# UAV Operations and Their Safety

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Erasmus+ Programme
of the European Union

Autonomian

# Mission steps

UAV

Before

During

After

# UAV mission steps

- Planning UAV mission
  - Choose right hardware and software
  - Recognize mission area
  - Identify potential dangers and apply suitable scenarios
  - Identify necessary legal requirements, i.e. specific permissions, limitations, etc.
  - Check weather forecast!

Planning an RC (VLOS) mission in known environment: usually Ad hoc.
Planning a VLOS in unknown environment: 48h-7 days in advance.
Planning a BVLOS mission: even up to 180 days in ahead (need for specific permits).

# UAV mission steps

- Technical preparation
  - Allocate resources: i.e. charge battery packs to full
- Mission
  - Before start procedures
  - In-flight procedures (flight path, control, monitoring, communication)
  - Landing and after-landing procedures
  - Emergency procedures (i.e. RTH)

-------- check-list based procedures sample --------

# UAV mission steps

Final procedures, result processing, i.e.:

- Download movies from the cards.
- Archive logs.
- Discharge/charge batteries to the storage mode.

# UAV mission steps

- **Working in hurry and without preparation and procedures may result as follows:**

# Human

as a UAVO

Physiological limits

Psychological limits

Drugs

Impact on the mission

# UAVO

UAVO shares same responsibility (according to the law) as a plane pilot and officers.

So far, in many countries, current legislation usually do not distinguish a professional pilot from the professional drone operator!

**You're responsible for yours and others safety!**

**Neglect approach and seemingly irrelevant things may involve a catastrophe.**

# Physiological limits: your health and body

- Some scenarios and UAVO categories require medical health check, comparable with the one for professional pilots.

# Physiological limits: your health and body

Consider: in case of the multirotor, stabilisation (position correction) happens at least 100x per second so action is executed at least every 10ms (usually PID loop is 32kHz that is much more!).

Human operator can act no quicker than 5 times per second as minimum reaction time for the human brain is considered to be around 100ms from the excitation to the muscle reaction.

Considering above, full control of the multirotor has to be postponed to the Flight Controller (hardware + software).

# Physiological limits: your health and body

Habits = trap of modern technologies:

- Manufacturers used to “surprise” users in an undesirable way, i.e. during firmware update:
  - New function, new user interface, different GUI may appear and surprise user.
  - Updates frequently reset personal settings (i.e. throttle curve).
    - A good example is a reset of the FC rotation (correction) after each firmware upgrade that causes quadcopter to be unusable!

# Physiological limits: health, mood, drugs


What impacts UAV operations?

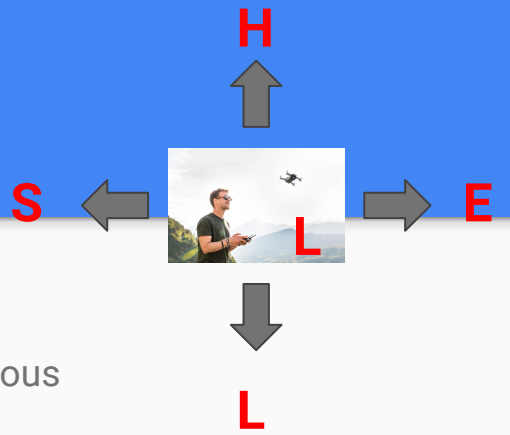
- Sickness and its curation:
  - Popular and available freely medicaments like i.e. ephedrine impacts strongly reaction time
  - Chronic diseases related curation (i.e. cardiovascular that may impact blood pressure)
- Tiredness
- Headache, muscle pain
- Popular drugs alcohol, drugs, smart drugs, power ups
- Anxiety / stress / neurosis / emotional problems

# Physiological limits


What impacts UAV operations?

- Environment and other human around operator (crowd pressure)
- Weather
- Period (women)

# Physiological limits




- Model SHELL
  - Designed in 1972 and updated in 1984 presents impact of the various human-related factors to the aerial operation safety:
    - S - Software: procedures, software, safety politics, cards, check-lists, manuals;
    - H - Hardware: drone hardware, ground station, control software, comm.
    - E - Environment: world around you including physics, organisation, politics, economy
    - L - Lifeware: social and human relations and limitations
    - L - Lifeware central: individual - you as a UAVO / controller

# Physiological limits - poor statistics

“It is human to err, but to voluntarily abide in error is diabolical. ...” - st. Augustin.

Murphy’s law: “Anything that can go wrong will go wrong”.

Statistic says, about 80% of incidents / accidents happen because of the human, not technical factor. Applies both for aviation as well as human operations.

# Physiological limits - emotions

Lack of communication - common problem in hierarchical societies (i.e. Asia), invalid communication procedures (i.e. informing incorrect unit / person on problem).

Habit and routine - it occurs and develops over time.

Lack of knowledge and belief in infallibility - ignorance and lack of training.

# Physiological limits - emotions

Fatigue, distraction, stress - our everyday life can be disastrous.

Bad preparation of the workplace - due to a lack of knowledge, resources, under-financing or inadequate organization.

Time pressure, circumstances - see Smolensk accident.

Personality - lack of assertiveness.

# Physiological limits - emotions

Facilitation and carelessness - taking shortcuts and breaking (often own) standards and rules.

Treating deviations as rules.

Nearsightedness - incorrect assessment of the consequences of actions.

# Physiological limits - coffee

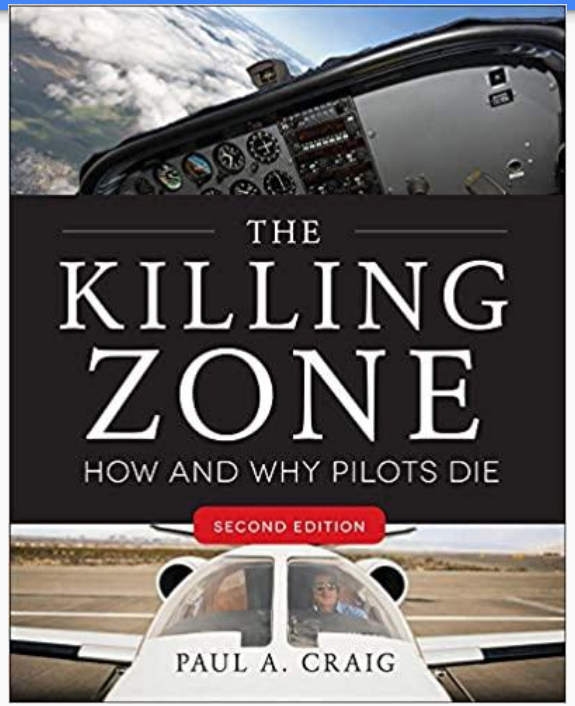
Some interesting fact about one of the most popular, legal drugs. A coffee:

- It is absorbed up to 45 minutes after consumption
- Has a relaxing effect on the muscles
- There is a lethal dose!
- It's addictive
- It works on the nervous and vascular systems

# Emotional limits - The Death Zone

Routine leads to a disaster:

- The death zone is (statistically) a period between 50h and 350h of a flight (UAVO operations)
- There is bravado and the belief that everything related "is already behind me".
- A routine appears and, for example, quickly going through checklists.



# Direct, physical dangers

- Operation type (VLOS, BVLOS, FPV), the hardware condition of the drone, all this affects the safety of not only the operator, but also bystanders.
- You can hurt someone seriously even with a small quadcopter

# What is a difference between incident and accident in aviation?

Accident - there is loss (hurt) of people / equipment.

Incident - there is no loss but procedures and rules were broken.

I.e. if you hit with your drone into another drone, it is considered to be an accident.

In many countries drone accident is subject of the NTSB (National Transportation Safety Board) investigation, same as plane accident.

# Flying in the public airspace

Airspace and operations

Chicago Convention on International Civil Aviation

# Where am I?

- In no doubt, you MUST be aware, where are you flying. This involves possible limitations (regular, additional), demand on communication, and so on.

  Drone operator is responsible for ensuring all necessary permissions and go along with all procedures that apply for the mission.
- Lack of knowing it may cause unpleasant consequences, occurrence of incidents and accidents, eventually crime liability.

# Who am I?

- You need to identify flight category and scenario.
- You need to identify operation type (relates to above)?
  - VLOS - Visual Line Of Sight
  - BVLOS - Beyond Visual Line Of Sight
  - FPV - First Person View

# Airspace definition in short

It is 3D space, located above:

- Land territories and border sea zone (national)
- Seas and oceans outside the above-mentioned border zone
- Territories that do not belong to any country (e.g. Antarctica)

# National Airspace

National / state space (applies to each state):

- Over land territory
- Over the inland waters
- At the territorial sea (border zone)

# Airspace components

- FIR - Flight Information Region
  - From GND do FL660 (66000 ft >=~ 20000m)
  - There is a FIS service available there (Flight Information Service) along with ALRS (ALaRm Service).
- It is common that a country holds just one FIR covering their National Airspace, i.e. Poland is EPWW.

# Airspace components

- For the aviation, there are two general classes of the operations in the airspace:
  - VFR (Visual Flight Rules) - you need to visually identify, where are you at the moment and where are you flying.
  - IFR (Instrument Flight Rules) - no need as above (higher/more demanding category) - in short you’re piloting without an outside view, just using on-board instruments and communication (mostly voice based) with ground section.

# Airspace components

- Aforementioned (VFR / IFR) categories are for aviation (piloted aircrafts) and shall not be directly nor indirectly identified as i.e. VLOS / BVLOS, even if seems to be similar.
- Drone operations present two major categories:
  - VLOS (Visual Line of Sight) - operator must be able to see the drone with naked eye (obviously you can wear glasses if you do daily), you can temporary lose sight and observe i.e. telemetry but in any case you need to be able to recover sight and find the drone
    - FPV flights also apply here;
  - BVLOS (Beyond Visual Line of Sight) - you use telemetry/camera/other to identify drone location and position but you temporary or permanently keep it out of sight.

# Airspace classes

- There are two general categories of the airspace:
  - Regulatory and Nonregulatory. Below we focus on Regulatory
- There are also 4 classes:
  - Controlled
  - Uncontrolled
  - Special Use
  - Other

A great document covering airspace classification along with components, authored by FAA (applied to the US) is here:
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/17_phak_ch15.pdf

# Airspace classes

- Controlled and uncontrolled airspaces.
- In short, controlled airspace is in between FL095 up to FL660 + airport areas. Classes A to E, (not all required, i.e. in Poland only C & D are used). Airspace provides ATC (Air Traffic Control) service for ALL aerial vehicles, including drones.
- In short, uncontrolled airspace it is over FL660 and from GND to FL95 but excluding many zones (Special Use Airspaces). Classes F & G (in Poland there is only G used). There is no ATC service.

# Airspace classes

- Currently, standard operations cover up to 120m AGL and operations above 120m AGL require special scenarios and acceptance by agency governing airspace.

# Airspace classes

- Detailed class definition vary by country. Following review is based on the Polish regulations and gives general overview.
- The standardised is a class A through F definition on the service level:
  - Class A - only IFR flight mode, there is a FIS and separation between users is provided;
  - Class B - Same as class A but for both IFR and VFR.
  - Class C - both IFR and VFR. IFR flight is warranted to be separated from any other IFR and VFR flights. VFR flight is separated from other IFR flights but not from other VFR flights, there is information about other VFR flights, however.

# Airspace classes

- Class D - is for IFR and VFR, whereas IFR is provided with information about VFR, IFR is ensured to be separated from other IFRs and they have information about other VFR flights but they are not ensured to be separated from other VFR.
- Class E - is for IFR and VFR, similar to class D but information on VFR is delivered only if available/possible. You can ask for guidance and collision avoidance if willing, however.
- Class F - is for IFR and VFR, and is uncontrolled one. Separation is only partial/fragmented, if possible. Flight Information on demand.
- Class G - is for IFR and VFR, and is uncontrolled one. There is no separation between flights offered at all. Flight Information on demand.

# Airspace classes

- ATC contact requirements:
  - Classes A,B,C,D - obligatory for all flights;
  - Class E - only for IFR flights;
  - Class F - strongly advised (but not obligatory) ATC contact;
  - Class G - there is no ATC (there is FIS only) but ...

    **Drones can use UTM (U-Space). Follow the lecture to know more!**
    - https://www.nasa.gov/ames/utm
    - https://www.easa.europa.eu/sites/default/files/dfu/what_is_u-space.pdf

# Airspace classes

- Any airspace class can have 3D structures that are managed the “special” way, so called zones
  - There are “flexible” zones, that may be activated in a daily period;
  - And there are “permanent” zones, that are considered to be fixed (slowly changing) and are subject of change only by the next AIRAC period*

# Airspace zones

- Permanent (non-flexible) zones (structures) include:
  - TMA (TCA) - Terminal Maneuvering Area - Airport region. No drone flights possible.
  - R - Restricted areas - UAV operations with special permission, i.e. National Parks.
  - P - Protected - flights permitted under acceptance of the zone manager. No ultrasonic flight allowed ;-).
  - ADIZ - Air Defence Identification Zone - near border regions, by the external UE border. In Poland those are 3 ADIZes: ADIZ RUSSIA, ADIZ BELARUS i ADIZ UKRAINE. Drone operation is possible once obtaining special permit.
  - RMZ - Radio Communication Mandatory Zone. Obligatory contact, depending on the particular RMZ, i.e. RMZ Warsaw a phone call to the Tower. Some RMZs may require bi-directional radio communication that requires radio operator certification.

# Airspace zones

- Flexible Zones can be activated in a daily regime. It is announced on the airspace management agency, i.e. http://airspace.pansa.pl
  - AUP (Airspace Use Plan) is announced at 6:00 UTC, containing all flexible zones (their activations) as ordered by the previous day.
  - NEXT AUP - an AUP for the following day, containing changes to the main AUP. NEXT AUP is announced at 14:00 UTC.
  - UUP (Updated Use Plan) - containing real (activated) airspaces, as reported to be in use.
    - Below FL095 you can only shorten reservation time.
  - Warning: booking a zone is not like “create” a new zone ad-hoc. AUP contains only activation / deactivation status for existing, flexible structures. Having an airspace map, it is clearly visible that particular zone exists in the considered area, it is just a matter of whether it is active or inactive.

# Airspace zones

- Flexible structures:
  - TSA (TS) - Temporary Segregated Area - temporary denied flights. No flights possible when active.
  - TRA (TR) - Temporary Restricted Area - flights are temporary restricted. It is possible to make an UAV operation once obtained acceptance from the zone manager.
  - D - Dangerous - same rules as TRA but presents information for the operator that there is a danger. I.e. fireworks show area that can shut down your drone.

# Airspace zones

- 
  - ATZ - Aerodrome Traffic Zone - usually small, “club” airports, flight within the zone possible once approval from the zone manager obtained; Otherwise 30m AGL limit.
  - MCTR (MATZ) - Military ATZ - same as civil ATZ, but you apply for an approval from the military manager.
  - MRT - Military Routes - a military transport occurs in this zone. No drone flight is possible.

# Airspace zones

Additionals are ad-hoc reservations, distributed via NOTAM messages (Notification to Airman), i.e. with informations about BVLOS bookings.

```
G0214/19 NOTAMN
Q) EPWW/QWULW/IV/BO /AW/000/005/5216N02053E001
A) EPBC B) 1902201000 C) 1902231600
D) 1000-1600
E) NAVIGATION WARNING:
FLIGHTS OF UNMANNED AERIAL VEHICLES (UAV) BEYOND VISUAL
LINE OF
SIGHT (BVLOS) - ATZ BABICE.
LATERAL LIMITS (WGS-84):
1.521641N 0205325E
2.521637N 0205323E
3.521632N 0205354E
4.521637N 0205356E
VERTICAL LIMITS:
GND-500FT AMSL
CONTACT: +48 723 298 168
F) GND G) 500FT AMSL
CREATED: 18 Feb 2019 12:49:00
SOURCE: EUECYIYN
```

# Airspace zones

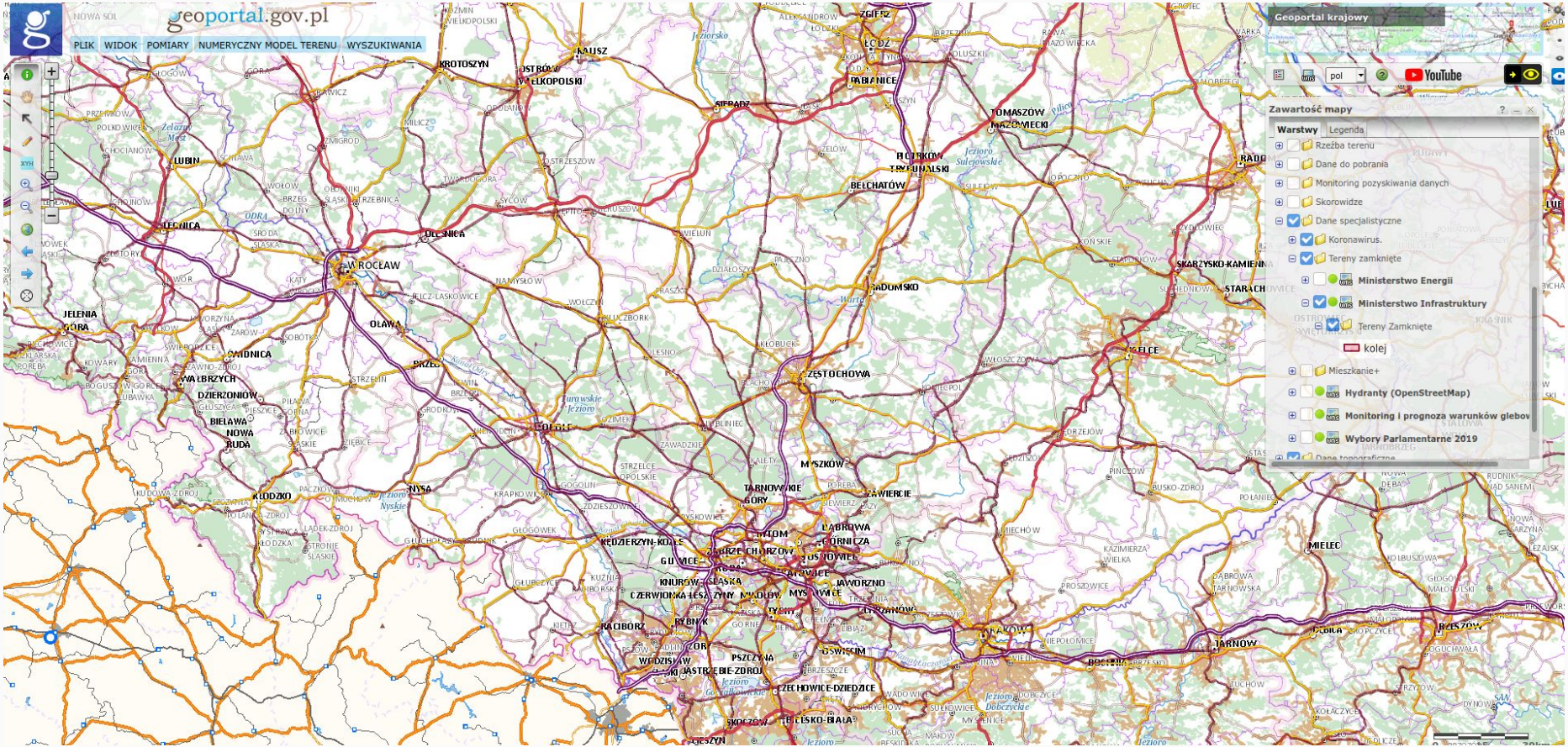
- Zone naming:
  - Prefix is specific for the country, i.e. EP is for Poland + zone type and number.
    If a zone was removed, its number can be reused no earlier than in a year from removal, to avoid concerns.

    I.e. restricted zone in Poland (class R): EPR 22

# Airspace zones - other restrictions and regualtons

As a UAVO, you may expect other than aforementioned limitations. I.e. Restricted, no-fly zones used to be automatically implemented in the area if the military and strategic industry, including i.e. dams, railways, nuclear and other power plants. Majority of those do contain EPRs while some other require getting familiar with other to the aviation resources.

An example GIS portal delivering information for Upper and Lower Silesia region in Poland is present below.




Geoportal.gov.pl - Closed areas, Polish Geportal, Upper and Lower Silesia region.

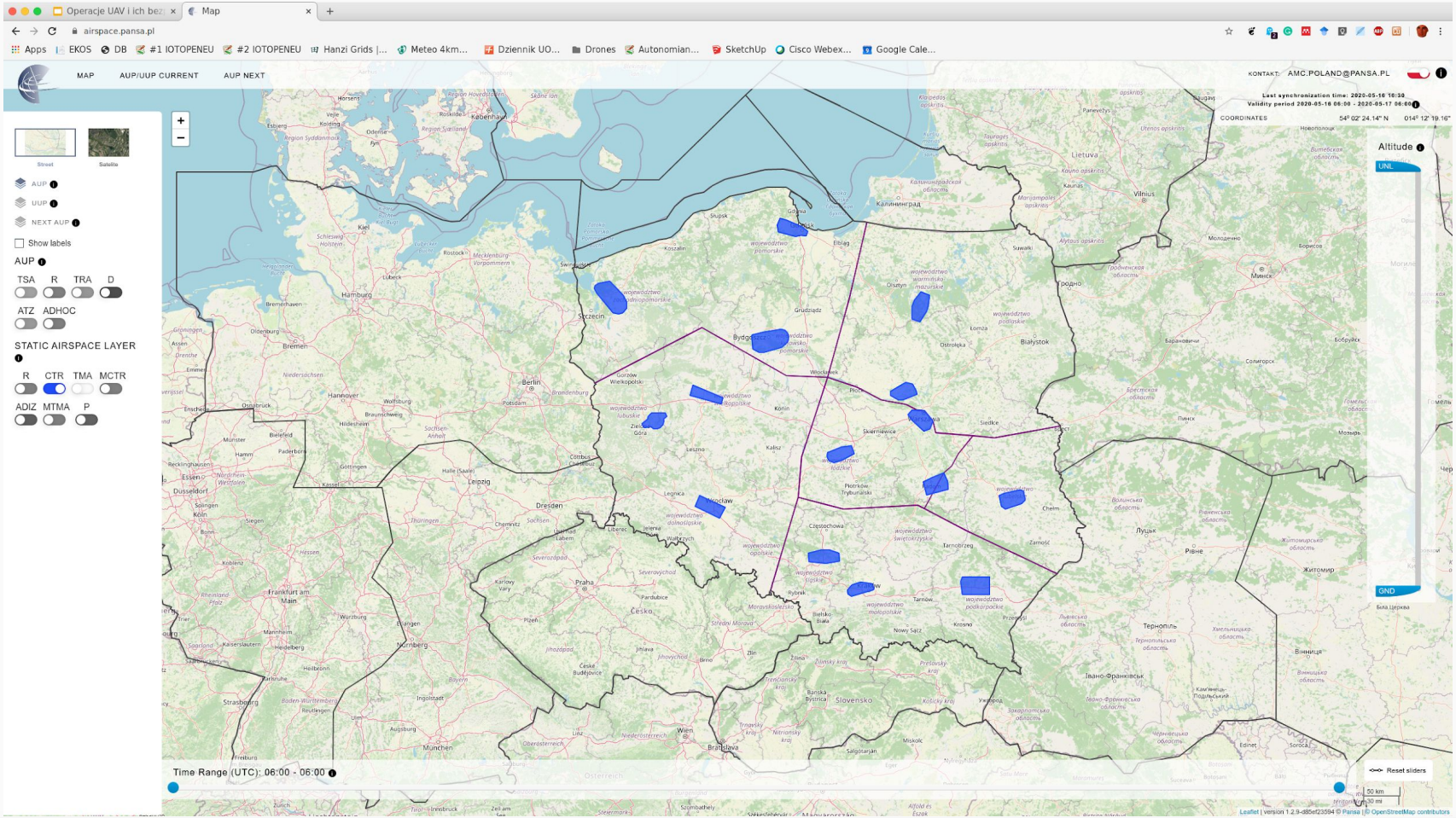
# FIS

Flight Information Services in Poland (example):

- Gdańsk
- Poznań
- Olsztyn
- Warszawa zachód
- Warszawa wschód
- Kraków

# Airspace zones

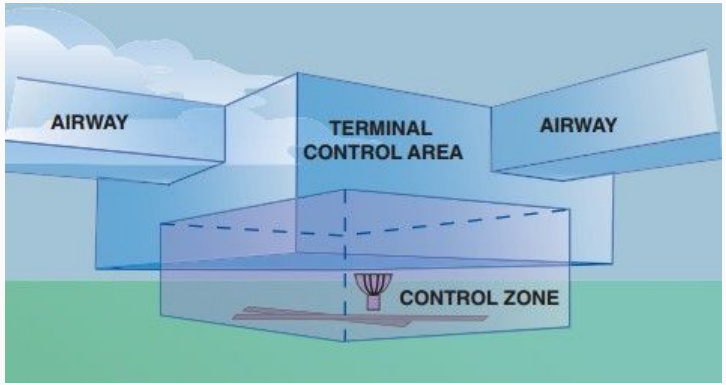
- CTR (Control Zone)
  - Controlled airspace, usually close to the commercial, large airports. Its size reflects not only airport above ground area but is large enough to cover airways approaching to the airport, both VFR and IFR.
  - Commonly it is extended at least 5 nautical Miles from the airport, in particular in the direction of the vectors to final approach.
  - Single CTR can cover many airports located nearby.
  - Interestingly, a controlled, commercial airport can have no CTR zone at all, but that is rare.
  - You can fly the drone if you’re certified and you’ve got permission of the zone manager only!




CTRs in Poland ((c) PANSA, airspace.pansa.pl

# Airspace zones

- TMA (TCA) Terminal Maneuvering Area
  - It is located above CTR to allocate all vectors to final approach to CTR (both VFR and IFR).
  - Usually around 200m AGL up to FL660.



# Airspace zones

- Airspace Regulation Agency (i.e. PANSA in Poland) delivers a periodical report with regulations, procedures and airspace components.
  - It contains (among others) information about shape, amount, symbols (names) and regulations of the flexible and non-flexible airspace zones.
  - It is so called AIP (Aeronautical Information Publication)
    - AIP is published in exact periods (every 28 days) in so-called AIRAC period: https://www.nm.eurocontrol.int/RAD/common/airac_dates.html

# Organisations and their duties

- Chicago convention regulates exact responsibility regarding the scope.
- Regulating body is ICAO (International Civil Aviation Organisation).
- In short, their duty is to regulate everything related to the airspace and aviation, including (among other) drones, indirectly however (as for now).

National Aviation Agency usually implements at least:

- ATM - Air Traffic Management
- ANS - Air Navigation Services

# Organisations and their duties

From the UAVO point of view essential services are the following ones (on high level):

- ATS (Air Traffic Services) - a service that regulates airspace operations, including (among others) collision avoidance, guidance
  - ATC - Air Trafic Services - in short, ground-based air traffic control to separate flights
  - FIS - Flight Information Services in other than ATC spaces (varies by country)
- AIS - Airspace Information Service - responsible to collect and disseminate information for whole airspace.

# Practice

… makes master ...

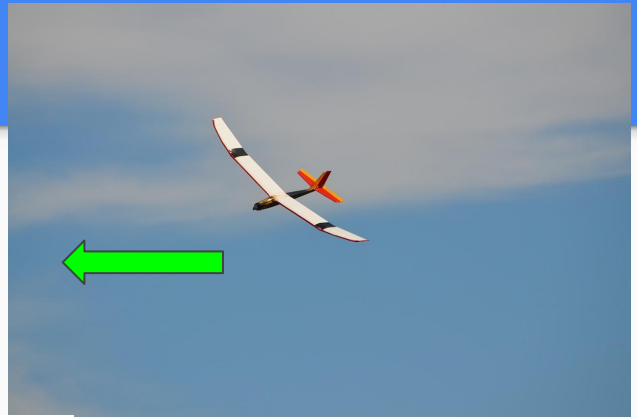
I own a fixed wing model. What should I practice?

I have a multirotor drone. What should I practice?

# I own a fixed wing model. What should I practice?

- In short: “everything” :-)
- In long:
  - Flying fixed wing is more demanding on your focus and … more stressful.
  - Fixed wing cannot hover, so if you do not control it, it will fly away, eventually fall down due to the lack of control.
    - Multirotor is more “static” in their nature. Depending on current flight mode, you can give yourself a break and automation will keep your UAV in its position (obviously it won’t work if your drone does not contain positioning/navigation feature or you’re flying in Acro mode, i.e. FPV).

# I own a fixed wing model. What should I practice?



- In particular, one practice is very important: flights towards you, when your fixed wing approaches you. Practice direction change as in this moment it is “opposite” as to the operator.
- You need to imagine yourself you’re in the cockpit.
- And practice to induct automation of the reactions

# I own a fixed wing model. What should I practice?

- Landing (approach observed from the distance and in from the angle):
  - It is quite difficult to land precisely, observing from outside.
- It is essential to take-off and land towards wind.

- Practice solving critical situation, when you intentionally stall the model then recover it.

# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

- Flying with different orientation - similar problem to the fixed wing models, as described previously.
- Practice outdoors with GPS off to manually correct UAV position (careful, in particular in strong wind!)
- Practice operations with no altitude hold (warning - for experienced pilots) - try to keep drone stable, on the level.

# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

- Quick descend (racing style) not only via throttle down but also forwards
- Operations requiring two or more control surfaces (degrees of freedom) included:
  - Pivot (scan 360) around selected object: keep altitude, orientation towards the object and maintain constant speed. Drones used to implement this feature automatically nowadays yet, practicing manual is advised.
  - Circular flight with front always perpendicular to the center.
  - Vertical circular flight.
  - 8-style vertical flight.

# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

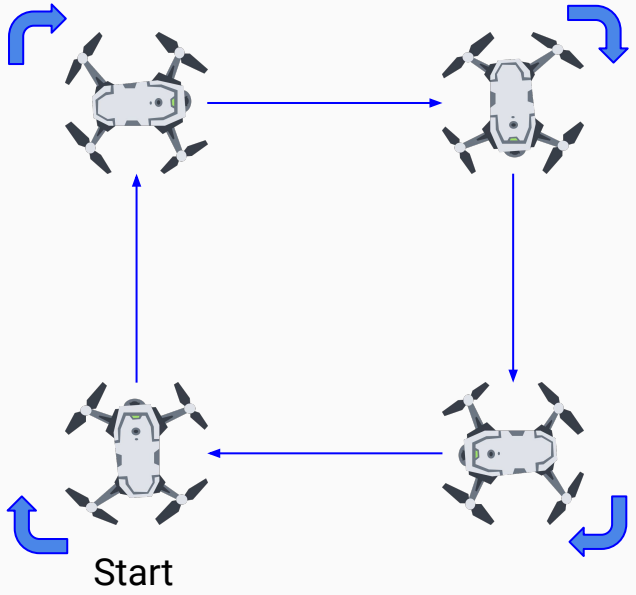
Warning! Never practice above people nor close to them!

Flight on the square path, change direction each corner (view from above).

Stop for a moment in each corner.

Two variants:

- With GPS / positioning on (for beginners)
- Without GPS (for advanced, this used to be included in practical exams)

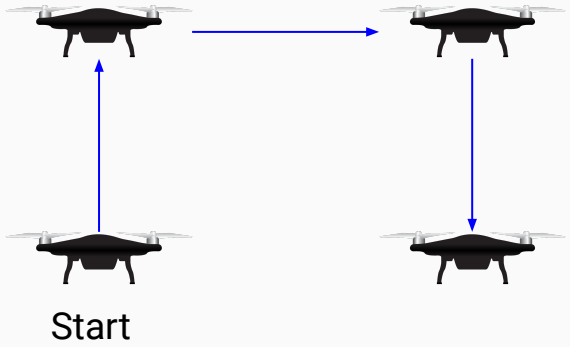



"Icon made by Pixel perfect from www.flaticon.com"

# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Warning! Never practice above people nor close to them!

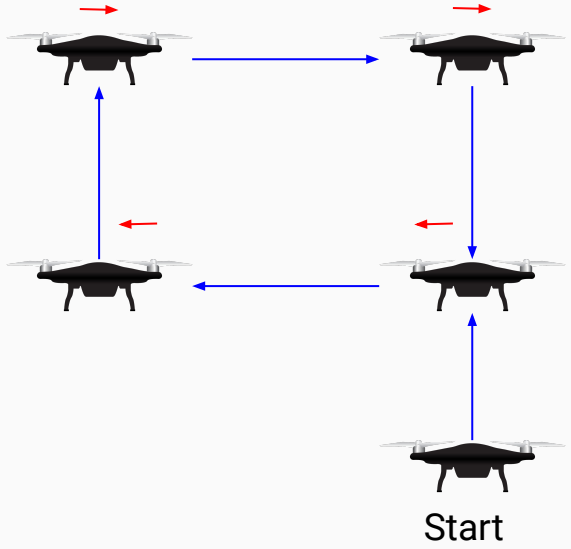
Side flight on vertical square.



# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Warning! Never practice above people nor close to them!

Vertical square path flight. Mind to change direction in the corners.



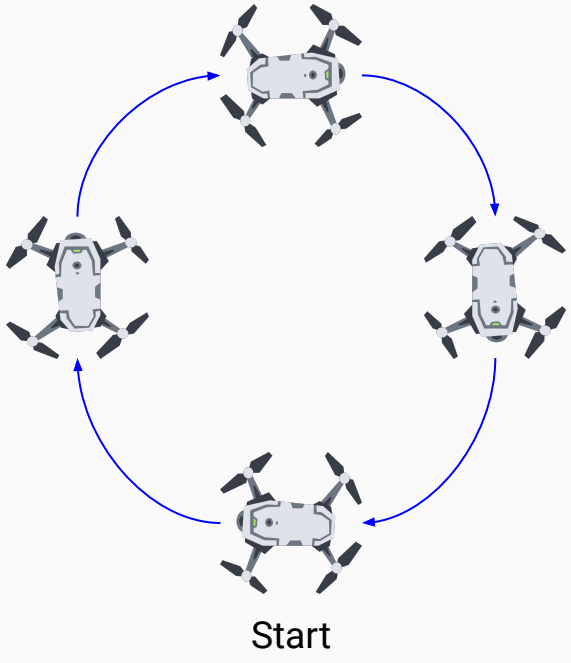
# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Warning! Never practice above people nor close to them!

Circular flight (as seen from above).

Front perpendicular to the circle centre.

It is good to practice both directions!



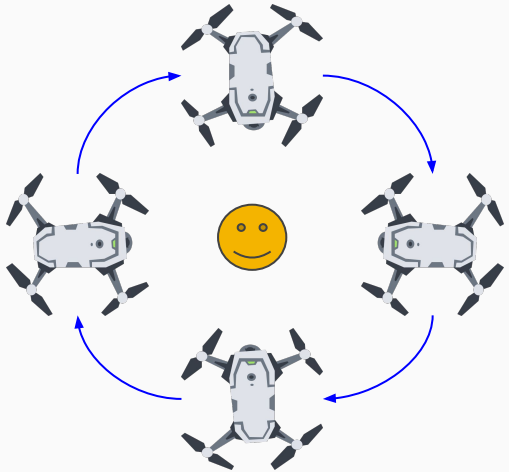
# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Warning! Never practice above people nor close to them!

Horizontal, circular flight (as seen from above).

Your MR should point (head) towards the centre, as it is “observing the object located there.

It is good to practice both directions!



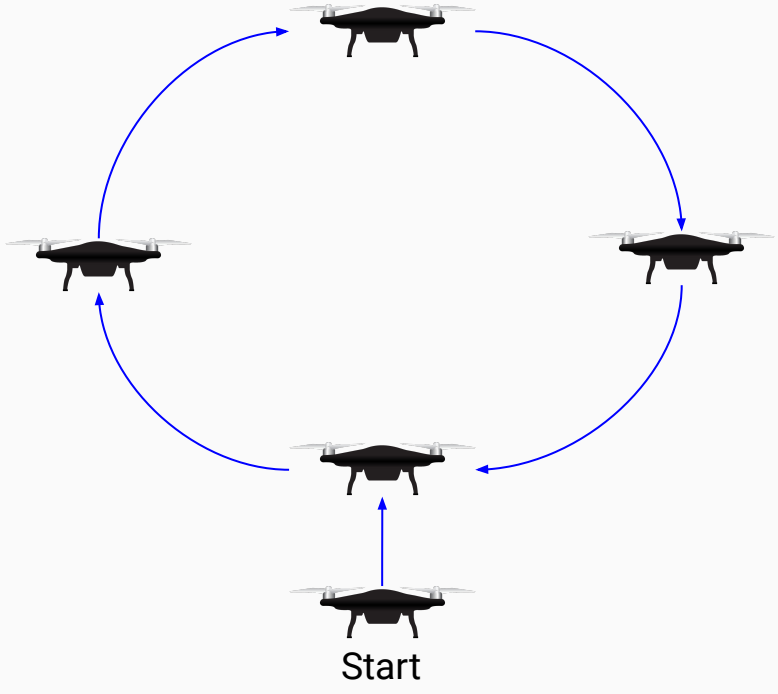
Start

# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Warning! Never practice above people nor close to them!

Vertical, circular flight (as seen from the side).

It is good to practice both directions!

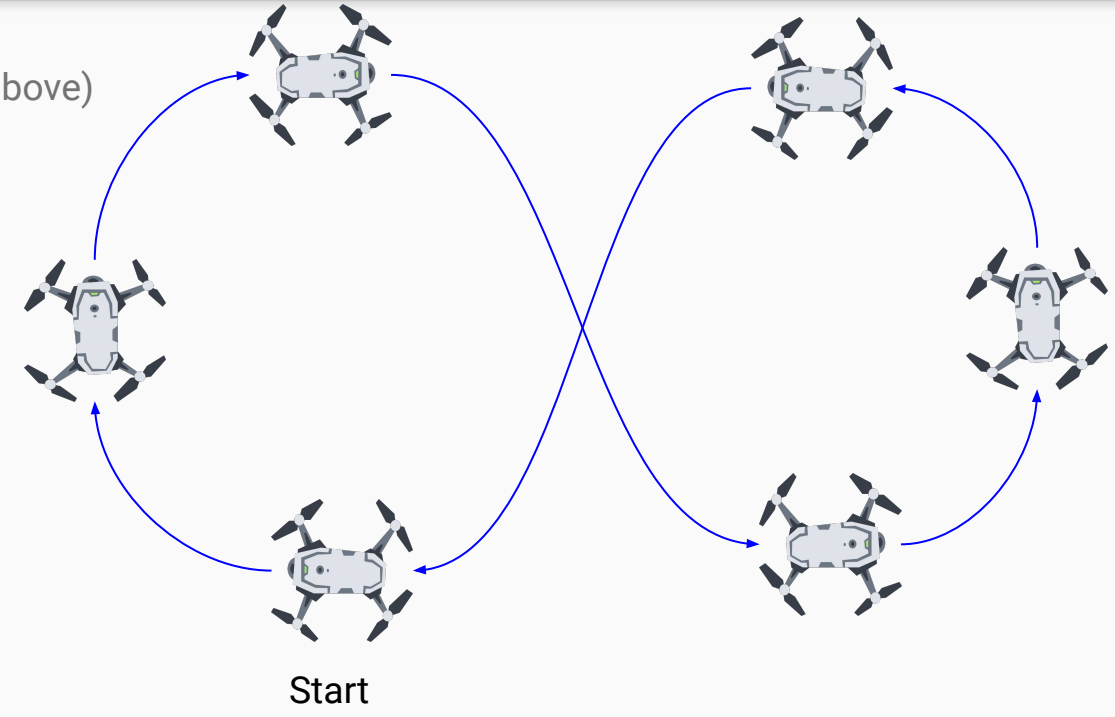


# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Warning! Never practice above people nor close to them!

8-shape flight (horizontal, as seen from above)
Including continuous heading change.

It is good to practice both directions!

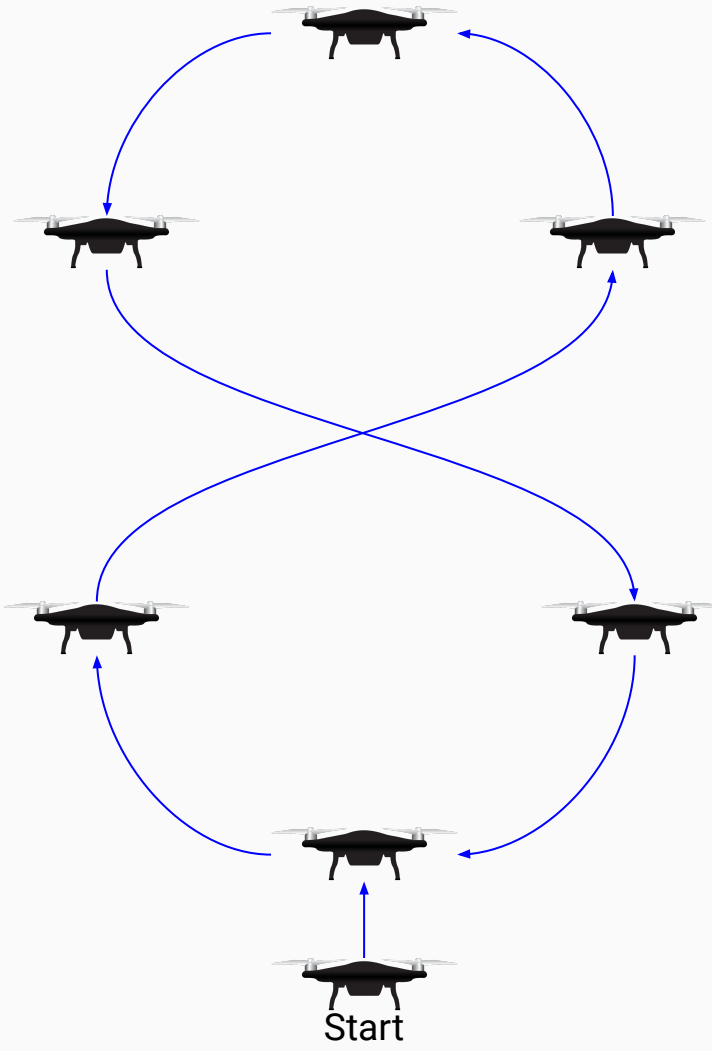


Warning! Never practice above people nor close to them!

# I have a multirotor drone (quad, hex, octa, etc.). What should I practice?

Vertical 8-shape flight (as seen from the side) including direction changes.

It is good to practice both directions!



# UTM components

Unmanned Aircraft System (UAS) Traffic Management (UTM)

Including UAV operations to the existing airspace.

General concept for the UTM

Ground components

Aerial components

# UTM (USpace) introduction

UTM is supposed to manage all flight (both VLOS and BVLOS) and integrate all UAVOs.

It integrates other airspace users, including planes, helis, ground components, communication and existing infrastructure.

UTM is a name for this solution in the US, as developed mostly by NASA.

In EU this solution works as USpace and is mostly developed by EASA and local agencies.

# UTM (USpace) introduction - DTM

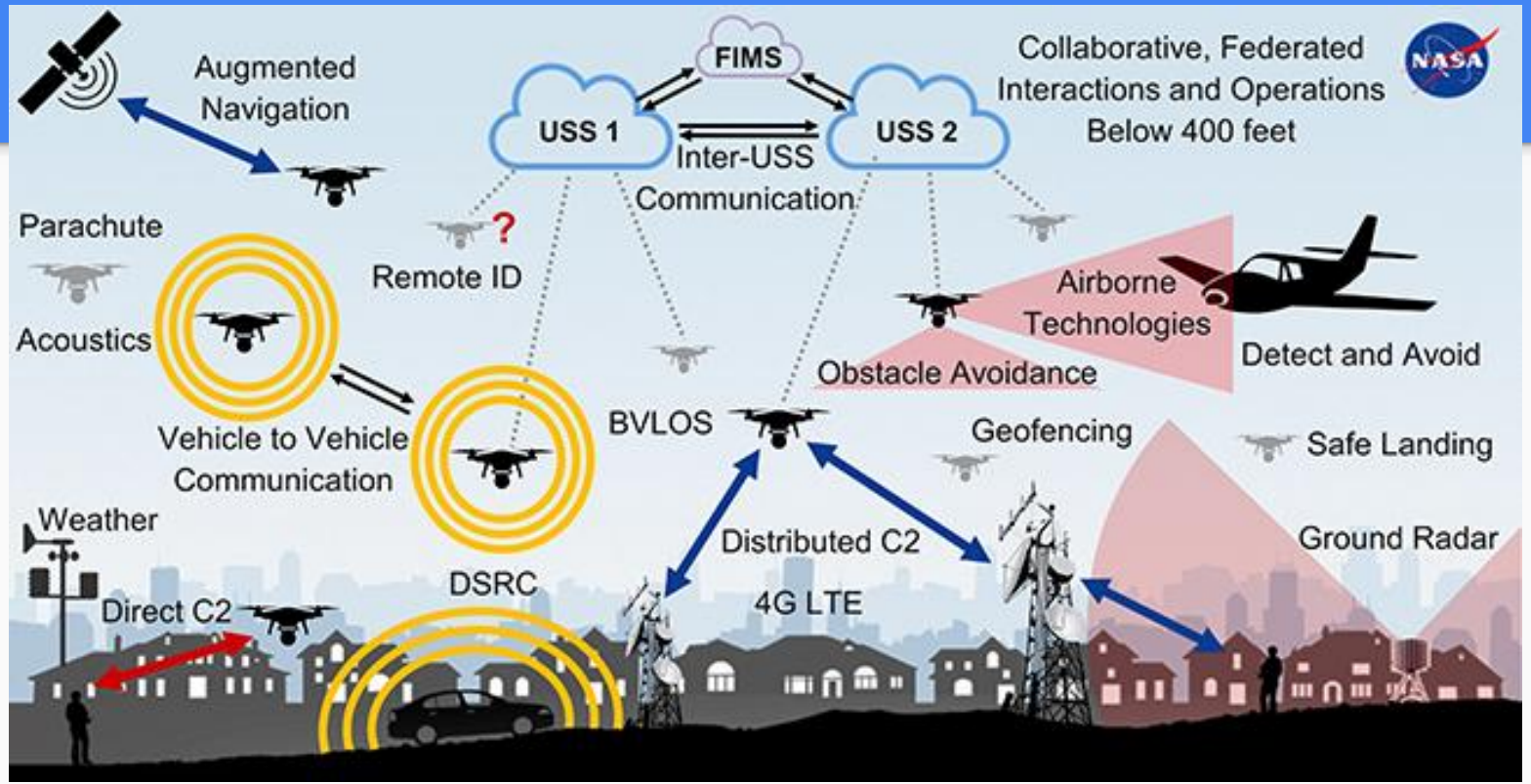
By the UTM and USpace we also identify local solution that covers limited area (i.e. at the single airport) named DTM (Drone Traffic Management).

It is common that local aviation agency implements this solution along with public-private procurement.

# UTM (USpace) introduction

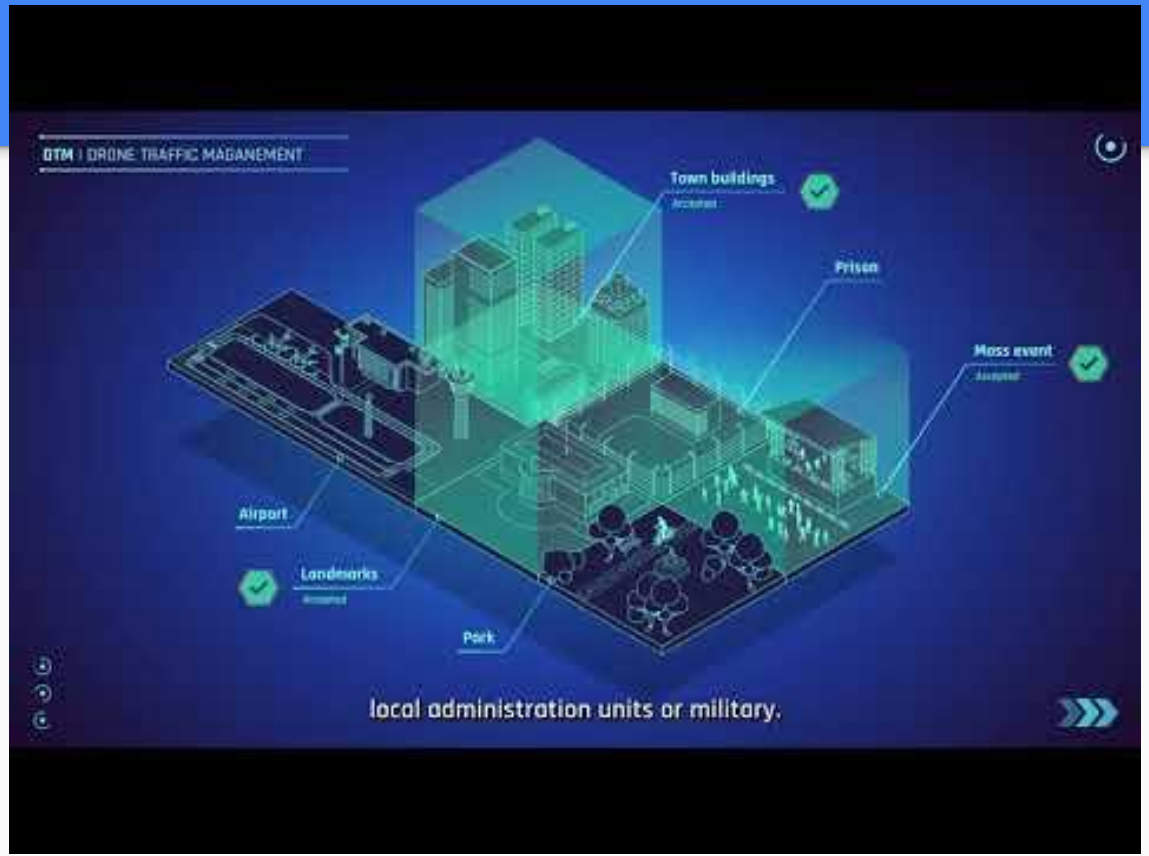
UTM has to be included by drone manufacturers as well as it is essential to let the UAVs present ability to broadcast their current 3D position, heading, speed, condition, etc.

# General UTM structure (by NASA)




Źródło https://utm.arc.nasa.gov/index.shtml

# USpace as implemented in Poland



# Components for UTM (selected)

Essential for UAV / UAVO.

- Continuous broadcasting of the drone position, heading, speed, flight parameters, state
  - Warning - that is not the UAVO position as registered in the UTM system on take-off, but real-time UAV position
- Automatic/manual operation claim:
  - Required i.e. in the limited use airspace zones but also to notify other users about operation running.
- Information about other users
- Collision avoidance
- Warning and alarm system, i.e. on lost control, immediate landing required and so on

# Functions and their implementation possibilities

Theoretically this technology is already present in aviation (both military and civil) i.e.:

- transponder,
- TCAS.

# Functions and their implementation possibilities

...they cannot be used straightforward, because:

- Devices are large, heavy and require a lot of power to operate
- They are certified and very expensive
- Altitudes and flight speed of UAVs are usually much slower than planes / helicopters so i.e. collision avoidance algorithms would require major redesign.

# Functions and their implementation possibilities

- On the other hand, majority of the drones is already equipped with positioning systems (this is how RTH works), so data about their current position is available and precise.
- Drones do have downlink to the operator.
- Conclusion:
  - It is possible to broadcast UAV position indirectly via some other channel (i.e. 4G/5G/LTE) via operator (ground station).
  - It is a matter of availability of the services / stability of the solution.

# Functions and their implementation possibilities

- The response channel is problematic as for now:
  - I.e. how to remotely force drone to safely land?
  - Via RC
  - Via remote flight plan modification (during operation).
- It requires advanced features of the flight controllers.
- Some drones already provide those functionalities (i.e. those based on the Pixhawk stack).
- But majority of the devices won't let someone control it additionally to the main UAVO.
  - It is a matter of the operator then, to interact with flight control and introduce modifications as required.

# Functions and their implementation possibilities

- Interestingly, those drones that use mobile as a main controller are the easiest to adopt to the UTM.
- In case of the professional solutions it is forecasted to equip them with ADS-B transponders.

# UTM implementation - some selected challenges

- Remote drone control, executed ad-hoc to take over and force land the drone needs to know exact ground shape including obstacles.
  - Requires precise GIS database, as i.e. the one delivered by Creotech.

- Flight plan acceptance (in particular for the BVLOS) are supposed to be accepted in up to 7 days.

# Using ADS-B for collision avoidance

- Professional drones may benefit from the aerial traffic information, broadcasted by airplanes:
  - It is possible to build pretty good ADS-B receiver, using popular USB DVB-T tuner and SDR solution. Transmission uses 1090 MHz bandwidth.
- Professional solutions:
  - Among others, delivered by Aerobits:
    - TT-MC1 - quick, FPGA based solution
      - You can use PPS (pulse per second) to time-tag frames
    - TT-SC1 - miniature receiver, 1g, 70mA, 3.3V
    - There are development boards available
    - Some pixhawk-based FCs contain ADS-B integrated solution, i.e. Orange Cube.

# Radiocommunication

Let you know, what happens around you and let the other know...

Transmission

Reception

# Radiocommunication - transmission

- Airspace users (mostly pilots) use wide bandwidth with multiple channels to communicate with other users and ground services. Some frequencies are used for radio-navigation services, some for voice communication.
  - Civil aircraft use 118-137 MHz with AM for voice communication
    - Base channel step is 25kHz, but since 2010 it is also 8.33 kHz
- **It is illegal to transmit without certification! This bandwidth is not public!**

# Radiocommunication - reception

- Understanding and being aware of what is happening in the airspace around you is essential to ensure your safety as well as safety of others.
  - It is not only about you, but also about others!
- You can benefit from listening (individually) to the voice communication of the pilots and ground section, i.e. to notice starting HEMS rescue team in the nearby airfield.
- In selected airspace zones it is required to keep radio-based voice communication with ATC, so certification for radio communication for the drone operator is required then.

# Radiocommunication - reception

- Professional radio communication is expensive but to listen to the voice communication one may use popular radio scanners.
  - It is essential to pay attention to the following features:
    - Bandwidth covering at least voice communication
    - Frequency step changeable with at least 25 kHz and 8.33 kHz steps (otherwise you may not be able to reach all channels).
    - Exchange-able antenna to fit to the frequency for best reception range.
    - Use of headset (note, in many countries, broadcasting pilots voice communication is banned by law, but you can listen to it privately).
    - Note - some models do have some frequencies banned depending on region/country version. Refer to current policies and law before use.

# Aerial video recording and photography

Using UAV for video recording and for taking photos

Filming techniques

Basics of photography for drone users

# Video recording using drones

Drone footage techniques

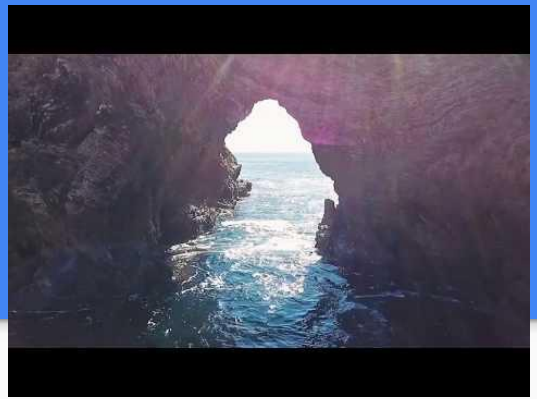
Basics of photography

# Footage techniques

Hints:

1. Operate slowly, i.e. use Cinematic Mode (or correct control stick curves).
2. Use 2 axis of movement i.e.:
    a. backwards + up (pull-back/zoom-out)
    b. forwards + down (approach/zoom).
3. Strafe the object
4. Orbit around the object

# Footage techniques



Hints:

5. Pass-through - spectacular but also demanding (possibility of running out of range).

6. Gimbal operations along with drone movements provide great flexibility but it is quite hard to operate both parallel. It is common that professional drones are operated by two persons: a pilot and a camera/gimbal operator (movie maker). Eventually some automation is included, i.e. optical flow of the object.

# Footage techniques

Hints:

7. Parallax - enhances depth of the field of recording

8. 360 panoramas

9. Spherical photos (using dedicated cameras or set of photos then postprocessing.

In many cases it is essential to control camera recording parameters that use presets.


Footage techniques (youtube.com)

# Basics of phothgraphy

Focal length / zoom (mm)

Aperture (f)

Sensitivity (ISO)

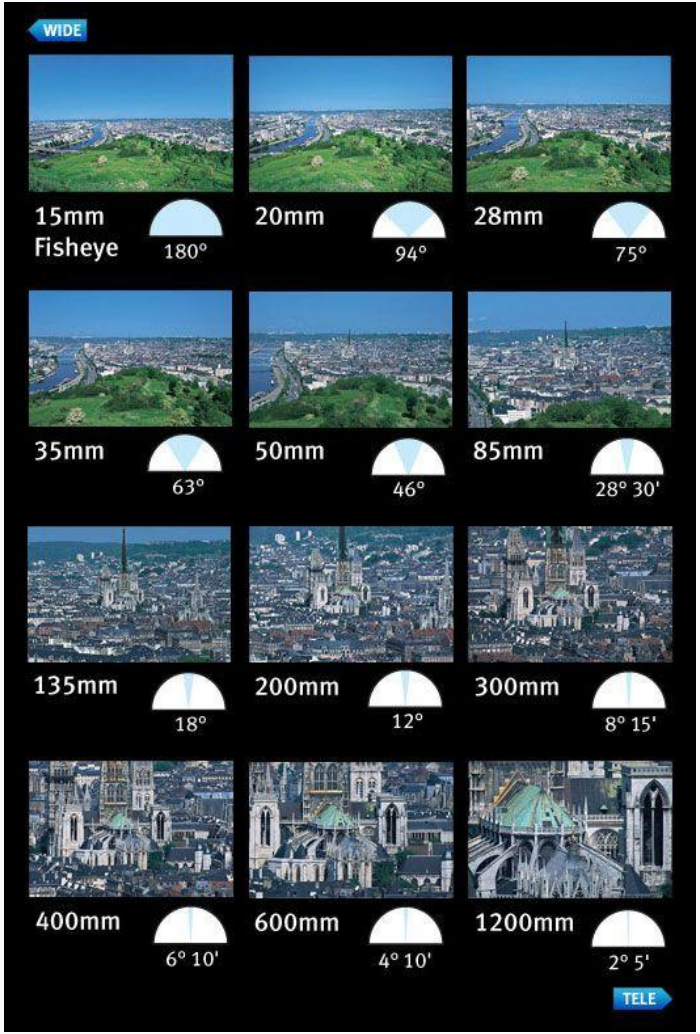
White balance (AWB, inne)

Photo profiles (automation)

# Focal length

Following footage is for 35mm equivalent (full frame)

For majority of the integrated drone cameras it is different as photo sensor has much smaller diameter, but general relation is still valid.




Tony Eallonardo

# Focal length

Note that using different focal lengths can be compensated with changing the distance from the object but… in impacts object shape.

Note face shape/size/proportions change regarding focal length change.


Carla Day

# Aperture

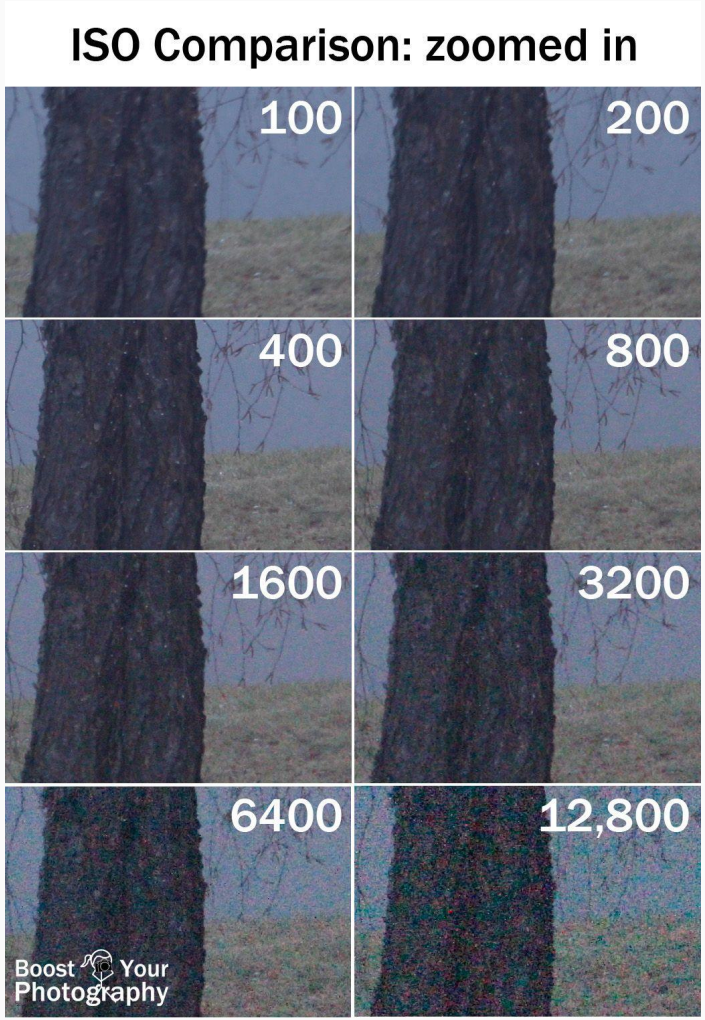
Aperture impacts depth of the field of view (f). In general, the higher aperture number, the deeper is the sharp DOF.


Kristin Merck Photography

# Sensitivity

ISO presents current sensor sensitivity.

In general, lower number means less noise.



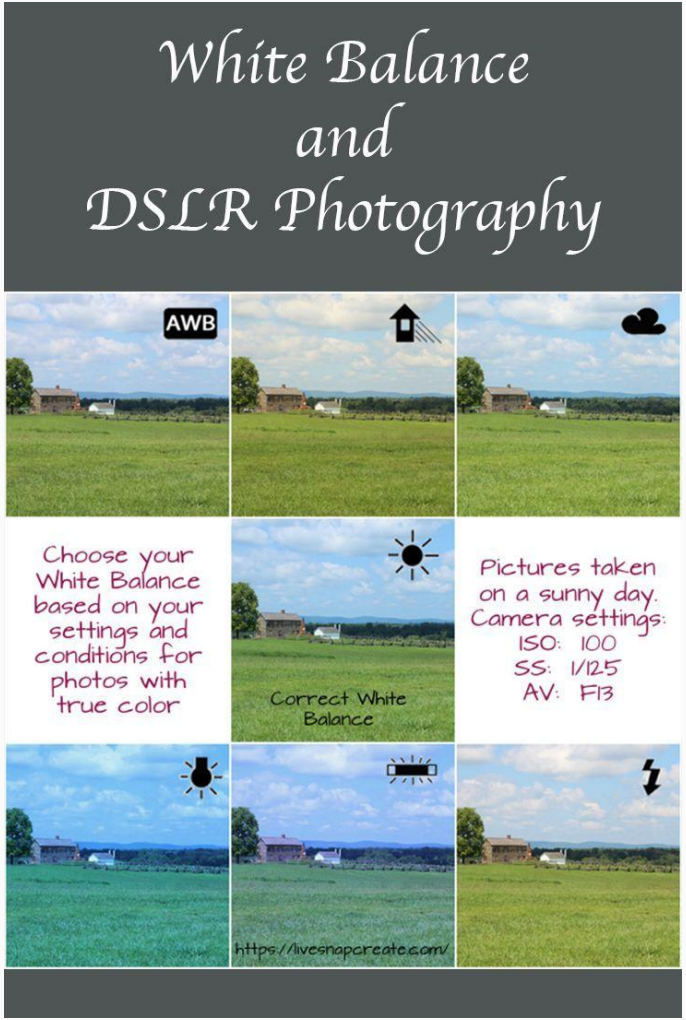
# White balance

White balance setting impacts the colours and overall presence of the recording/photo.

As shooting in different light conditions, it is a matter of colouring the scene.

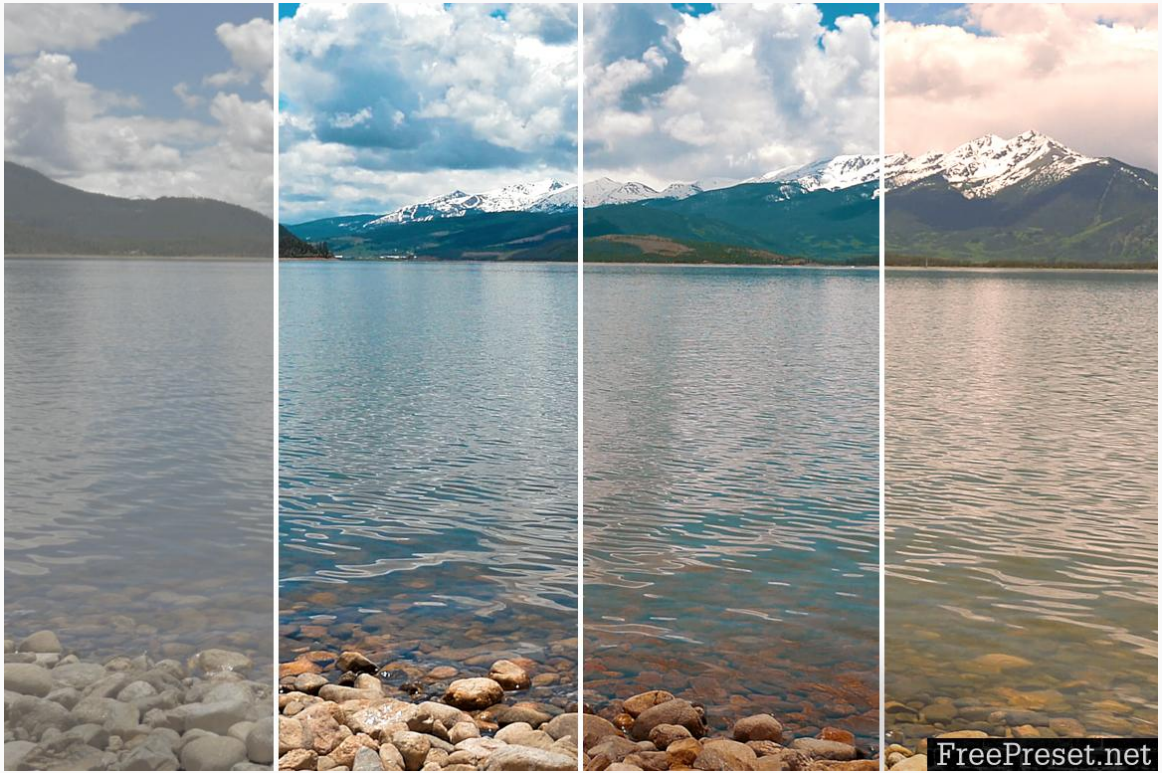
It general, WB used when compressing only. In case of recording of the RAW images, there is usually no WB profile applied.

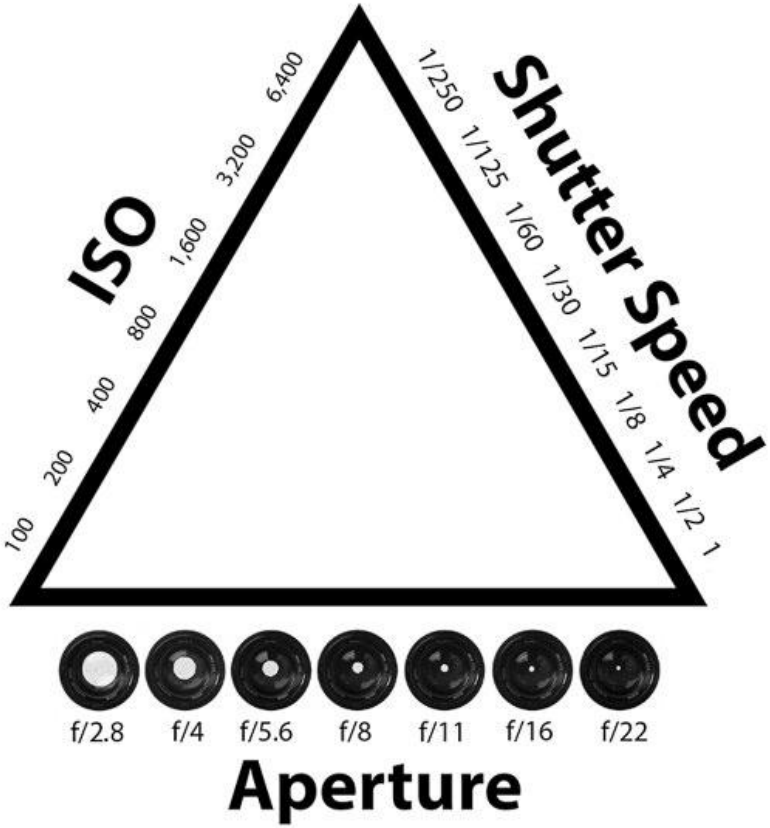
**Live Snap Create**



# LUTs

Photo and video postprocessing can enhance recorded material to let it become more vivid, remove haze and so on. It is common to use ready settings (LUTs) regarding particular camera as there are know drawbacks of some of them. LUTs are related to the postprocessing but may be included in the drone-attached software pack.






Photography / video recording triangle of relations

# Meteorology

Mind the weather!

Basics

Temperature

Wind

Clouds

Precipitation

# Air pressure and air density

# Meteorology basics: air pressure

Air pressure (and related air density/atmospheric density) is defined as:

- It is hydrostatic pressure caused by air weight.
- **Normal** pressure (average sea-level pressure) is 1013.25 hPa as measured at the 45 deg. latitude, temp. 0C on the average sea level.
    - 1013.25 hPa = 760 mmHg;
    - 1hPa = 0.75 mmHg;
- Related to the altitude - decreases non linearly along with rising altitude.
    - As for the UAV operations it is common to approximate this change as linear decrease up to about 3 km AMSL (FL095)

# Meteorology basics: air density

Air density is a mass per cubic unit of the air.

$\rho = m/V$

- In SI the unit is kg/m^3 and defined as mass of 1 cubic meter of air

Relative air density is given as proportion to the standard atmosphere and measured in percent.

Standard atmosphere density is defined and it is about 1.293kg/m^3.

# Meteorology basics: air density

Air density impacts lift force generation and drag.

By the altitude, it is related to the temperature and humidity of the air and changes non-linear way regarding those parameters.

In case of the UAV operations (up to about 3 km AMSL / FL095) it is common to approximate linear decrease of the air density assuming other parameters are constant.

# Meteorology basics: air pressure

Pressure changes according to the movement of the high and low pressure areas.

High pressure area rotates clockwise on the Northern hemisphere and opposite (Counterwise) on the southern one.

Low pressure areas rotate opposite to the high pressure areas, so counterwise in North hemisphere and clockwise in the southern one.

# Wind

# Meteorology basics: wind

Pressure difference causes the wind to appear. It blows from high pressure area to the low pressure area.

- It can be beneficial (i.e. fixed wings start and land always against the wind as it decreases ground speed thus lowes energy needed to take-off / stop),
- or it can be dangerous (i.e. when too strong winds blows away the multirotor, unable to hoover and go against the wind to keep its position)
- In aviation, wind speed is measured in knots (kt) and in m/s.
- It is common to provide two values: average wind speed and gusts speed.

# Meteorology basics: wind

The higher the altitude, the stronger the wind!

There is a jet stream (strong wind in between 9 km and 12 km AMSL) that can flow with a speed reaching hundreds of km, causing regular passenger planes to over exceed 1200 km/h ground speed (not air speed) or even more.

Depending on the flight direction, jet stream may be beneficial for fuel consumption.

# Temperature

# Meteorology basics: air temperature

- Temperature changes regarding altitude, daytime, solar radiation, season, weather.
- Temperature change regarding the altitude change is called temperature gradient and its value depends on other air parameters.
  - Usually it is about in between 0.5C and 1.2C decrease each 100m of the altitude increase.
  - It is not very rare that rule above is broken, i.e. so called inversion.

# Meteorology basics: air temperature

Concluding?

Even in very constant weather conditions, assuming ground level temperature is +20C (quite warm), flying to FL095 means temperature is much lower than 0C that strongly impacts UAV performance.

Frequently it means wing/propeller icing.

# Humidity and clouds

# Meteorology basics: humidity and clouds

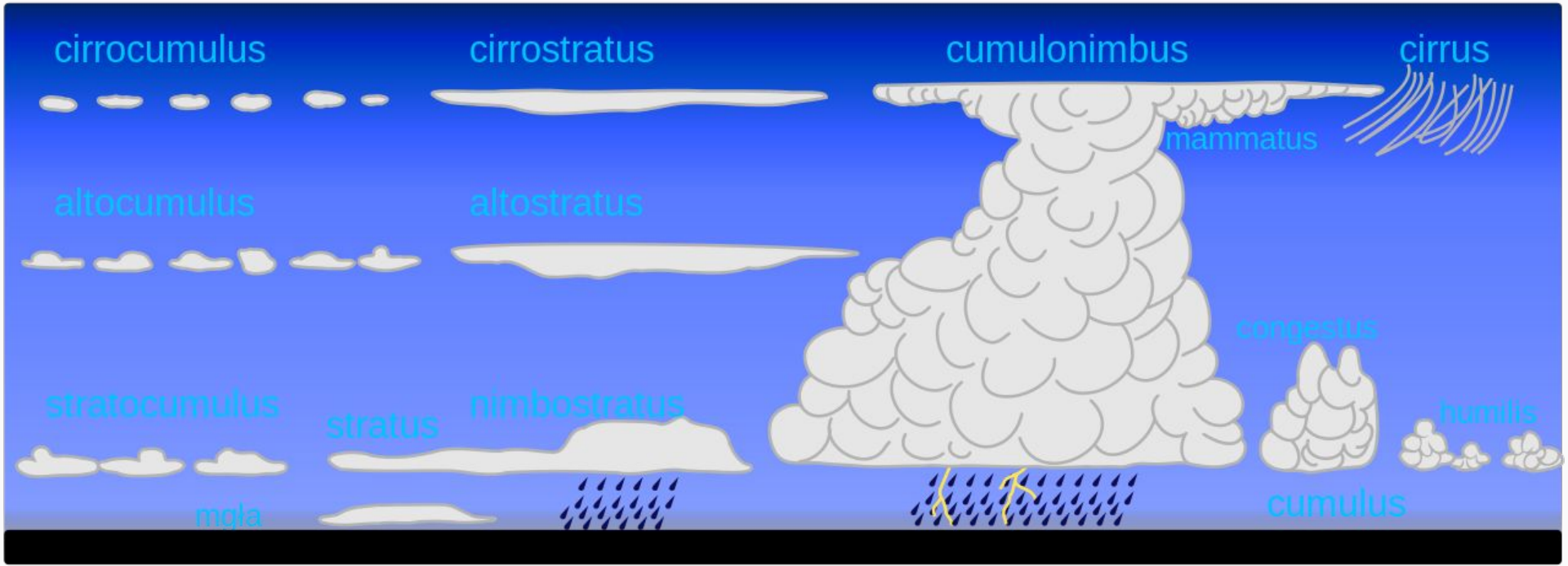
- Humidity impacts air density.
- I causes clouds and fogs and may cause the flight condition changes (VLOS -> BVLOS, VFR->IFR)
- In low temperature, humidity causes icing that impacts lift force generation and drone control. It is considered to be hazardous condition!

Several plane and drone accidents were caused by wing / propeller / instruments icing.

# Meteorology basics: humidity and clouds

- Absolute humidity is a mass of the water contained in the 1 cubic meter of the air
- It is rather the relative humidity that is common to refer to, given in percentage. It is defined as:
  - Relative humidity, expressed as a percentage, indicates a present state of absolute humidity relative to a maximum humidity given the same temperature. In details it is a ratio of the partial pressure of the water vapor related to the mixture of the equilibrium vapor pressure of the water over a flat surface of the water at a specific temperature.
    - Equilibrium vapor pressure is a particle pressure exerted by a vapor in the air. Its value can be as low as less than 1 in polar circle area during winters and as high as 30 hPa in the humid, equator region.

# Meteorology basics: cloud types



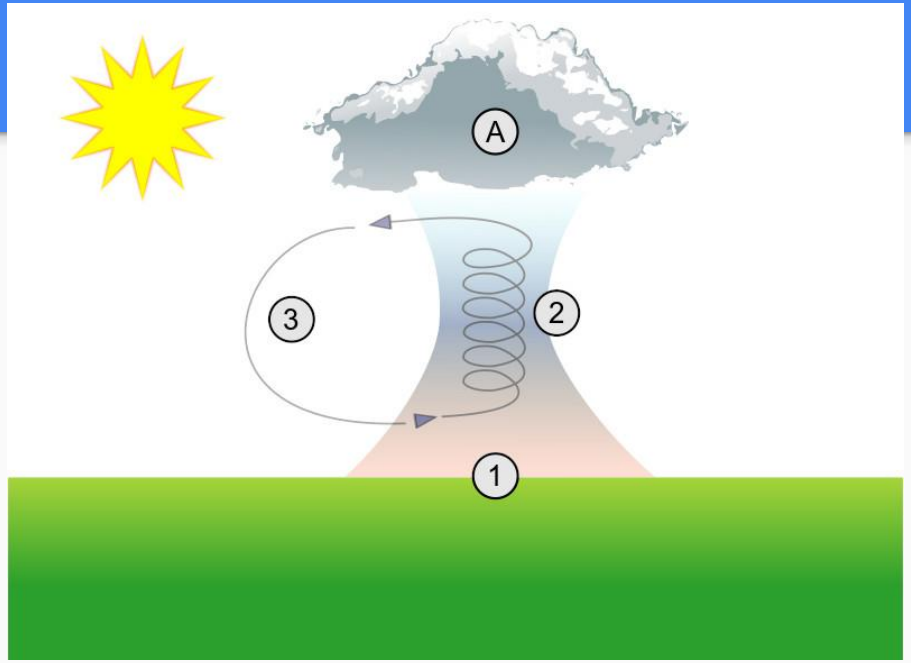
# Meteorology basics: humidity and clouds

Probability of icing when passing the cloud:

- Cumulonimbus, cumulus (growing): 100%!
- Nimbostratus: 70-90%
- Stratocumulus: 50-60%
- Altostratus, Altocumulus: 20-50%
- Stratus: 90% during winter, none during summer.

# Meteorology basics: humidity and clouds

- Cumulonimbus cloud generates lift by its centre.
- Theoretically, UAVs may benefit from it to increase altitude but that is dangerous!
    - There is usually an opposite wind towards down by the sides of the cloud, however.



# Meteorology basics: humidity and clouds

Hint: Knowing some elementary data you can estimate altitude of the base of the cumulus cloud:

- H=125*(T-Tp), where T is current air temperature and Tp is dew point.
- A dew point depends on the humidity, temperature:
  - In short, dew point is a temperature (along with fixed pressure, humidity) that water vapor starts to condensate, creating rainfall, snowfall, icefall and visible clouding.

# Meteorology basics: humidity and clouds

- Icing is dangerous not only because of the changing of the lift generation but also about the mass added to the flying vehicle. It also impacts instruments, i.e. Pitot/Prandtl pipes:
  - Refer to the Air France flight no 447 crash, caused by icing.
  - It can also cause blocking of the liquid fuel management system (if drone is fossil fuel powered).
- As a rule of thumb, it is important to avoid areas with icing hazards. If it is impossible to avoid it, you should do a rapid ascend / descend (increase speed) but it is very risky and works mostly for fixed wings.

# Meteorology basics: humidity and clouds

- Warning: vertical projection of the Icing curve can pass more than one time through the hazardous (0C) level. Icing is then even stronger and more dangerous.
- Weather maps present icing hazard using symbols. Maps are published for flight levels (range of levels/altitudes).
- It is also included in METAR messages, using one of the 9 levels of icing hazard.

# Meteorology basics: max altitude reached!

- Every UAV construction has its own limits on maximum altitude it can operate. Exceeding it causes significant flight time drop or even inability to take-off due to the negative weight to lift force generated ratio.
- Consider i.e. when heading to the high mountains. You may not be technically able to fly or take-off, eventually flight time will be very limited.

# Meteorology basics: summary

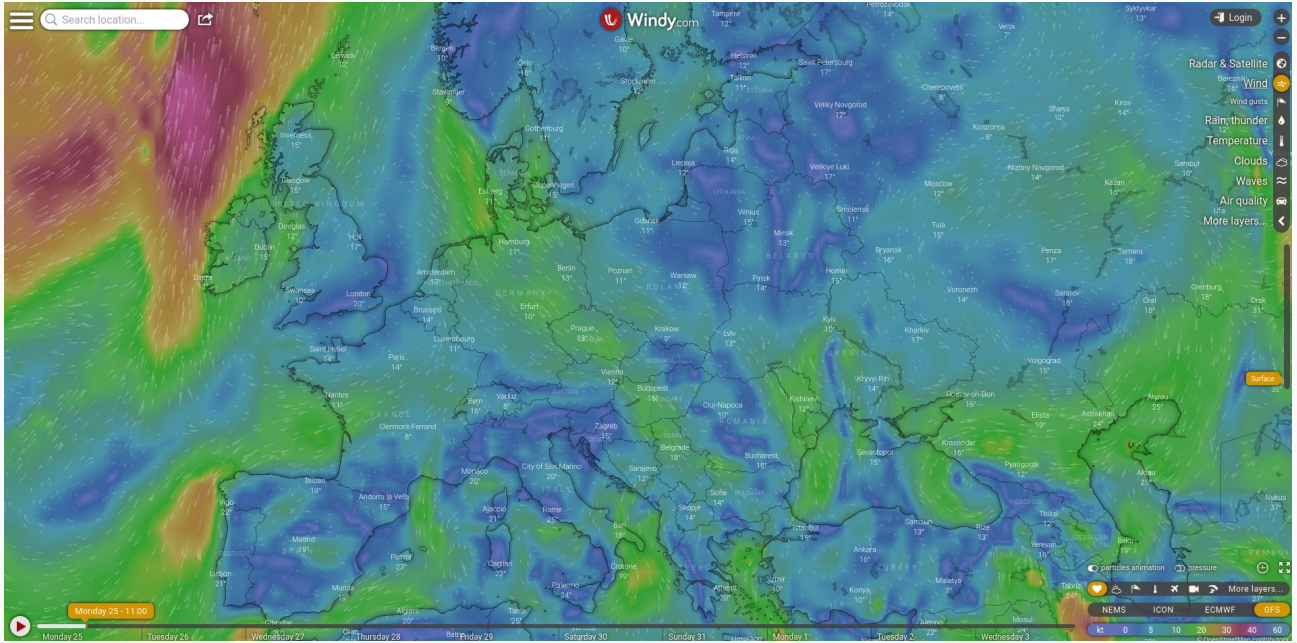
- In short, air pressure, humidity, temperature, all it causes possibility of appearance of unwilled flight conditions like clouds, fog, icing and so on.
- All aforementioned factors affect both professional aviation as well as drone operations.
- Evaluating risks of the operation in terms of the weather is crucial for successful drone operation and its safety.

# Meteorology basics: data sources

- Local, for the country / region:
  - Usually quite precise yet low in forecast time and area (i.e. www.meteo.pl)
- Global weather models, used by many web portals and also mobile apps:
  - GFS
  - NEMS
  - ICON
  - ECMWF
- Professional information for aviation, presenting both forecast as well as current conditions, i.e. as delivered via METAR messages.

# Meteorology basics: weather forecast

Number of publicly available services is available on the web. I.e. windy.com



# Some hints regarding weather

- During sunny days when convection may appear (thunderstorms, rising of the cumulonimbus clouds) winds used to blow pretty strong during daytime. However right before sunset it is usually a calm period (in terms of wind), however ….
- Over the metropolis, also over i.e. large municipality garbage dumps it is common to expect strong convection flows upwards that fixed wings (i.e. soarers) may benefit from to gain lift for free.

# UAV applications

Can I have a job here?
Infrastructure characteristics

Moviemaking

3D object scanning

Surface scanning

SAR

Monitoring i inspection of the areas

Environmental monitoring

Agriculture

Racing

# Moviemaking

Historically, one of the earliest drone applications

- Low entry level (cheap equipment)
- Large community (and competitive market)
  - Number of amateurs and also photographers are “in”
- Low investment return
- Additional services usually required (i.e. video post processing that may generate additional costs)

# 3D object scanning

- More advanced cameras needed comparing to the video filming.
- Professional post processing software is needed (also training) i.e. Agisoft
- Niche and not so popular services, still pretty well paid (assuming post processing is included).
- Requires some sort of other skills from the operator (i.e. good scenery planning to capture all critical details).
- Requires BVLOS usually.

# Surface scanning

- BVLOS is essential.
- Multispectral (expensive) cameras are requires
- Professional drone platforms required allowing high level of autonomy flights.

# Search and Rescue

- Due to the nature, flight in “heavy” weather conditions is needed. Heavy drones (even over 25kg) are needed and it involves special certification.
- Thermal cameras are commonly needed and those with high resolution = high cost
- Requests are usually coming from officials.
- Cooperation with emergency services and in crisis situations is often necessary

# Monitoring i inspection of the areas

- FPV and BVLOS usually required
- Pretty common is a need to use thermal cameras, i.e. monitoring of the thermal insulation
- Drones vary by exact application: medium to heavy for outdoor, lightweight for indoor flights:
  - Different skills required both for indoor and outdoor flying.
- May require autonomous flights when performing large area / long (i.e. highway, power lines) inspections.

# Environmental monitoring

- A drone that can carry variety of different sensors is needed usually.
  - Drone class: some kg - dozen of kg of MTOM
- Usually night flights required
- Currently niche applications, as there are competitors from the municipality services (i.e. Municipality Police)

# Agriculture

- Heavy drones, sometimes carrying containers with liquids, seeds, vaccines, etc.) - usually more than quadcopters (hexa, octa)
- A need for autonomous flights according to the flight plans

# Racing

- Rather lightweight drones (FPV)
- Relatively frequent repairs, a need for owning a repair infrastructure (a service)
- High demand on individual predisposition for FPV flying

# 100%

Koniec wykładów