IMAV 2023 – Micro Aerial Vehicles Indoor Competition

Competition Rules

Changelog:

Version	Changes
0.1	First draft version
0.2	Added preliminary block design, added overweight factor
1.0	Added final block design. Adapted the rules to black block designs. Linemarkings added
1.1	Added additional navigational ArUco codes, included return flight points, added starting zone

Changes compared to previous versions are highlighted

Content

1. Introduction

This document provides cumulative information about the IMAV 2023 indoor competition. Besides general remarks and a schedule, it gives a detailed description of the competition areas, the mission elements, and the scoring rules.

The indoor competition focuses on precise operation in an unknown environment. The main challenges for this competition are:

- Multi MAV operations
- Precise operations in unknown environments
- Autonomous operations

2. Safety and Security Requirements

For safety and security details see the latest version of the *IMAV 2023 safety regulations document* which is published on the website (https://2023.imavs.org/). This document will contain general flight safety rules and regulations, as well as flight safety zones and failsafe requirements. All participants are required to be familiar with the contents of the latest version of this document and comply with it.

Before the first flight, each team has to demonstrate that all MAVs can sustain the security and airworthiness check.

Should a person need to enter the flight area, all flying MAVs must land and deactivate their engines. Only then is it allowed to enter the flight area.

3. Indoor Competition

3.1 Location - Indoor

This year's indoor competition will be held at the Derby Arena in Herzogenrath.
Address:

Derby Arena
Kaiserstraße 96
52134 Herzogenrath

3.2 Practice Day - Indoor

On Monday, 11th of September a practice day will be carried out. This will allow each team to prepare for the competition day and become familiar with the local procedures. Upon registration, team leaders will have to indicate whether they want to attend the practice day.

3.3 Competition Slot - Indoor

Each team will be assigned a time slot to set up their equipment, prepare the flights, fly the competition, land and retrieve the MAVs, clear the flight team area and flight zones, and switch off all radio equipment. After the time slot, all MAVs and equipment must be switched off. The order of the teams' slots will be drawn by lot on the morning of the competition day. At any time (before or during the mission) each team can decide once to postpone the rest of its mission. In this case, the flight slot of that team will be shifted to the end. Therefore, all teams must be ready to fly at any time. Failure to comply can lead to a penalty or disqualification. Before the competition slots, each team must communicate which kind of cones (3 g, 50 g, 100 g, or 200 g) will be transported. Changing a cone type is possible by calling out a time-out. The score is reset to 0 and the remaining competition slot time will continue.

Any MAVs that have been lost during the mission should be retrieved as soon as possible in cooperation with the flight safety officer.

The timeslots for the indoor autonomy missions are 15 minutes per team.

3.4 Setting

This year's indoor competition focuses on precise operation in an unknown environment. For this task, teams will have to repeatedly pick up cones, fly through a transit zone into a drop zone and ideally stack these cones on top of each other. The lanes from the pickup zone to the drop zone will be colour coded on the ground according to the transit lane. The free lane will be marked with a blue rope on the ground with a diameter of 6 mm. The window lane will be marked with a red rope (diameter 6 mm) and the moving window lane with a yellow rope on the ground. Ropes are depicted in the appendix. From the pickup locations to the color-coded lanes, line markings will be placed on the ground (see. Appendix). Following the ropes is optional since they only serve for navigation purposes. Additionally, ArUco markers are positioned in the different zones. All ArUco markers have a size of 15x15 cm. The competition will take place in an indoor soccer cage. Here the floor is green with white soccer markings. The overall soccer cage size is 15 x 30 x 4 m.

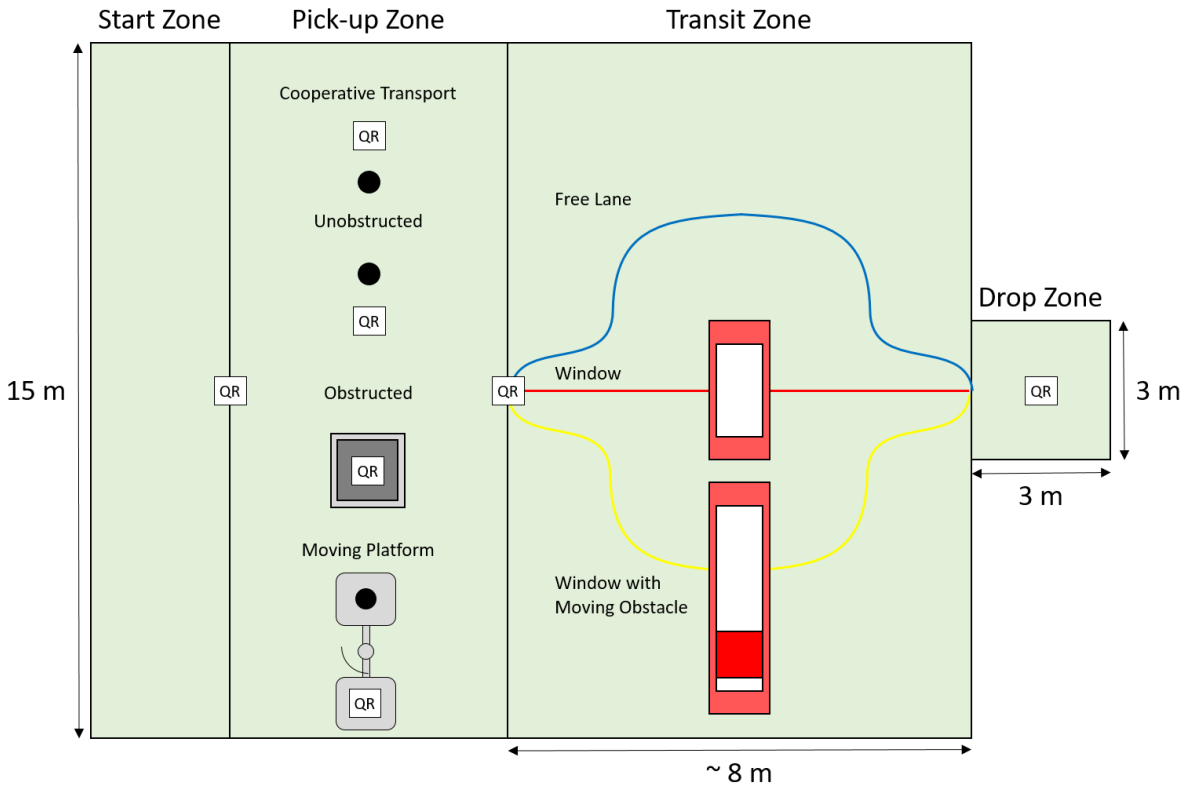


Figure 1 Indoor Competition field

Start zone

To start the competition, the MAV must be in the start zone. After that, the MAV can fly to the pick-up zone and pick up the cone either manually or automatically. For assistance, an ArUco marker (ArUco 5x5 ID 0) is positioned between the start zone and the pick-up zone.

When a MAV has dropped a cone in the drop zone, the MAV does not have to fly to the start zone again, but can directly pick up a new cone in the pick-up zone.

If a MAV crashes, it must be brought back to the start zone and restarted from there.

Pickup zone

The pickup zone consists of four pickup points where the cones can be manually or automatically mounted to the MAVs. Except for the cooperative carrying, only one cone per MAV per pick-up is allowed to be transported. There are four cones pickup stations:

- Cooperative transport: Here a minimum of two independent operating MAVs have to attach a rope to a cone and carry it to the drop zone. This type of cone consists of two standard cones stacked on top of each other. For manual mounting, all involved MAVs in the cooperative transport mission have to land near (~2m) the cooperative transport cone and shut down their propellers. For assistance, a QR code is positioned next to the cone. The ArUco marker for the cooperative transport pick-up is ArUco 5x5 ID 100.
- Unobstructed: Here, the organizing team will place a cone on the ground. For manual mounting, the MAV has to land at the QR code marked location and shut down its propellers. The ArUco marker for the unobstructed pick-up is ArUco 5x5 ID 200.
- Obstructed: The organizing team will place a cone on the ground. A wooden plate will be positioned 1 m above and 0.75 m behind the cone. The sides and front of the covering will be left open. For manual mounting, the MAV has to land at the QR code marked location and shut down its propellers. For this pick-up, two ArUco markers are provided. One ArUco will be on top of the wooden plate (ArUco 5x5 ID 300) and another code will be positioned next to the cone (ArUco 5x5 ID 400).

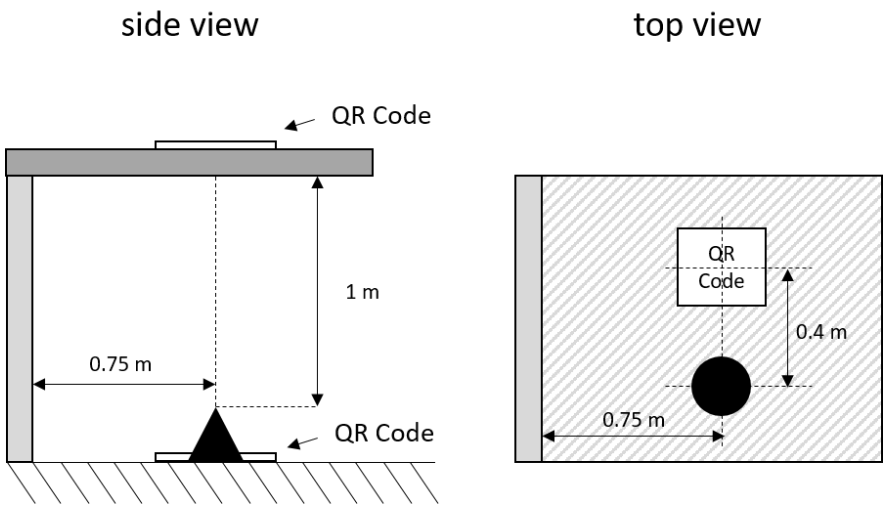


Figure 2 Sketch of the obstructed pickup location

- Moving platform: A cone will be placed on a rotating platform. The platform rotates at approximately $10\ \frac{^\circ}{s}$. For manual mounting, MAV has to land at the QR code location and shut down its propellers. The ArUco marker for this pick-up is ArUco 5x5 ID 500. After the MAV has shut down its propellers, the platform will stop moving and the cone can be attached. Afterward, the platform spins up to its original speed, and the MAV is allowed to take off again.

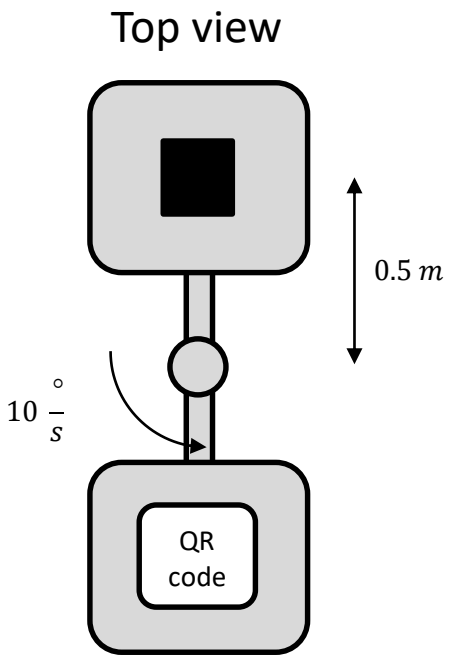


Figure 3 Sketch of the moving platform

Manual mounting of the cones does not affect the autonomy level. Once the MAV comes to a full stop with disabled propellers, team members can manually attach the cones by picking up the drone and the cone.

Transit zone

Next to the pick-up zone is the transit zone. For assistance an ArUco marker (ArUco 5x5 ID 600) is positioned there. The transit zone consists of three lanes with increasing difficulty. The free lane consists of open spaces where the MAVs can pass freely. The window lane consists of a red window with a window size of 1 m x 1 m. The MAV has to fly through the window to get points. Most points are awarded for trespassing a lane with a window (dimension 2 m x 1 m) and moving obstacles. The obstacle consists of a red color-coded plate moving along the height of the window. The plate moves with approximately 0.25 m/s along the vertical axis.

Drop zone

In the drop zone, cones can either be dropped from the MAV or stacked on top of each other for maximum points. After completing the time slot, the highest tower of cones will be counted. If a tower falls over due to propeller downwash, the judges may decide to reconstruct the tower to its original height. For assistance, an ArUco marker (ArUco 5x5 ID 900) is positioned in the middle of the drop zone.

3.5 Scoring - Indoor

Total score

During the competition slot, teams will have repeated attempts to collect, transport, and drop/ stack the cones as long as there are cones remaining. Each attempt to pick up, transport, and drop will be counted and the final score will be determined using the following formula:

$$S = \left[\sum (B_n + R_n) \cdot A_n \cdot D_n\right] \cdot H \cdot O$$

Type of cones picked up B_n

The cones used in this competition will consist of 3-D printed cones. For detailed information see Appendix 3.6. A cone counts as successfully picked up, manually or automatically, when the MAV drops or stacks the cone in the drop zone. If a cone is dropped before reaching the drop zone or no cone has been picked up, no points will be awarded.

Pickup Location	B_n
No cone attached upon reaching the drop site	0
Unobstructed	1
Obstructed	2
Moving platform	3
Cooperative carrying	10

Transit lane R_n

The transit zone consists of three lanes with increasing difficulty. Points are awarded for successfully entering the transit lane from the pickup zone and exiting the transition zone at the drop zone. A lane can only be repeated if a cone attachment attempt has been initiated. (i.e. the MAV lands at the unobstructed site and shuts down its propellers). If a MAV is lost in the transition zone no points will be awarded and the mission has to be restarted from the start zone. In case of an automated pick-up the cone has to be detached from the MAV prior to continuing the mission.

Route (Pick-up zone to drop zone)	R_{n1}
MAV lost	0
Successful passage of free lane	0.5
Successful flight through the window	1
Successful flight through the window with moving obstacle	2

Route (drop zone to pick-up zone)	R_{n2}
MAV lost or manually transport to a different pick-up zone	0
Successful return to one of the four pick-up zones (landing or new automated pick-up)	0.25

$$R_n = R_{n1} + R_{n2}$$

Level of autonomy A_n:

The level of autonomy describes how a MAV is operated to fulfil the mission elements. The teams have to announce the intended MAV and autonomy level before the flight. The jury will decide which level of autonomy the team's MAV used.

Autonomy Level	A_n
Line of sight flying	**0**
Remote piloted through video link	1
Autonomous flight control: Flight is controlled autonomously but the operator is still controlling mission aspects, e.g., commanding mission changes, control of payload, processing perception, and decision-making.	4
Autonomous mission control: All aspects of the flight and mission are automated, including detection and decision-making. Typically, the operator does not touch the controls: hands-off control	5
External aids Using visual markers etc. (Except the essential ones provided by the IMAV2023 organization)	*/2* (will be divided from A_n)

Manually attaching the cones to the MAVs does not affect the autonomy level.

Design factor D_n:

The design factor is introduced to reward teams with the self-made design of their aircraft system. The jury will decide on this individually.

Type of Design	**Factor D**
Commercial aircraft design	*1*
Self-made aircraft frame	*2*

Tower height H:

The tower height factor accounts for the number of cones successfully stacked on top of each other. In the case of multiple towers that have been built, only the highest tower will be counted. If no tower has been built $H = 1$.

Oversize factor 0:

To penalize oversize MAVs that can fly for longer times due to smaller payloads, an oversize factor 0 is introduced.

Oversize factor O	**Payload ratio**
$O = -0.0005 \cdot (MAV_{weight} - \frac{block_{weight}}{0.1}) + 1$	$\frac{block_{weight}}{0.1} < MAV_{weight}$
$O = 1$	$\frac{block_{weight}}{0.1} > MAV_{weight}$

With MAV_{weight}: weight of the heaviest MAV in grams per team

$block_{weight}$: cones weight in gram

3.6 Cone Dimension

Cones will be provided in four different weight classes: ~3 g, 50 g, 100 g, and 200 g total weight. The final designs have been uploaded as 3-D printable files at https://2023.imavs.org/index.php/indoor-competition including printing instructions. On the practice and on the competition day cones will be provided by the organizers.

The final cone design can be seen in Figure 4. To allow a wider weight range, 50 g cones are screwed together and, if necessary, weighted down with a 100 g copper ring. This allows for 50 g, 100 g, and 200 g constellations. So 3 constellations are provided: 50g, 100g, and 200g. 3 g cones are standalone. For cooperative tasks, two cones are connected.

Stacking has been tested and validated with a gift ribbon from a height of 1 m. The screws are minor magnetic and can be lifted by a strong magnet. Teams can modify the cones after consultation with the organizers. Teams are encouraged to notify changes to the cones in advance before arriving at IMAV2023.

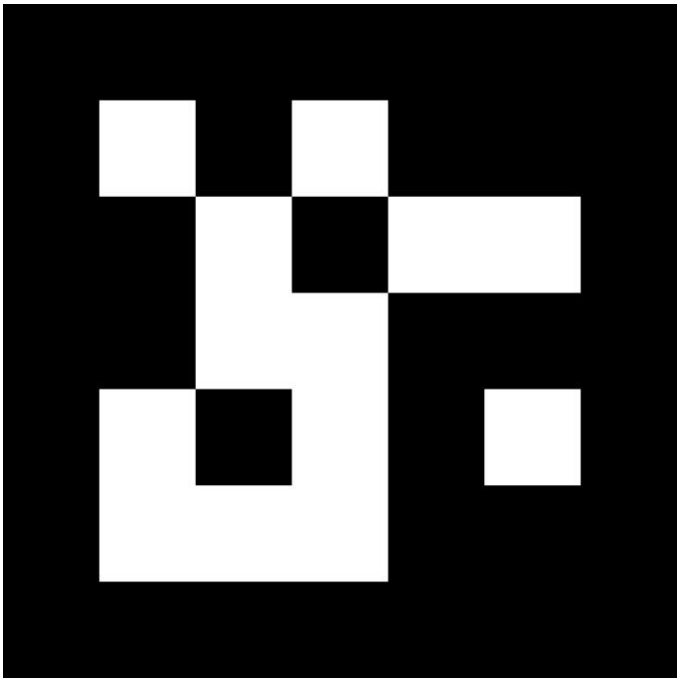
Figure 4: Pictures of the stacked cones 100 g (left), unstacked 50 gr (middle) and stacked cones with dummy weight between (200 g).

4. Appendix

Figure 5: Ropes for transit lane marking

Figure 6: Markings from pick-up zone to transit lane

ArUco ID 0:



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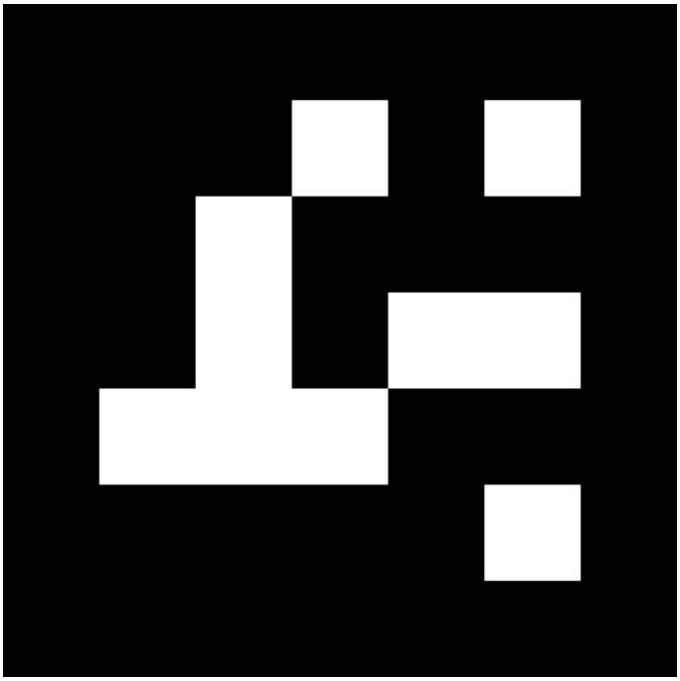

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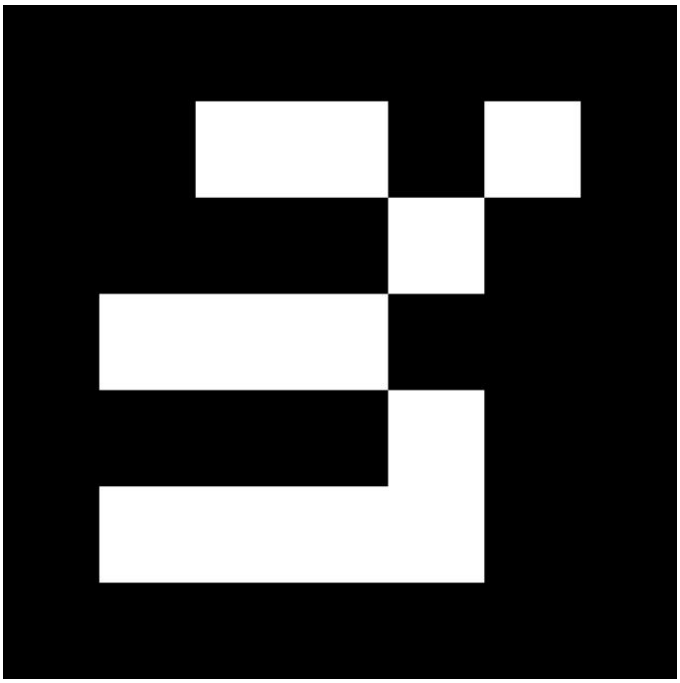

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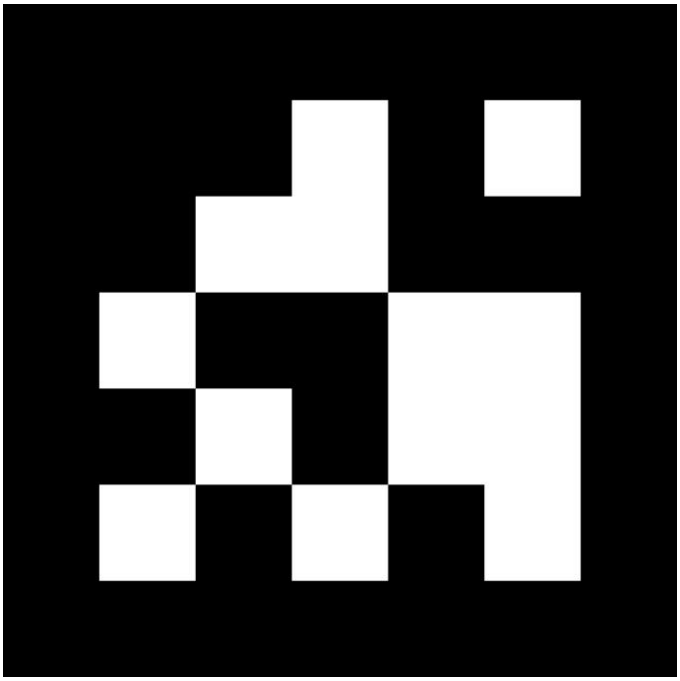

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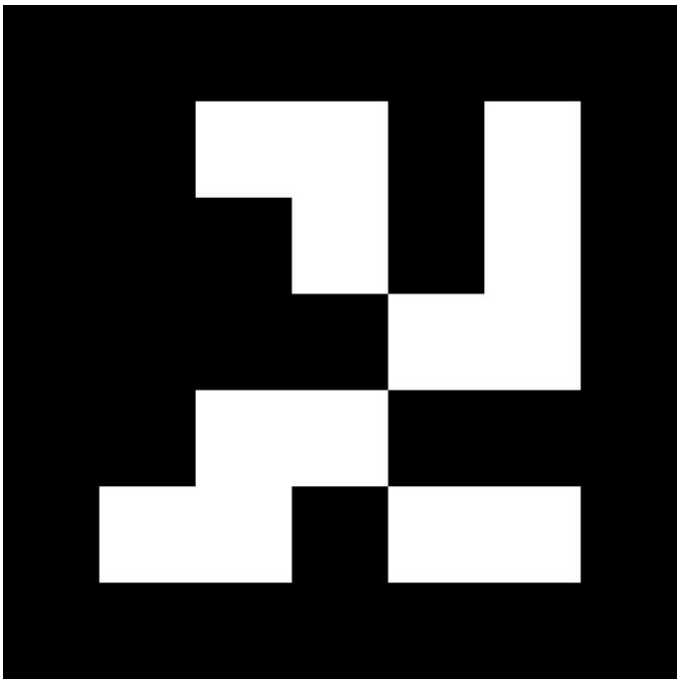

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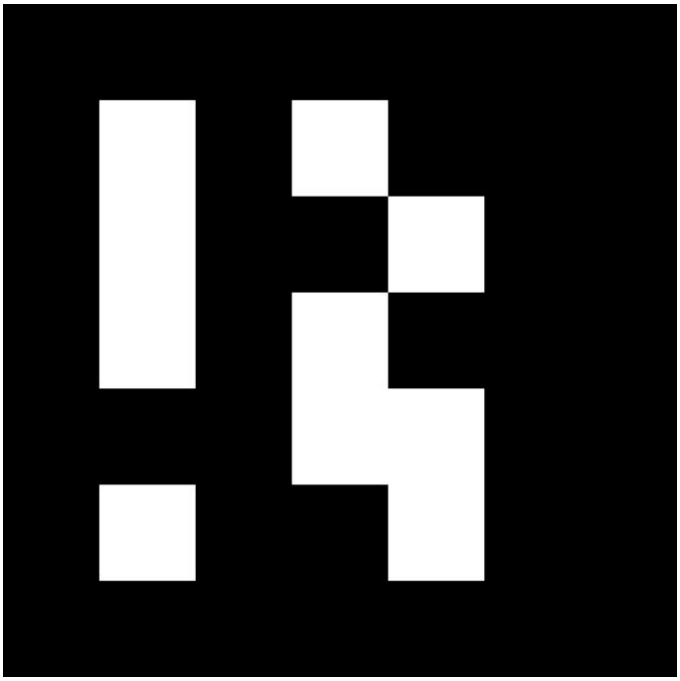
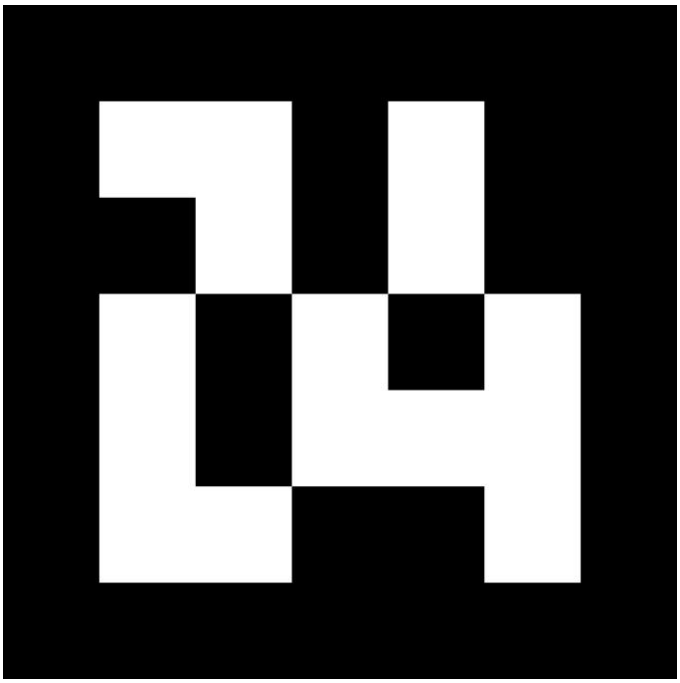


ArUco ID 600:



ArUco ID 900: