many projects. Being the percentage of completing a planned task low and mishap rates unacceptably high were two other major concerns for unmanned aviation. Recent advances of concept of operation, comprehension of UAS and technological maturity helped the improvement on these factors. Furter advancements should be expected with determination and implementation of airworthiness certification standards of UAS.

Results acquired by this study shows project management has vital importance for completing aviation projects. As expensive, long term and complex projects should have a flexible, fast and scientific project management structure. This suggestion is valid for all contributors of a procurement or research project setup. Requirement owner, contractor, project manager etc. should have a clear understanding of process and expected results, while being ready with contingency plans to overcome unexpected results.

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