MODULE - 1

Introduction

TOPICS COVERED

- Aviation History and Overview of UAV systems
- Classes and Missions of UAVs
- Definitions and Terminology
- UAV fundamentals
- Examples of UAV systems –
  - very small
  - Small
  - Medium
  - Large UAV

INTRODUCTION

- UAV – Unmanned Aerial Vehicle
- RPV – Remotely Piloted Vehicle
- Drone
- UAV System or UAS (Unmanned Aerial Systems)

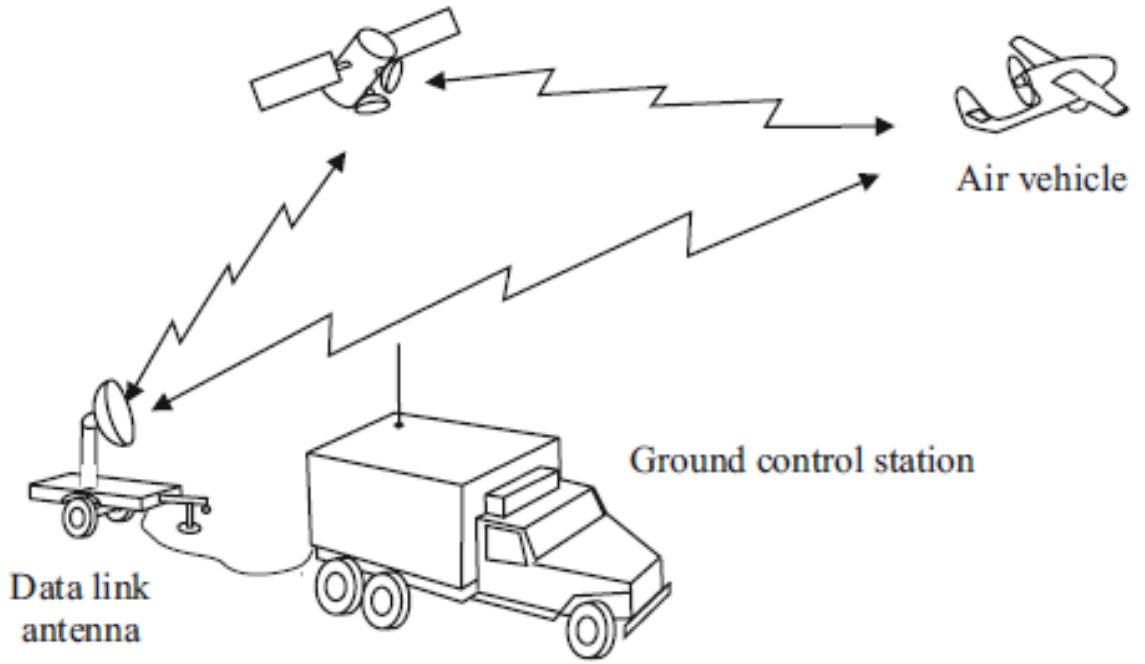


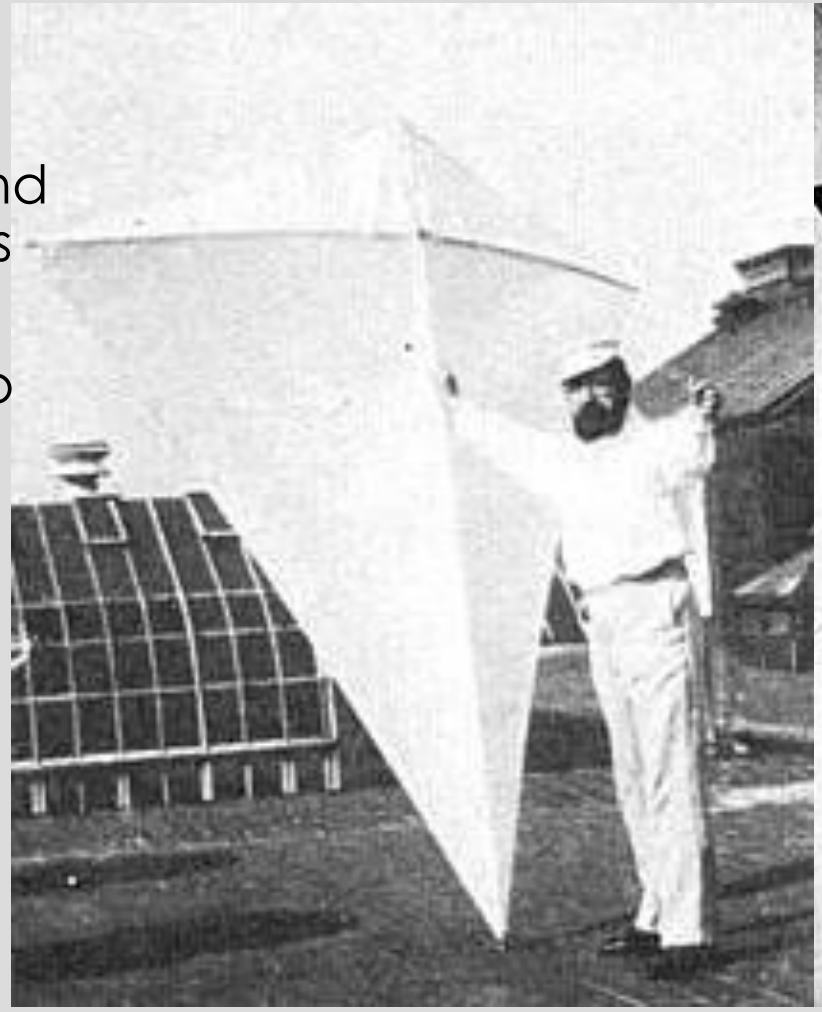
Figure 1.1 Generic UAV system

HISTORY
EARLY HISTORY

- UAV systems have tended to be driven by military applications
- One could say that the first UAV was
  - **a stone thrown by a caveman** in prehistoric times
  - or perhaps a **Chinese rocket** launched in the thirteenth century.
- These "vehicles" had little or no control and essentially followed a **ballistic trajectory**.
- If we restrict ourselves to vehicles that generate **aerodynamic lift and/or have a modicum of control**, the **kite** would probably fit the definition of the first UAV.

HISTORY
EARLY HISTORY

- In 1883, an Englishman named **Douglas Archibald** attached an anemometer to the line of a kite and measured wind velocity at altitudes up to 1,200 ft.
- Mr. Archibald attached cameras to kites in 1887, providing one of the world's first reconnaissance UAVs.
- **William Eddy** took hundreds of photographs from kites during the Spanish-American war, which may have been one of the first uses of UAVs in combat.

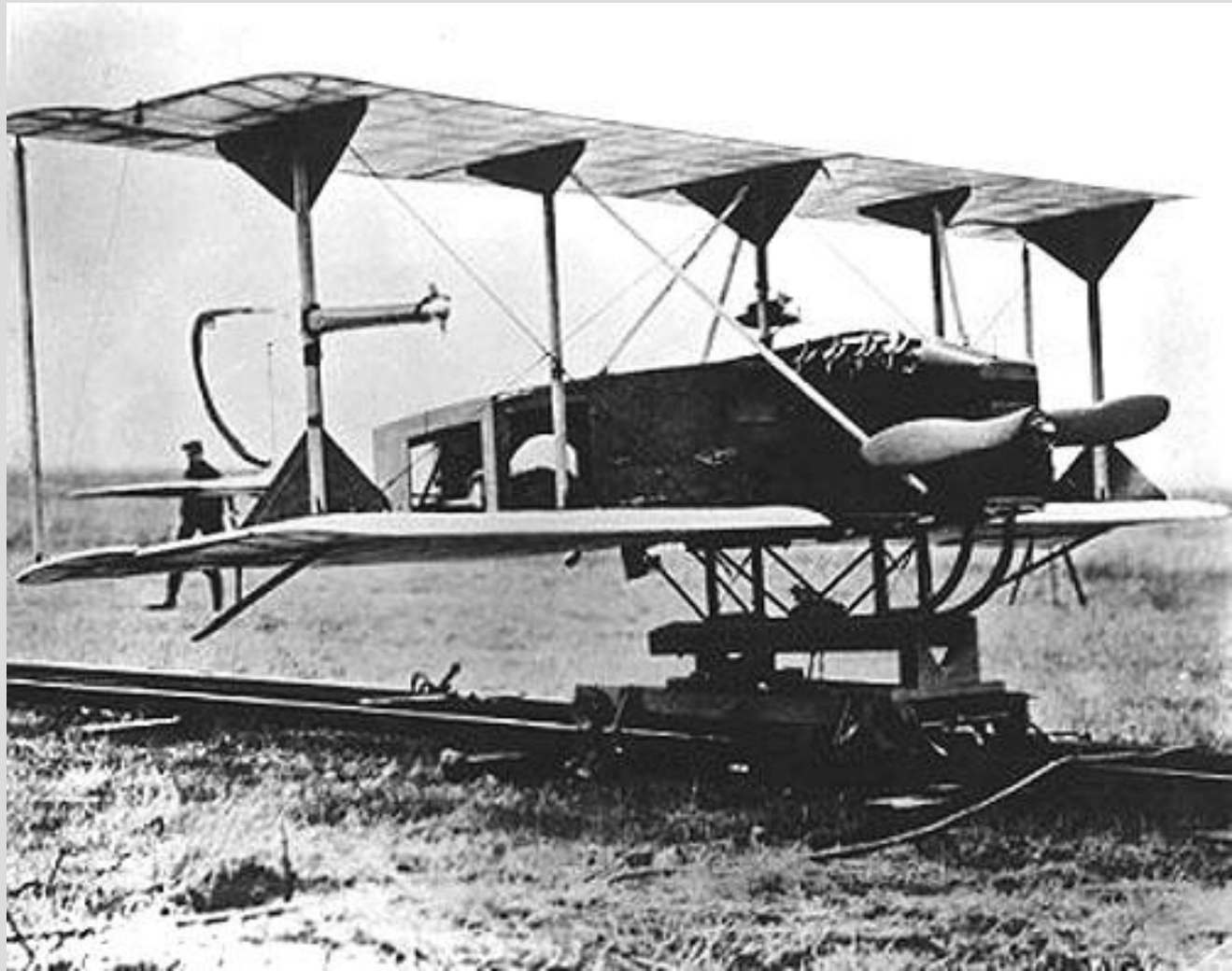


HISTORY
EARLY HISTORY

- **Charles Kettering** (of General Motors fame) developed a biplane UAV for the Army Signal Corps.
- It took about 3 years to develop and was called **the Kettering Aerial Torpedo**, but is better known as the **"Kettering Bug" or just plain "Bug."**
- The Bug could fly nearly 40 mi at 55 mi/h and carry 180 lb of high explosives.
- The air vehicle was guided to the target by preset controls and had detachable wings that were released when over the target allowing the fuselage to plunge to the ground as a bomb.

HISTORY
EARLY HISTORY

- in 1917, **Lawrence Sperry** developed a UAV, similar to Kettering's, for the Navy called the **Sperry-Curtis Aerial Torpedo**.
- It made several successful flights out of Sperry's Long Island airfield, but was not used in the war.

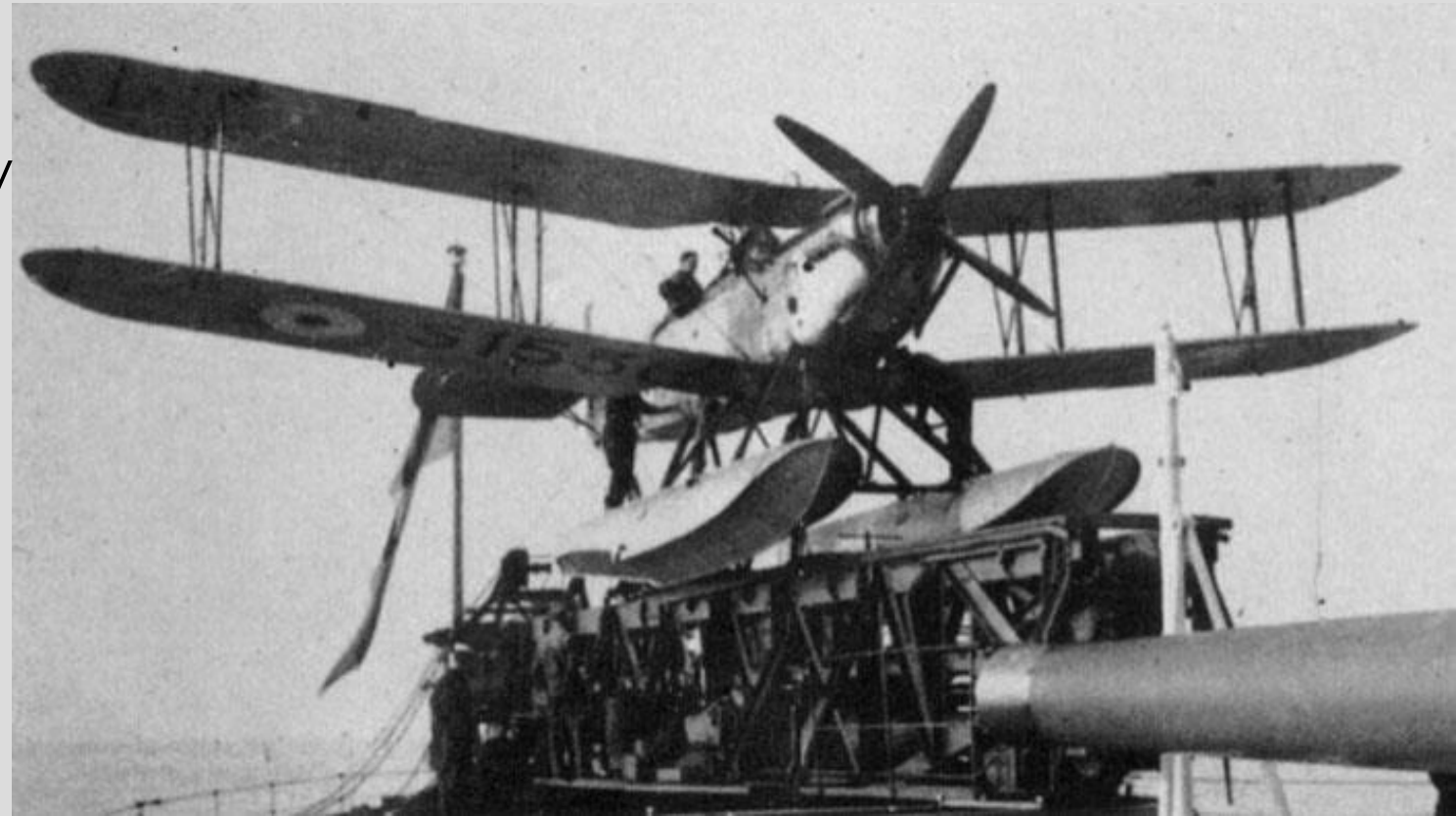


HISTORY
EARLY HISTORY

- We often hear of the UAV pioneers who developed the early aircraft but other pioneers were **instrumental in inventing or developing important parts of the system**.
- One was **Archibald Montgomery Low,** who developed **data links**. Professor Low, born in England in 1888, was known as the **"Father of Radio Guidance Systems."**
- He developed the first data link and solved interference problems caused by the UAV engine. His first UAVs crashed, **but on September 3, 1924, he made the world's first successful radio controlled flight**. He was a prolific writer and inventor and died in 1956.

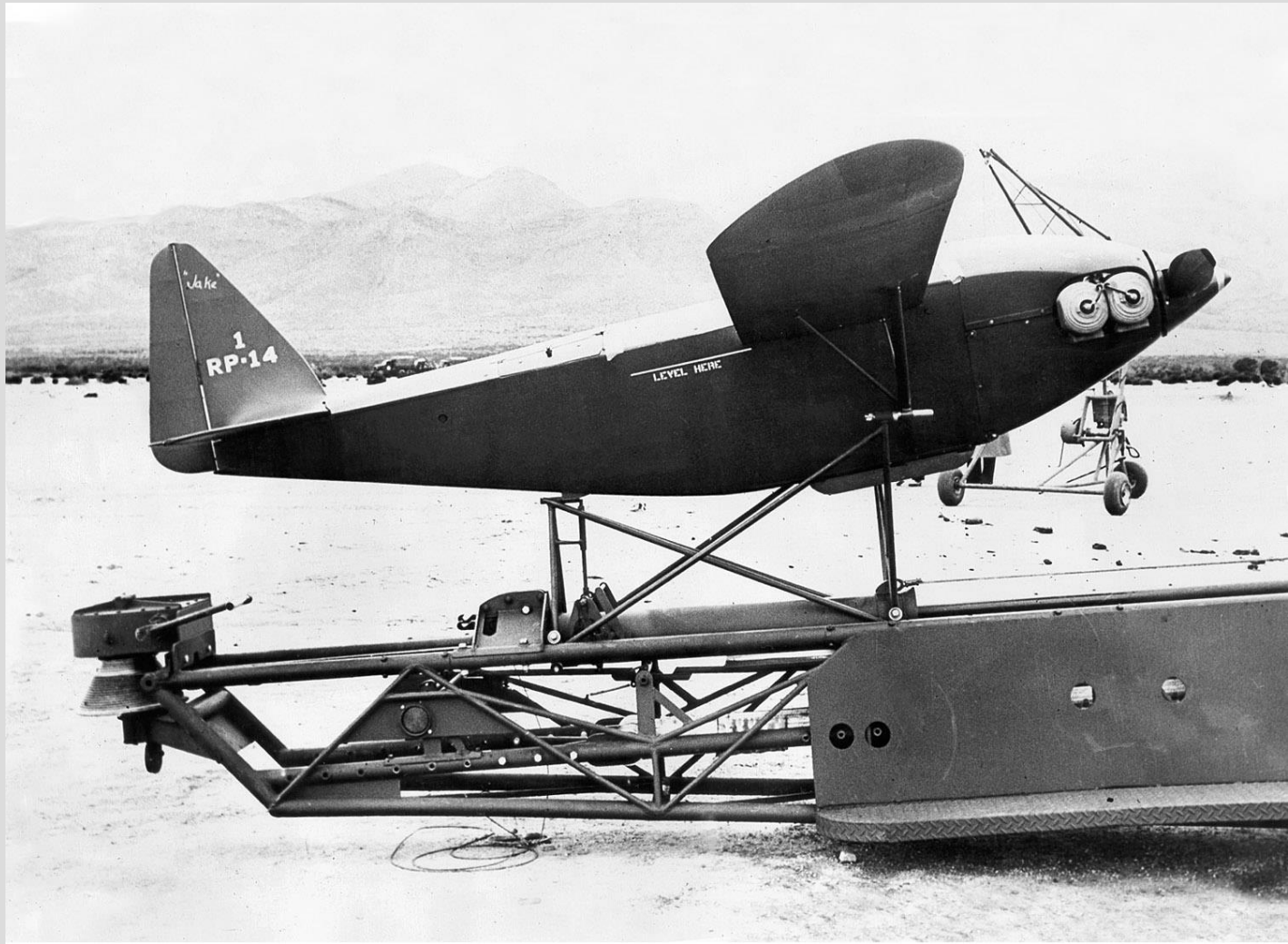
HISTORY
EARLY HISTORY

- In 1933, **the British** flew three **refurbished Fairey Queen biplanes by remote control from** a ship.
- Two crashed, but the third flew successfully **making Great Britain the first country to fully appreciate the value of UAVs**, especially after they decided to use one as a target and couldn't shoot it down.



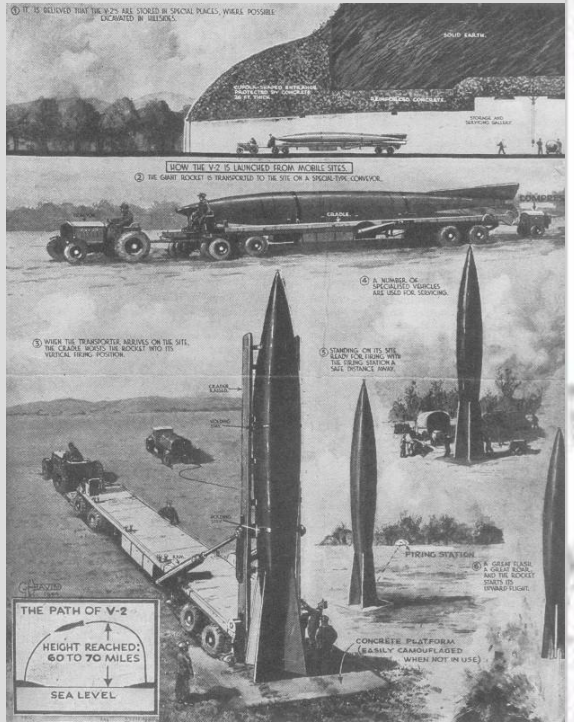
HISTORY
EARLY HISTORY

- In 1937 another Englishman, **Reginald Leigh Denny**, and two Americans, **Walter Righter and Kenneth Case**, developed a series of UAVs **called RP-1, RP-2, RP-3, and RP-4**.
- They formed a company in 1939 called **the Radioplane Company**, which later became part of Northrop-Ventura Division.
- **Radioplane built thousands of target drones during World War II.**



HISTORY
EARLY HISTORY

- Of course **the Germans** used **lethal UAVs** (**V-1's and V-2's**) during the later years of the war, but it was not until the Vietnam-War era that UAVs were successfully used for reconnaissance.



HISTORY
THE VIETNAM WAR

- During the **Vietnam-War era**, UAV were used **extensively in combat**, but for **reconnaissance missions only**.
- The air vehicles were usually air launched from **C-130's** and recovered by **parachute**.
- The air vehicles were what might be called **deep penetrators** and were developed from existing target drones.
- **Ryan Firebee target drone/Fireflys**

HISTORY
THE VIETNAM WAR

- A total of 3,435 sorties were flown, and most of these (2,873, or nearly 84%) were recovered.
- One air vehicle, the TOMCAT, successfully completed 68 missions before it was lost.
- Another vehicle completed 97.3% of its missions of low altitude, real-time photography.
- By the end of the Vietnam War in 1972, air vehicles were experiencing 90% success rates.

HISTORY
RESURGENCE

- At the end of the Vietnam War, general interest in UAVs dwindled until the Israelis neutralized the Syrian air defense system in the Bekaa Valley in 1982 using UAVs for reconnaissance, jamming and decoys.
- Actually, the Israeli UAVs were not as technically successful as many people believe, with much of their operational success being achieved through the element of surprise rather than technical sophistication.
- The air vehicle was basically unreliable and couldn't fly at night, and the data-link transmissions interfered with the manned fighter communications.
- However, they proved that UAVs could perform valuable, real-time combat service in an operational environment.

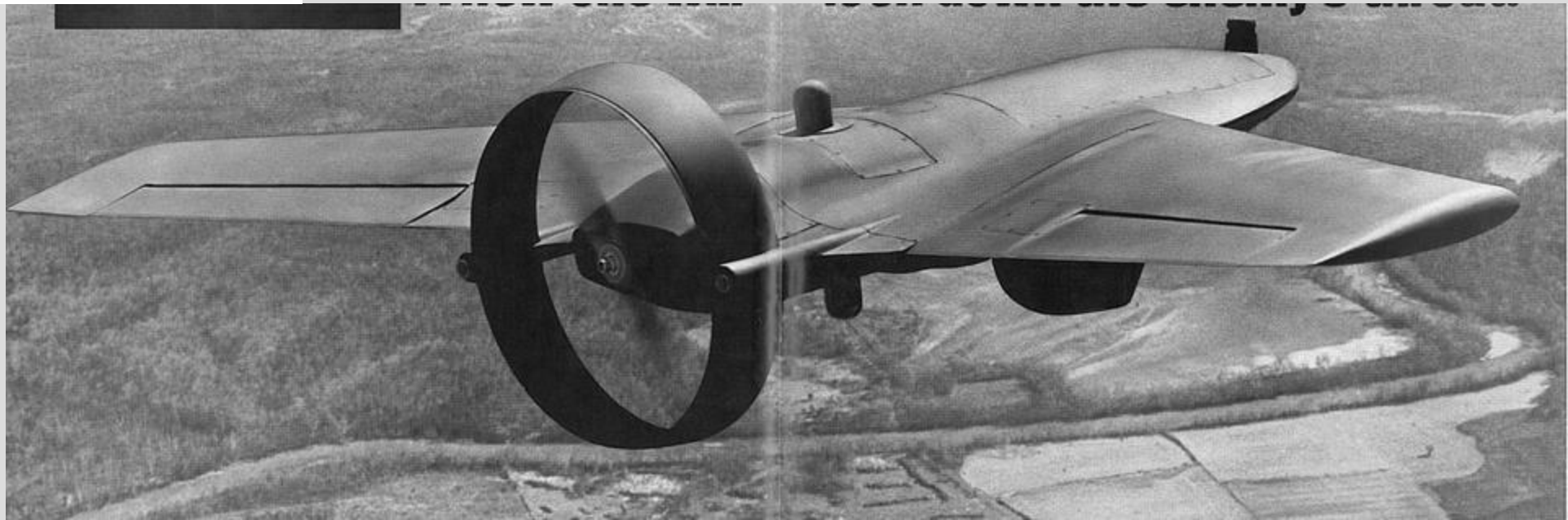
HISTORY
RESURGENCE

- The United States began to work again on UAVs in August 1971 when the Defense Science Board recommended mini-RPVs for artillery target spotting and laser designation.
- In February 1974, the Army's Materiel Command established an RPV weapons system management office and by the end of that year (December) a "Systems Technology Demonstration" contract was awarded to Lockheed Aircraft Company, with the air vehicle subcontracted to Developmental Sciences Incorporated (later DSC, Lear Astronics, Ontario, CA).
- The launcher was manufactured by All American Engineering (later ESCO-Datron), and the recovery net system by Dornier of the then still-partitioned West Germany.
- Ten bidders competed for the program.
- The demonstration was highly successful, proving the concept to be feasible.
- The system was flown by Army personnel and accumulated more than 300 flight hours.

HISTORY
RESURGENCE

- In September 1978, the so-called Target Acquisition/Designation and Aerial Reconnaissance System (TADARS) required operational capability (ROC) was approved, and approximately 1 year later, in August 1979, a 43-month Full Scale Engineering Development (FSED) contract was awarded to Lockheed sole source.
- The system was given the name "Aquila"
- For a number of reasons that provide important lessons to UAV system developers, Aquila development stretched out for many years and the system was never fielded.
- In 1984, partly as a result of an urgent need and partly because the Army desired some competition for Aquila, the Army started a program called Gray Wolf, which demonstrated, for the first time for a UAV, hundreds of hours of night operations in what could be called "combat conditions." This program, still partly classified, was discontinued because of inadequate funding.

LOCKHEED MQM-105 AQUILA



HISTORY
JOINT OPERATIONS

- The US Navy and Marine Corps entered the UAV arena in 1985 by purchasing the Mazlat/Israeli Aircraft Industries (IAI) and AAI Pioneer system, which suffered considerable growing pains but still remains in service.
- However, the Congress by this time became restless and demanded that a joint project office (JPO) be formed so that commonality and interoperability among the services would be maximized.
- The JPO was put under the administrative control of the Department of the Navy.
- This office has developed a master plan that not only defines the missions but also describes the desirable features for each kind of system needed by the services.

HISTORY
JOINT OPERATIONS

- The US Air Force was initially reluctant to embrace UAVs, notwithstanding their wealth of experience with target-drone unmanned aircraft.
- However, this attitude changed significantly during the 1990s and the Air Force not only has been very active in developing and using UAVs for a variety of purposes but also has been the most active of the four US services in attempting to take control of all UAV programs and assets within the US military.

HISTORY
DESERT STORM

- The Kuwait/Iraq war allowed military planners an opportunity to use UAVs in combat conditions.
- They found them to be a highly desirable asset even though the performance of the systems then available was less than satisfactory in many ways.
- Five UAV systems were used in the operation:
  (1) the Pioneer by US forces,
  - (2) the Ex-Drone by US forces,
  - (3) the Pointer by US forces,
  - (4) the "Mini Avion de Reconnaissance Telepilot" (MART) by French forces, and
  - (5) the CL 89, a helicopter UAV, by British forces.

the Pioneer

the Pointer

“Mini Avion de Reconnaissance Telepilot” (MART)

helicopter UAV

HISTORY
DESERT STORM

- Although numerous anecdotal stories and descriptions of great accomplishments have been cited, the facts are that the UAVs did not play a decisive or a pivotal role in the war.
- For example, the Marines did not fire upon a single UAV-acquired target during the ground offensive according to a Naval Proceedings article published November 1991.
- What was accomplished, however, was the awakening in the mind of the military community of a realization of "what could have been." What was learned in Desert Storm was that UAVs were potentially a key weapon system, which assured their continuing development.

HISTORY
BOSNIA

- The NATO UAV operation in Bosnia was one of surveillance and reconnaissance.
- Bomb damage assessment was successfully accomplished after NATO's 1995 air attacks on Bosnian-Serb military facilities.
- Clearly shown in aerial photographs are Serbian tanks and bomb damaged buildings.
- Night reconnaissance was particularly important as it was under the cover of darkness that most clandestine operations took place.
- The Predator was the primary UAV used in Bosnia, flying from an airbase in Hungary.

The Predator

HISTORY
AFGHANISTAN AND IRAQ

- The war in Iraq has transformed the status of UAVs from a potential key weapons system searching for proponents and missions to their rightful place as key weapon systems performing many roles that are central to the operations of all four services.
- At the beginning of the war, UAVs were still under development and somewhat “iffy,” but many developmental UAVs were committed to Operation Iraqi Freedom.
- The Global Hawk was effectively used during the first year despite being in the early stages of developmental.
- The Pioneer, the Shadow, the Hunter, and the Pointer were used extensively.

The Global Hawk

HISTORY
AFGHANISTAN AND IRAQ

- The Marines flew hundreds of missions using Pioneers during the battle for Fallujah to locate and mark targets and keep track of insurgent forces.
- They were especially effective at night and could be considered one of the decisive weapons in that battle.
- The armed version of the Predator, mini-UAVs such as the Dragon Eye, and a wide range of other UAV systems have been used on the battlefields of Afghanistan and Iraq and have proven the military value of UAVs.

OVERVIEW OF UAV SYSTEMS

- There are three kinds of aircraft, excluding missiles, that fly without pilots. They are
  - **Unmanned aerial vehicles (UAVs),**
  - **remotely piloted vehicles (RPVs),** and
  - **drones.**
- All, of course, are **unmanned** so the name "unmanned aerial vehicle" or **UAV** can be thought of as the generic title.
- Some people use the terms **RPV and UAV** interchangeably, but to the purist the **"remotely piloted vehicle"** is piloted or steered (controlled) from a remotely located position so an **RPV is always a UAV, but a UAV, which may perform autonomous or preprogrammed missions, need not always be an RPV.**

OVERVIEW OF UAV SYSTEMS

- In the past, these aircraft were all called **drones**, that is, a **"pilotless airplane controlled by radio signals,"** according to **Webster's Dictionary**.
- Today the **UAV developer and user community does not use the term drone** except for vehicles that have limited flexibility for accomplishing sophisticated missions and fly in a persistently dull, monotonous, and indifferent manner, such as **a target** drone.
- This has not prevented **the press and the general public** from adopting the word drone as a convenient, if technically incorrect, general term for UAVs.
- Thus, even the most sophisticated air vehicle with extensive semiautonomous functions is likely to be headlined as a "drone" in the morning paper or on the evening news.

OVERVIEW OF UAV SYSTEMS

- Whether the UAV is controlled manually or via a preprogrammed navigation system, it should not necessarily be thought of as having to be "flown," that is, controlled by someone that has piloting skills.
- UAVs used by the military usually have autopilots and navigation systems that maintain attitude, altitude, and ground track automatically.
- Manual control usually means controlling the position of the UAV by manually adjusting the heading, altitude, speed, etc. through switches, a joy stick, or some kind of pointing device (mouse or trackball) located in the ground control station, but allowing the autopilot to stabilize the vehicle and assume control when the desired course is reached.
- Navigation systems of various types (global positioning system (GPS), radio, inertial) allow for preprogrammed missions, which may or may not be overridden manually.

OVERVIEW OF UAV SYSTEMS

- As a minimum, a typical UAV system is composed of **air vehicles, one or more ground control station (GCS) and/or mission planning and control stations (MPCS), payload, and data link.**
- In addition, **many systems include launch and recovery subsystems, air-vehicle carriers, and other ground handling and maintenance equipment**.

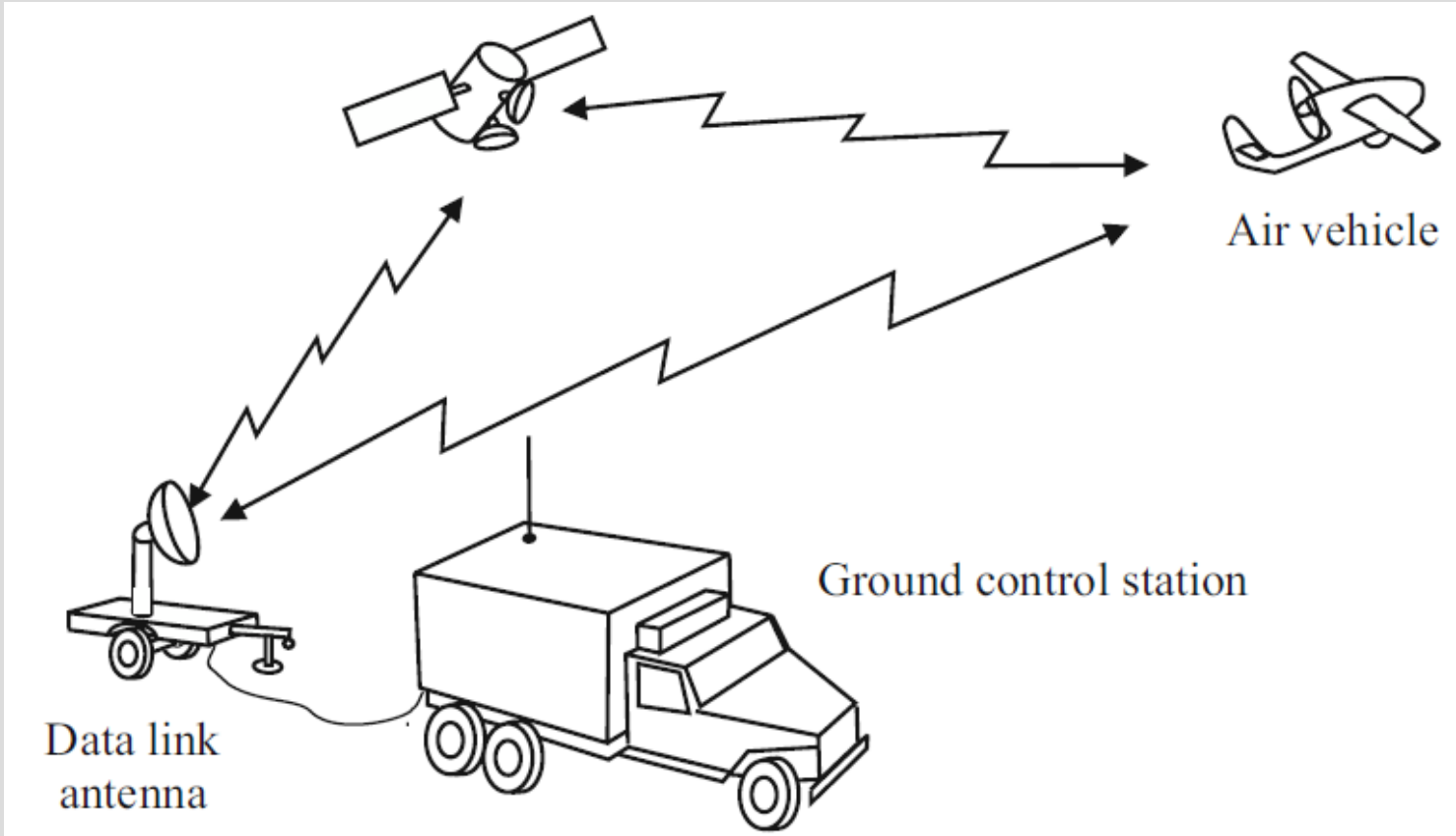


Figure 1.1 Generic UAV system

OVERVIEW OF UAV SYSTEMS
AIR VEHICLE

- The air vehicle is the airborne part of the system that includes **the airframe, propulsion unit, flight controls, and electric power system**.
- The **air data terminal is mounted in the air vehicle**, and is the airborne portion of the communications data link.
- The **payload is also onboard the air vehicle**, **but it is recognized as an independent subsystem** that often is easily interchanged with different air vehicles and uniquely designed to accomplish one or more of a variety of missions.
- The air vehicle can be **a fixed-wing airplane, rotary wing, or a ducted fan**.
- **Lighter-than-air vehicles are also eligible to be termed UAVs**.

OVERVIEW OF UAV SYSTEMS
MISSION PLANNING AND CONTROL STATION

- The MPCS, also called **the GCS**, is the operational control center of the UAV system ***where video, command, and telemetry data from the air vehicle*** are processed and displayed.
- These data are usually **relayed through a ground terminal, which is the ground portion of the data link**.
- The MPCS shelter incorporates a **mission planning facility, control and display consoles, video and telemetry instrumentation, a computer and signal processing group, the ground data terminal, communications equipment, and environmental control and survivability protection equipment**.

OVERVIEW OF UAV SYSTEMS

MISSION PLANNING AND CONTROL STATION

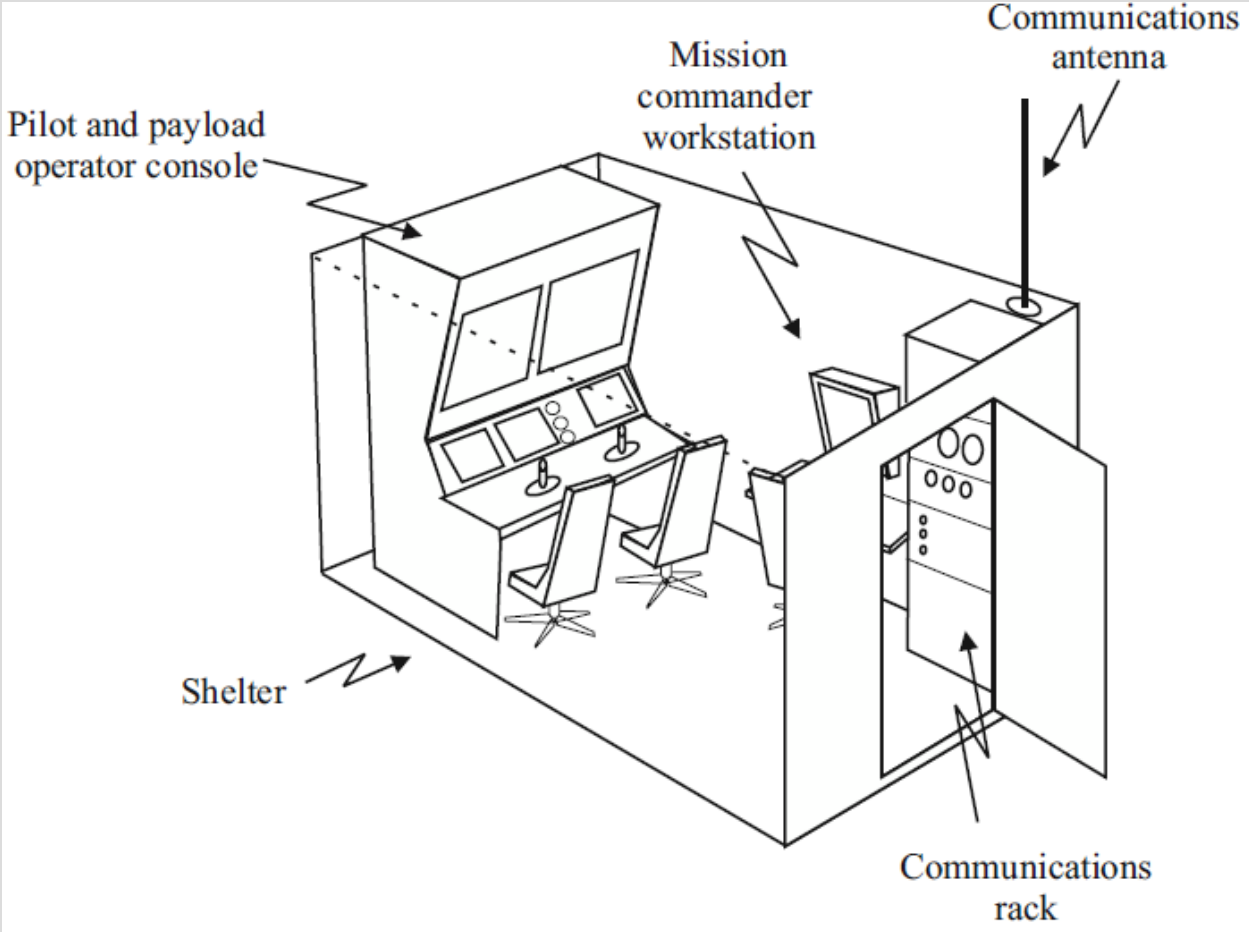


Figure 1.2 Mission planning and control station

OVERVIEW OF UAV SYSTEMS
MISSION PLANNING AND CONTROL STATION

- The MPCS can also serve as **the command post** for the person who performs mission planning, receives mission assignments from supported headquarters, and reports acquired data and information to the appropriate unit, be it weapon fire direction, intelligence, or command and control,
- for example, the mission commander. The station usually has positions for both the air vehicle and mission payload operators to perform monitoring and mission execution functions.

OVERVIEW OF UAV SYSTEMS
MISSION PLANNING AND CONTROL STATION

- In some small UAS, the ground control station is contained in a case that can be carried around in a back-pack and set up on the ground, and consists of little more than a remote control and some sort of display, probably augmented by embedded microprocessors or hosted on a ruggedized laptop computer.
- At the other extreme, some ground stations are located in permanent structures thousands of miles away from where the air vehicle is flying, using satellite relays to maintain communications with the air vehicle. In this case, the operator's consoles might be located in an internal room of a large building, connected to satellite dishes on the roof.

OVERVIEW OF UAV SYSTEMS
LAUNCH AND RECOVERY EQUIPMENT

- Launch and recovery can be accomplished by a number of techniques ranging from **conventional takeoff and landing on prepared sites to vertical descent using rotary wing or fan systems**.
- **Catapults using either pyrotechnic (rocket) or a combination of pneumatic/hydraulic arrangements are also popular methods for launching air vehicles**.
- Some small UAVs are launched **by hand**, essentially **thrown into the air like a toy glider**.
- **Nets and arresting gear are used to capture fixed-wing air vehicles in small spaces**.
- **Parachutes and parafoils are used for landing in small areas** for point recoveries.
- One advantage of a rotarywing or fan-powered vehicle is that elaborate launch and recovery equipment usually is not necessary.
- However, operations from the deck of a pitching ship**, even with a rotary-wing vehicle, will require hold-down equipment unless the ship motion is minimal**.

OVERVIEW OF UAV SYSTEMS
PAYLOADS

- Carrying a payload is the **ultimate reason for having a UAV system**, and the payload usually is **the most expensive subsystem of the UAV**.
- Payloads often include **video cameras, either daylight or night (image-intensifiers or thermal infrared), for reconnaissance and surveillance missions**.
- **Film cameras were widely used with UAV systems in the past, but are largely replaced today with electronic image collection and storage, as has happened in all areas in which video images are used.**

OVERVIEW OF UAV SYSTEMS
PAYLOADS

- If target designation is required, a **laser is added to the imaging device** and the cost increases dramatically.
- **Radar sensors, often using Moving Target Indicator (MTI) and/or synthetic aperture radar (SAR) technology, are also important payloads for UAVs conducting reconnaissance missions.**
- Another major category of payloads is **electronic warfare (EW) systems**.
- They include **the full spectrum of signal intelligence (SIGINT) and jammer equipment.**
- Other sensors such **as meteorological and chemical sensing devices have been proposed as UAV payloads**

OVERVIEW OF UAV SYSTEMS
PAYLOADS

- **Armed UAVs carry weapons to be fired, dropped, or launched. "Lethal" UAVs carry explosive or other types of warheads and may be deliberately crashed into targets.**
- there is a **significant overlap between UAVs, cruise missiles, and other types of missiles.**
- The **design issues for missiles, which are "one-shot"** systems intended to **destroy themselves** at the end of one flight, are different from those of **reusable UAVs** and this book concentrates of the reusable systems, although much that is said about them applies as well to the expendable systems.
- Another use of UAVs is as a platform for data and communications relays to extend the coverage and range of line-of-sight radio-frequency systems, including the data links used to control UAVs and to return data to the UAV users.

OVERVIEW OF UAV SYSTEMS
DATA LINKS

- The data link for a UAV system provides **two-way communication, either upon demand or on a continuous basis.**
- An **uplink with a data rate of a few kHz provides control** of the air-vehicle flight path and commands to its payload.
- The **downlink provides both a low data-rate channel to acknowledge commands and transmit status information about the air vehicle and a high data-rate channel (1–10 MHz)** for sensor data such as **video and radar.**
- The data link may also be called upon to **measure the position of the air vehicle** by determining its azimuth and range from the ground-station antenna.
- This information is used to assist in **navigation and accurately** determining air-vehicle location.
- Data links require some kind of **anti-jam and anti-deception capability** if they are to be sure of effectiveness in combat.

OVERVIEW OF UAV SYSTEMS
DATA LINKS

- The ground data terminal is usually a **microwave electronic system** and **antenna that provides line-of-sight communications**, sometimes via satellite or other relays, between the MPCS and the air vehicle. It can be co-located with the MPCS shelter or remote from it.
- In the case of the remote location, it is usually connected to the MPCS by hard wire (often fiber-optic cables).
- The ground terminal transmits guidance and payload commands and receives flight status information (altitude, speed, direction, etc.) and mission payload sensor data (video imagery, target range, lines of bearing, etc.)
- The air data terminal is the airborne part of the data link.
- It includes the transmitter and antenna for transmitting video and air-vehicle data and the receiver for receiving commands from the ground.

OVERVIEW OF UAV SYSTEMS
GROUND SUPPORT EQUIPMENT

- Ground support equipment (GSE) is becoming increasingly **important because UAV systems are electronically sophisticated and mechanically complex systems.**
- GSE may include: test and maintenance equipment, a supply of spare parts and other expendables, a fuel supply and any refueling equipment required by a particular air vehicle, handling equipment to move air vehicles around on the ground if they are not man-portable or intended to roll around on landing gear, and generators to power all of the other support equipment.
- If the UAS ground systems are to have mobility on the ground, rather than being a fixed ground station located in buildings, the GSE must include transportation for all of the things listed earlier, as well as transportation for spare air vehicles and for the personnel who make up the ground crew, including their living and working shelters and food, clothing, and other personal gear.

EXAMPLES OF UAV SYSTEMS

- In the following sections, we use intuitive size classes that are not in any sense standardized but are convenient for this discussion.
  - Very Small UAVs
  - *Small UAVs*
  - *Medium UAVs*
  - *Large UAVs*
- **Expendable UAVs**

VERY SMALL UAVS

- "very small UAVs" range from **"micro"** sized, which are about the size of a **large insect** up to an AV with dimensions of the order of a **30–50 cm (12–20 in.).**
- There are two major types of small UAVs.
  - One type uses **flapping wings** to fly like an insect or a bird and
  - the other uses a more or less **conventional aircraft configuration**, usually rotary wing for the micro size range.

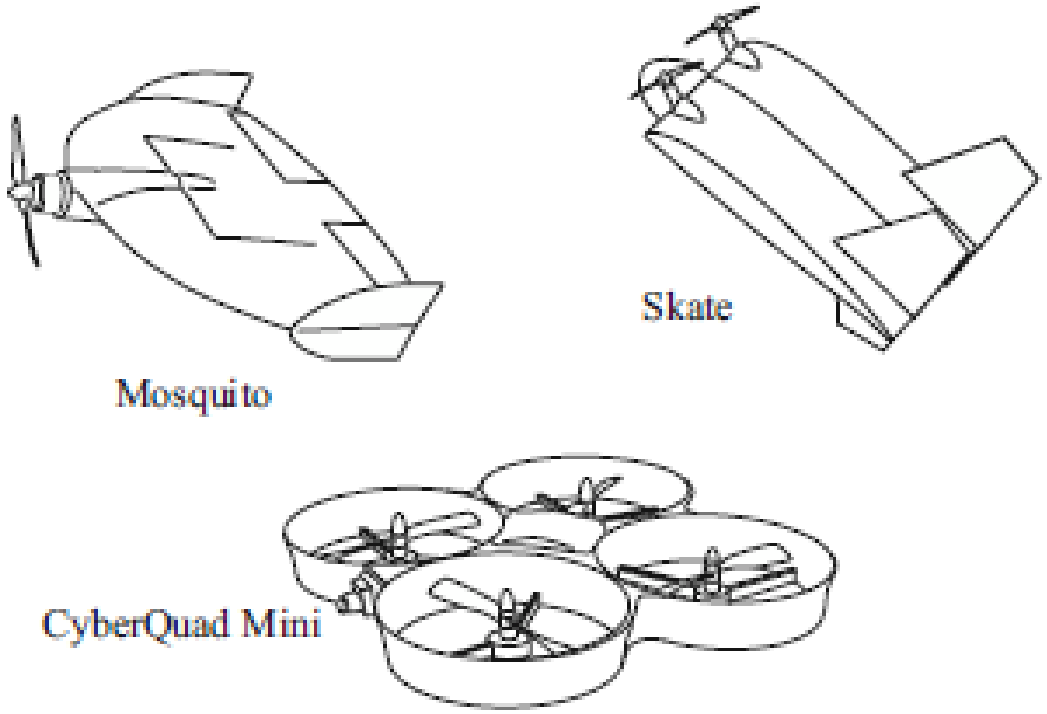
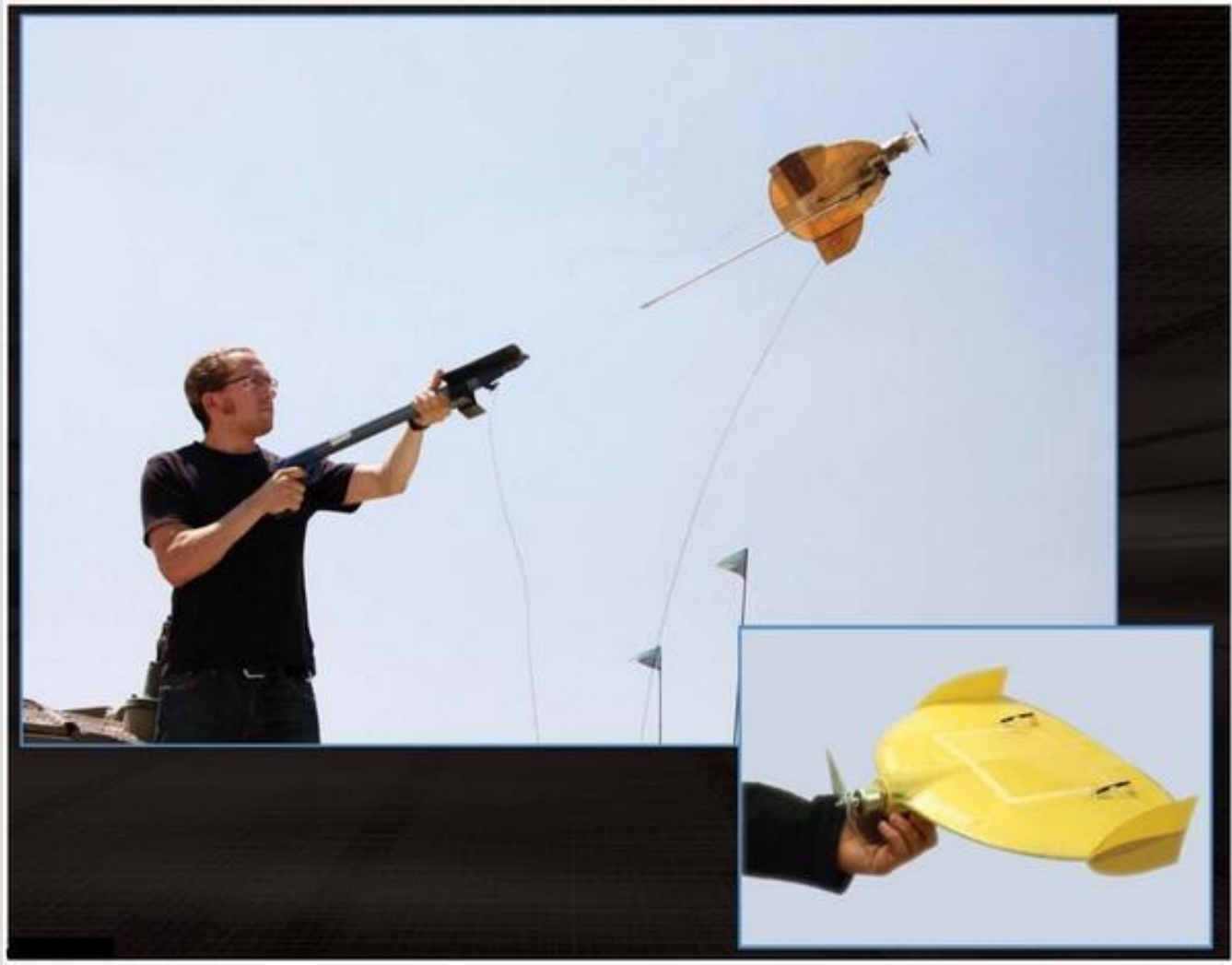


Figure 2.1 Very small UAVs

VERY SMALL UAVS

- the Israeli IAI Malat **Mosquito** wing/fuselage is **35 cm (14.8 in.)** long and **35 cm (14.8 in.**) in total span.
- It uses an **electric motor with batteries** and has an endurance of **40 minutes**, and claims a radius of action of about **1.2 km** (0.75 mi).
- It **is hand or bungee launched** and can deploy **a parachute** for recovery.



VERY SMALL UAVS

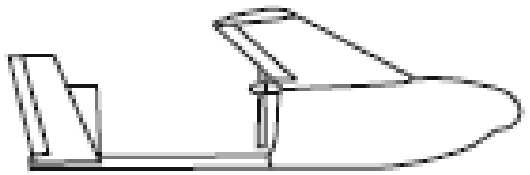
- the US Aurora Flight Sciences **Skate**, fuselage/wing has a wingspan of **about 60 cm (24 in.) and length of 33 cm (13 in.).**
- **It folds in half along its centerline for transport and storage**.
- It has **twin electric motors on** the leading edge that can **be tilted up or down** and **allow vertical takeoff and landing (VTOL**) and transition to efficient horizontal flight.
- There are no control surfaces, with all control being accomplished **by tilting the motor/propeller assemblies and controlling the speed of the two propellers.**
- It can carry a **payload** of **227 g** (8 oz) with a **total takeoff weight of about 1.1 kg** (2 lb)

VERY SMALL UAVS

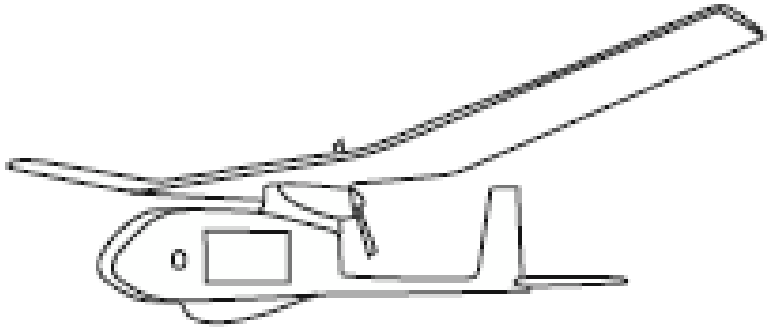
- the Australian Cyber Technology **CyberQuad Mini has four ducted fan**s, each with a diameter of somewhat less **than 20 cm (7.8 in**.), mounted so that the total outside dimension that include the fan shrouds are **about 42 by 42 cm (16.5 in.).**
- The total height including the payload and batteries, which are located in a fuselage at the center of the square, is **20 cm** (7.8 in.)

SMALL UAVS

- What we will call "small UAVs" have at least one dimension **of greater than 50 cm (19.7 in.)** and go up to dimensions of **a meter or two**.
- Many of these UAVs have the configuration of a **fixed-wing model airplane** and **are hand-launched** by their operator by throwing them into the air much as we launch a toy glider.



Bayraktar



Raven B

Figure 2.2 Small UAVs

SMALL UAVS

- the US AeroVironment **RQ-11 Raven** is an example of a UAV that is in the "model airplane" size range.
- It has a **1.4-m (4.6-ft) wingspan** and is **about 1 m (3.3 ft) long**.
- It weighs only a little **less than 2 kg (4.4 lb)** and is launched by **being thrown into the air by its operator.**
- It uses **electrical propulsion** and can fly for nearly **an hour and a half**.
- The Raven and its control "station" can be carried around by its operator on his/her back and can **carry visible, near-infrared (NIR), and thermal imaging systems for reconnaissance** as well as a **"laser illuminator"** to point out target to personnel on the ground.

SMALL UAVS

- The **Bayraktar Mini UAV** was developed by **Baykar Makina, a Turkish company**.
- It is a **conventionally configured, electrically powered** AV somewhat larger than the Raven, with **a length of 1.2 m (3.86 ft), wingspan of 2 m (5.22 ft), and weight of 5 kg (105 lb**) at takeoff.
- It is advertised to have **a spread-spectrum, encrypted data link, which is a highly desirable**, but unusual, feature in an off-the-shelf UAV. **The data link has a range of 20 km (12.4 mi),**
- The Bayraktar Mini has **a gimbaled day or night camera**. It offers **waypoint navigation with GPS or other radio navigation systems**.

MEDIUM UAVS

- We call a UAV "medium" if it **is too large to be carried around by one person and still smaller than a light aircraft**.
- The UAVs that sparked the present resurgence of interest, such as the **Pioneer and Skyeye, are in the medium class**. They have typical **wingspans** of the order ***of 5–10 m (16–32 ft) and carry payloads of from 100 to more than 200 kg (220–440 lb).***

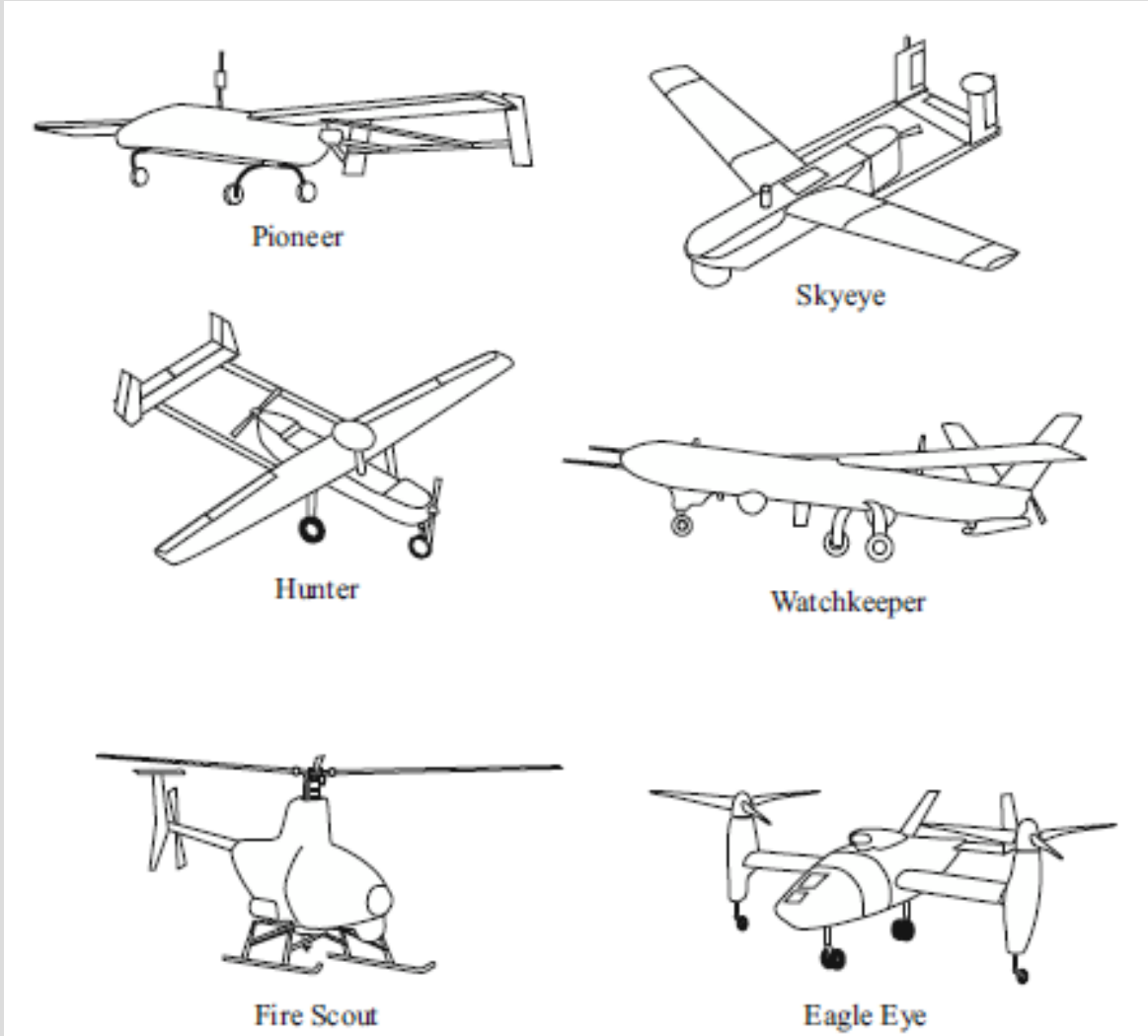


Figure 2.3 Medium UAVs

MEDIUM UAVS

- The **RQ-2 Pioneer i**s an example of an AV that is smaller than a light manned aircraft but larger than what we normally think of as a model airplane.
- **The 205-kg (452-lb), 5.2-m (17-ft) wingspan AV** had a conventional aircraft configuration. It **cruised at 200 km/h and carried a 220-kg (485 lb) payload**. Maximum altitude was **15,000 ft (4.6 km). Endurance was 5.5 h.**
- The ground control station could be housed in a shelter on a **High Mobility Multipurpose Wheeled Vehicle (HMMWV) or truck**.
- The fiberglass air vehicle had a **26-hp engine** and **was shipboard capable**. It had piston and rotary engine options.
- The Pioneer could be launched from a **pneumatic or rocket launcher or by conventional wheeled takeoff from a prepared runway. Recovery was accomplished by conventional wheeled landing with arrestment or into a net. Shipboard recovery used a net system**.

LARGE UAVS

- Our informal size groupings are not finely divided and we will discuss all UAVs that are **larger than a typical light manned aircraft** in the group called "large."
- This includes, in particular, a group of UAVs that **can fly long distances** from their bases, **loiter for extended** periods to **perform surveillance** functions. They also are **large enough to carry weapons** in significant quantities.

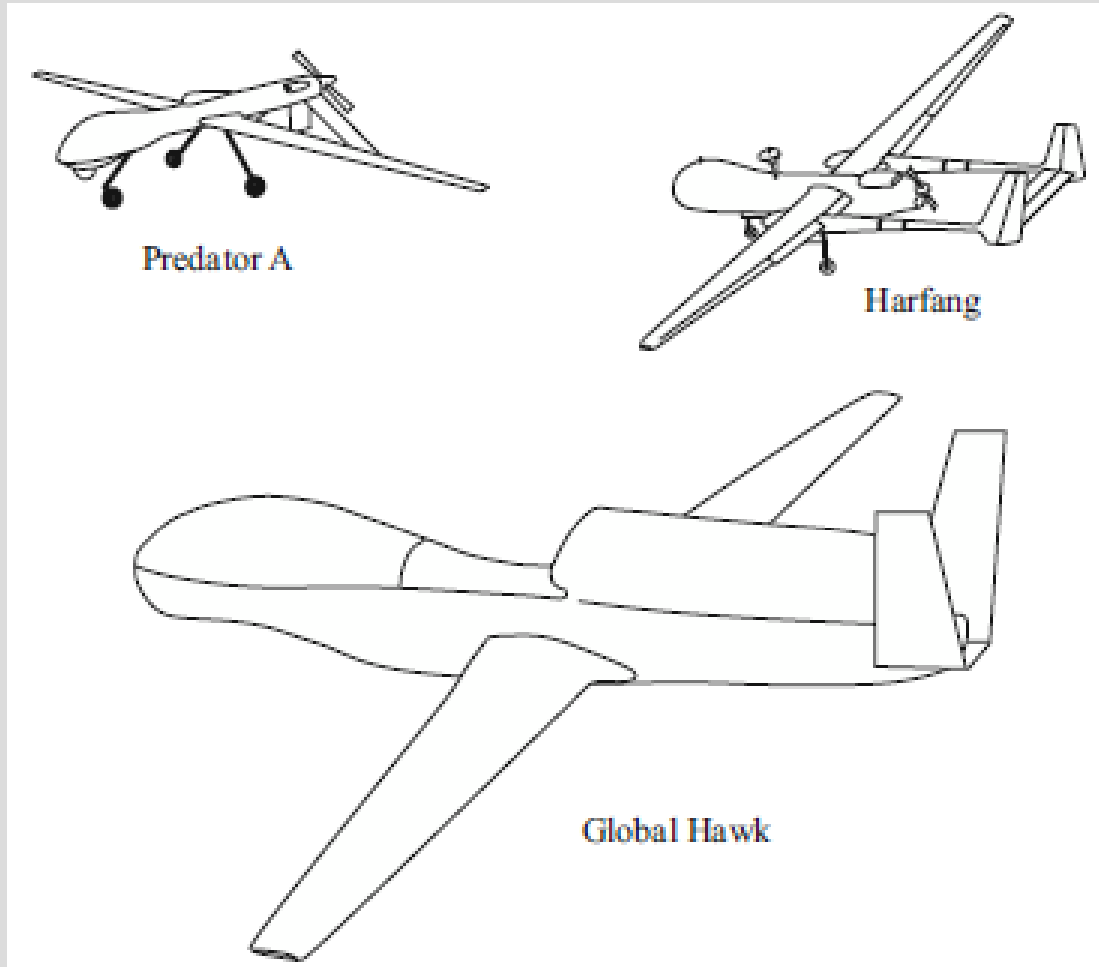


Figure 2.4 Large UAVs

LARGE UAVS

- **The MQ-1 Predator A** is larger than a light **single-engine** private aircraft and provides **medium altitude, real-time surveillance using high-resolution video, infrared imaging, and synthetic aperture radar**.
- It has a **wingspan of 17 m (55 ft) and a length of 8 m (26 ft). It adds significantly higher ceiling (7,620 m or 24,521 ft) and longer endurance (40 h**) to the capabilities of the smaller UAVs.
- **GPS and inertial systems provide navigation, and control can be via satellite.**
- **Speed is 220 km/h (119 knots**) and the air vehicle can remain on station for **24 h, 925 km (575 mi)** from the operating base.
- It can carry an internal **payload of 200 kg (441 lb)** plus an **external payload (hung under the wings) of 136 kg** (300 lb).

The Predator

LARGE UAVS

- **The RQ-4 Global Hawk** is manufactured by **Northrop Grumman Aerospace Systems**.
- It flies **at high altitude and utilizes radar**, **electro-optical, and infrared sensors for surveillance applications.**
- It uses a **turbofan engine** and appears to have **a shape that reduces its radar signature, but is not a "stealth" aircraft**.
- It is **14.5 m (47 ft) long with a 40-m (129-ft)** wingspan and has a **maximum weight at takeoff of 1,460 kg (3,219 lb).**
- It can loiter **at 575 km/h** (310 knots) and has an **endurance of 32 h.** It has a full set of potential payloads and it appears that it is **routinely controlled via satellite links.**

The Global Hawk

EXPENDABLE UAVS

- Expendable **UAVs are not designed to return after accomplishing their mission.**
- In the military world, this often means that they contain an **internal warhead** and are intended to be **crashed into a target destroying it and themselves**.
- There is a considerable area **of overlap between guided missiles and UAVs**, as illustrated by the fact that **the first "UAVs" of the aviation era were mostly guided weapons**.
- An alternative definition of an expendable is that it can (and should) be recovered if possible, but can have a very high loss rate.

CLASSES OF UAVS

CLASSIFICATION BY RANGE AND ENDURANCE

***Very Low Cost Close Range*:**

- the Army to have a **range of about 5 km (3 mi)** and cost **about $10,000 per air** vehicle.
- This UAV system fits into what could be called the "model airplane" type of system and its feasibility with regard to both performance and cost had not been proven but since has been demonstrated by systems such as the Raven and Dragon Eye.

***Close Range*:**

- It was to have a range of **50 km (31 mi)**, with **30 km (19 mi) forward of the FLOT (Forward line of own troops)**.
- The required **endurance was from 1 to 6 h** depending on the mission.
- All services agreed that the priority mission **was reconnaissance and surveillance, day and night.**

CLASSES OF UAVS
CLASSIFICATION BY RANGE AND ENDURANCE

Short Range:

- The Short-Range UAV also was required by all of the services and, like the Close-Range UAV, had the **day/night, reconnaissance and surveillance mission** as a top priority.
- It had a required **range of 150 km (93 mi)** beyond the FLOT**, but 300 km (186 mi)** was desired.
- The endurance time was to **be 8–12 h**.
- The Navy required the system to be capable of **launch and recovery from larger ships** of the Amphibious Assault Ship and Battleship class.

Mid Range:

- The Mid-Range UAV was required by all the services **except the Army**.
- It required the capability of **being ground or air launched and was not required to loiter**.
- The latter requirement suggested that the air vehicle was a **high-speed deep penetrator** and, in fact, **the velocity requirement was high subsonic**.
- The **radius of action was 650 km (404 mi)** and it was to be used for **day/night reconnaissance and surveillance.**
- A secondary mission for the Mid Range was the gathering of **meteorological data.**

CLASSES OF UAVS
CLASSIFICATION BY RANGE AND ENDURANCE

Endurance:

- The Endurance UAV was required by **all services** and, as the name suggested, was to have **a loiter capability of at least 36 h**.
- The air vehicle had to be able to operate from **land or sea and have a radius of action of approximately 300 km (186 mi).**
- The mission was **day/night reconnaissance first, and communications relay second**.
- Speed was not specified, but it had to be able to maintain station in the high winds that will be experienced at high altitudes.
- The altitude requirement was not specified, but it was thought probably to **be 30,000 ft (9.14 km) or higher.**

CLASSES OF UAVS
INFORMAL CATEGORIES OF SMALL UAV SYSTEMS BY SIZE

Micro

- They are envisioned to range in size from **a large insect to a model airplane** with a **one-foot wingspan**.
- The advent of the micro-UAV produces a whole new series of problems associated with scale factors particularly **Reynolds Number and boundary layer phenomena**.
- Assuming that **payload and power-plant problems** can be solved **the low wing loading** of these types of vehicles may prohibit operation in all but the most benign environmental conditions.

Mini

- This category stems from the old expendable definition and includes **hand-launched** as well as small UAVs that have some type of launcher.
- These are exemplified by **the electric-powered** Raven and Bayraktar mini-UAVs.

CLASSES OF UAVS
THE TIER SYSTEM

The levels in these hierarchies were called "tiers" and terms such as "tier II" often are used to classify a particular UAV or to describe a whole class of UAVs.

US Air Force tiers

- Tier N/A: Small/micro-UAV.
- Tier I: Low altitude, long endurance.
- Tier II: Medium altitude, long endurance (MALE). An example is the MQ-1 Predator.
- Tier II+: High altitude, long endurance (HALE) conventional UAV. Altitude: 60,000–65,000 ft (19,800 m), less than 300 knots (560 km/h) airspeed, 3,000- nautical-mile (6,000 km) radius, 24 h time-on-station capability. Tier II is complementary to the Tier III aircraft. An example is the RQ-4 Global Hawk.
- Tier III−: HALE low-observable (LO) UAV. Same as the Tier II+ aircraft with the addition of LO. An example is the RQ-3 DarkStar.

CLASSES OF UAVS
THE TIER SYSTEM

Marine Corps tiers

- Tier N/A: Micro-UAV. An example is the Wasp.
- Tier I: Mini-UAV. An example is the Dragon Eye.
- Tier II: An example is the RQ-2 Pioneer.
- Tier III: Medium Range—An example is the Shadow.

Army tiers

- Tier I: Small UAV. An example is the RQ-11A/B Raven.
- Tier II: Short-Range Tactical UAV. Role filled by the RQ-7A/B Shadow 200.
- Tier III: Medium-Range Tactical UAV

MISSIONS

- Defining the missions for UAVs is a difficult task because
  - (1) there are so many possibilities, and
  - (2) there have never been enough systems in the field to develop all of the possibilities.
- Two major divisions of missions for UAVs are
  - civilian and
  - military,
- but there is significant overlap between these two in the area **of reconnaissance and surveillance,** which **a civilian might call search** and surveillance or observation, which is the largest single application of UAVs in both the civilian and military worlds.
- **atmospheric sampling for radiation and/or chemical agents, providing relays for line-of-sight communications system, and meteorological measurements.**
- ***Reconnaissance*:** The activity to obtain by visual or other detection methods information about what is present or happening at some point or in some area.
- ***Surveillance*:** The systematic observation of aerospace, surface or subsurface areas, places persons or things by visual, aural, electronic, photographic or other means.
- An important mission in the military and intelligence area is Electronic Warfare (EW). Listening to an enemy transmission (communication or radar) and then either jamming it or analyzing its transmission characteristics falls under the category of EW.