Definition of UAVs

- What is a UAV?
  Aircraft controlled NOT by a pilot at least onboard

- Classifications of UAVs
  - Radio control (RC, Remote Control) Aircraft
    - Aircraft controlled by a remote pilot using a real-time radio control
    - Without human intervention, the aircraft is very likely to crash almost immediately
  - Autonomous UAVs: UAV chooses its mission parameters using a set of rules given by humans, but immediate decision of the aircraft cannot be predicted.
  - Remotely Piloted Aircraft (RPA)
    - Aircraft controlled by a pilot off the aircraft (ICAO prefers RPA to UAV)
    - Due to the incompatibility, autonomous UAVs are not allowed in civil Airspace
  "Drone": a nickname for UAVs, sometimes meaning attacking UAVs or these days more commonly small multi-rotors
• Various Applications of UAVs

<table>
<thead>
<tr>
<th>Reconnaissance/Surveillance</th>
<th>Attack/UCAV</th>
<th>Transport</th>
<th>Special Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Reconnaissance/Surveillance" /></td>
<td><img src="image2" alt="Attack/UCAV" /></td>
<td><img src="image3" alt="Transport" /></td>
<td><img src="image4" alt="Special Applications" /></td>
</tr>
<tr>
<td><img src="image5" alt="Parrot Bebop Drone" /></td>
<td><img src="image6" alt="Attack/UCAV" /></td>
<td><img src="image7" alt="Transport" /></td>
<td><img src="image8" alt="Special Applications" /></td>
</tr>
</tbody>
</table>
• Concept of Operation

- GPS Sat
- ADS-B Station
- Remote Pilot Station
- PSR
- Comm Sat
- VHF
- C2
- Command/Flight Status Camera Images
- Mobile Ground Station
- Recovering Net
- Launcher
- Air Traffic Control
- Warehouse
• Roadmap of Civil UAS

Military UAVs
- Operation in military airspace
- Airworthiness by Military Spec
- Fully established operation procedure, personnel licensing, etc

Limited use for Civil Applications
- Military UAV turned into civil application (dual-use)
- Special(temporary) airworthiness in segregated airspace

Test flights in Civil Airspace
- Test flight in dedicated airspace
- Military or born-civil UAVs are used for testing
- Data collection to prepare for fully integrated civil applications

Full Integration of Civil Airspace
- Complete procedures for airworthiness, operation, etc
- Fully integrated operation in civil airspace by existing rule of air.

UAS: Unmanned Aircraft System, consisting of UAV, Ground Station, and Comm Link
International Trend of Civil UAS

International Civil Aviation Organization (ICAO) started a study group (UASSG) on UAS integration from 2000s.

⇒ From 2014, ICAO stepped up the progress by promoting UASSG to RPAS Panel and started modifying Annexes, hoping to finish it by 2020.
⇒ ICAO limits its scope on international IFR (instrument flight rule) in controlled airspace.

Recently, small UAS, most notably the multi-rotors, are of greatest interests

- FAA proposed simpler rules for UAS under 25kg. Instead, FAA enforced registering all users of UAS over 250g (Dec ’15)
- Many countries work separately on legalizing small UAS. Oftentimes, UAS are limited within visual range.
- Originally ICAO considered small UAS out of its jurisdiction (still is), but ICAO began looking into UAS for better rule making for larger UAS.
• Categorization of UAVs

Who operates
- Military
  - Recon
  - Attack
  - Transport
- Civil
  - Aerial Photo
  - Delivery
  - Hobby

Shape
- Fixed-wing
- Rotary wing
- Compound

Weight
- Small UAS (<25kg)
- (<150kg)
- (>150kg)

Power Source
- Electric
- ICE
- Turbo
- **UAV Weight Spectra**

- Aerovironment Hummingbird: 0.67 ounce
- Hubsan X4: 8 ounces
- DJI Phantom 2: 1 kg
- Aerovironment Raven: 4.2 lb
- NOAA Weather Balloon: 2-6 lb
- Aerovironment Pointer: 9.6 lb
- Boeing/Insitu ScanEagle: 33 lb
- KAI Smart UAV: 2,200 lb
- KAI (Night Intruder): 300 kg
- Northrop-Grumman X-47B: 41,000 lb
- Northrop Grumman Global Hawk: 25,600 lb
- Gen. Atomics – Predator B: 7,000 lb

The diagram categorizes UAVs based on their weight, with micro, mini, tactical, medium-altitude, and high-altitude/UCAV categories.
### Classification of UAVs based on level of autonomy and weight

<table>
<thead>
<tr>
<th>Communication</th>
<th>BRLOS (Comm Relay/Transfer needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RLOS (In-land 120km, sea 200km), Situation awareness limited</td>
</tr>
<tr>
<td></td>
<td>Visual Line-of-Sight (&lt;500m), No latency</td>
</tr>
<tr>
<td>Remark</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>Level 2</td>
</tr>
<tr>
<td>Radio control</td>
<td>Semi-automatic</td>
</tr>
<tr>
<td>(fully manual)</td>
<td>(computer stabilized)</td>
</tr>
<tr>
<td>Level 3</td>
<td>Level 4</td>
</tr>
<tr>
<td>Waypoint</td>
<td>Task-level Autonomous Flight</td>
</tr>
<tr>
<td>Navigation</td>
<td></td>
</tr>
<tr>
<td>Level 5</td>
<td>Level 5</td>
</tr>
<tr>
<td>Intelligent/Full Autonomous Flight</td>
<td></td>
</tr>
<tr>
<td>Enabling Technology</td>
<td>Micro electronics</td>
</tr>
<tr>
<td>Small CPU, MEMS Sensors, Compact Communications</td>
<td></td>
</tr>
<tr>
<td>SW Technology</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>Weight</td>
<td>Small UAS (&lt;25kg)</td>
</tr>
<tr>
<td>Toy/RC</td>
<td>Toy/RC</td>
</tr>
<tr>
<td>Not often used</td>
<td>Some high-end photography drones.</td>
</tr>
<tr>
<td>(for close-range operation such as take-off and landing only)</td>
<td>Common for fixed wings</td>
</tr>
<tr>
<td>Used</td>
<td>Under Active Research</td>
</tr>
<tr>
<td>JARUS &lt;150kg</td>
<td>Under research</td>
</tr>
<tr>
<td>Small drones for aerial photography</td>
<td>Mainly driven by Electronics and ICT</td>
</tr>
<tr>
<td>Larger Aerial Photo drones and crop-dusting helicopters</td>
<td>Used to be a topic for SF movie, but becoming a reality</td>
</tr>
<tr>
<td>Small UAS</td>
<td>Advanced Recon, UCAV</td>
</tr>
<tr>
<td>&gt;150kg</td>
<td>Many existing UAVs UAVS</td>
</tr>
<tr>
<td></td>
<td>Advanced Recon, UCAV</td>
</tr>
<tr>
<td></td>
<td>Mainly driven by conventional Aerospace Industries</td>
</tr>
</tbody>
</table>
• Drone classifications by weight and capability

**PERFORMANCE**
- RC (VLOS only)
  - “Drones” Governed by VLOS rule
- Remote Control
- Flight Stabilization
- Waypoint Navigation
- DAA, C2

**MTOW [kg]**
- Not safe
- Not feasible

**UTM: UAV Traffic Management**
• “THE BIG PICTURE”

Class A
Above 18,000ft

Class E
10,000ft

Class G
500ft

Small UAS
Currently allowed to operate within VLOS and VLL

IFR International flight
Confinned to controlled Airspace/
Existing “rule of air” applies with amendments on C2 and DAA
Currently studied by ICAO RPAS Panel

Domestic IFR/VFR
Controlled/Uncontrolled Airspace
UAS with BVLOS capabilities should be
Integrated into civil airspace
• Age of Small “Drones”
• Widespread use of Civil UAS
• History of Autonomous Cars

**Look, No Hands**

“Kitt” from Knight Rider

**California PATH Project (1990s)**

1939
General Motors presents the concept of a driverless car at the 1939 World’s Fair

1984 & 1987
Carnegie Mellon University and Bundeswehr University Munich develop autonomous vans

1998
Mercedes, Toyota and Mitsubishi begin offering adaptive cruise control

2004
U.S. Defense Department issues a $1 million challenge to develop self-driving vehicles

2012
Google begins testing self-driving models on public roads

2015
Tesla promises to introduce a model with “auto-steering”

2016-17
Mercedes, Audi, BMW and Cadillac will offer models that drive hands-free

2017-20
Google promises to introduce the first fully autonomous car
• Levels of Autonomous Cars

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>The human driver is in complete control of all functions of the car</td>
</tr>
<tr>
<td>Level 1</td>
<td>One function is automated</td>
</tr>
<tr>
<td>Level 2</td>
<td>More than one function is automated at the same time, but the driver remains attentive</td>
</tr>
<tr>
<td>Level 3</td>
<td>Driving functions are sufficiently automated - the driver can safely engage in other activities</td>
</tr>
<tr>
<td>Level 4</td>
<td>The car is self-driving - no human driver required</td>
</tr>
</tbody>
</table>

Source: SAE
• Levels of Autonomy in terms of components

- **Component Level:** Engine/Transmission, ABS (simple physical quantity)
- **Functional Level:** Traction Control, Anti-roll Control (multiple physical quantities)
- **Behavioral Level:** Active Lane Keeping, Adaptive Cruise Control, Automatic Parking (+Vision)
- **Partial Autonomy:** Expressway Autonomous driving, traffic-jam assist, Self Valet Parking (+Complex decision making)
- **Full Autonomy:** indefinite autonomous driving without human intervention (AI)