UAS NIGHT OPERATIONS

DIRECTOR OF FLIGHT OPERATIONS

UNIVERSITY OF COLORADO BOULDER

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BACKGROUND

- In order to operate UAS under the CU owned blanket COA the remote PIC and VO must receive the required night training. This presentation satisfies that requirement.
- UCB Night certification requirements and training outlines are provided in the FOTM.
- UCB FOM defines night as “The time between the end of evening civil twilight and the beginning of morning civil twilight”.

COA STATEMENTS

E. **sUAS Night Operations.**

sUAS operations may be conducted at night, as defined in 14 CFR § 1.1, provided:

1. All operations under the approved COA must use one or more VOs;
2. Prior to conducting operations that are the subject of the COA, the remote PIC and VO must be trained to recognize and overcome visual illusions caused by darkness, and understand physiological conditions which may degrade night vision. This training must be documented and must be presented for inspection upon request from the Administrator or an authorized representative;
3. The sUAS must be equipped with lighted anti-collision lighting visible from a distance of no less than 3 statute miles. The intensity of the anti-collision lighting may be reduced if, because of operating conditions, it would be in the interest of safety to do so. Additionally, in order to comply with § 91.209, the aircraft must have position lighting that enables determination of location altitude, attitude, and direction of flight.

COA SPECIFICS

a. All operations under the approved COA must use one or more visual observers (VO);

Additional Notes: It is the PICs responsibility to make sure the VO has received the required night training and feel comfortable preforming the required actions. Recurrent night training is not required but is encouraged if either the PIC or VO feel they lack the required proficiency.

COA SPECIFICS

b. Prior to conducting operations that are the subject of the COA, the remote pilot in command (PIC) and VO must be trained to recognize and overcome visual illusions caused by darkness, and understand physiological conditions which may degrade night vision. This training must be documented and must be presented for inspection upon request from the Administrator or an authorized representative;

Additional Notes: Before conducting operations feel free to review this presentation and re-familiarize yourself with these specific topics and conditions. Upon completion of this training a note will be made in your training folder for record keeping.

COA SPECIFICS

c. The sUA must be equipped with lighted anti-collision lighting visible from a distance of no less than 3 statute miles. The intensity of the anti-collision lighting may be reduced if, because of operating conditions, it would be in the interest of safety to do so.

Additional Notes: Compliance with this lighting requirement is a function of airworthiness. The Director of Flight Operations must certify all required lighting is adequate, as indicated in the Airworthiness Certificate, before any CU Boulder UAS may be operated at night.

CURRENCY

- **FOM 1.2:** Night Definition- The time between the end of evening civil twilight and the beginning of morning civil twilight.
- **FOM 1.2:** Day Definition- Is defined as 30 minutes prior to official sunrise until 30 minutes after official sunset
- **FOM 2.3.5:** In order for an individual to act as PIC of an aircraft at night, the PIC must have completed thee landings to a full stop from the hours of 60 minutes past official sunset to 60 minutes prior to official sunrise within the preceding 90 days. These landings can be completed on any aircraft, UAS category, difficulty level, or type (if typerating is applicable).
- **Logbook entries:** To track night currency, it's acceptable to explicitly stating the flight was done at night in the note/remarks section of the logbook but it's recommended to add a new night column which is easily identifiable and can track night flight total times.

TRAINING REASON

- Pilots rely more on vision than on any other sense to orient themselves in flight. The following visual factors contribute to flying performance: good depth perception for safe landings, good visual acuity to identify terrain features and obstacles in the flightpath, and good color vision to determine orientation. Although vision is the most accurate and reliable sense, visual cues can be misleading, contributing to incidents occurring within the flight environment.

GOALS OF PRESENTATION

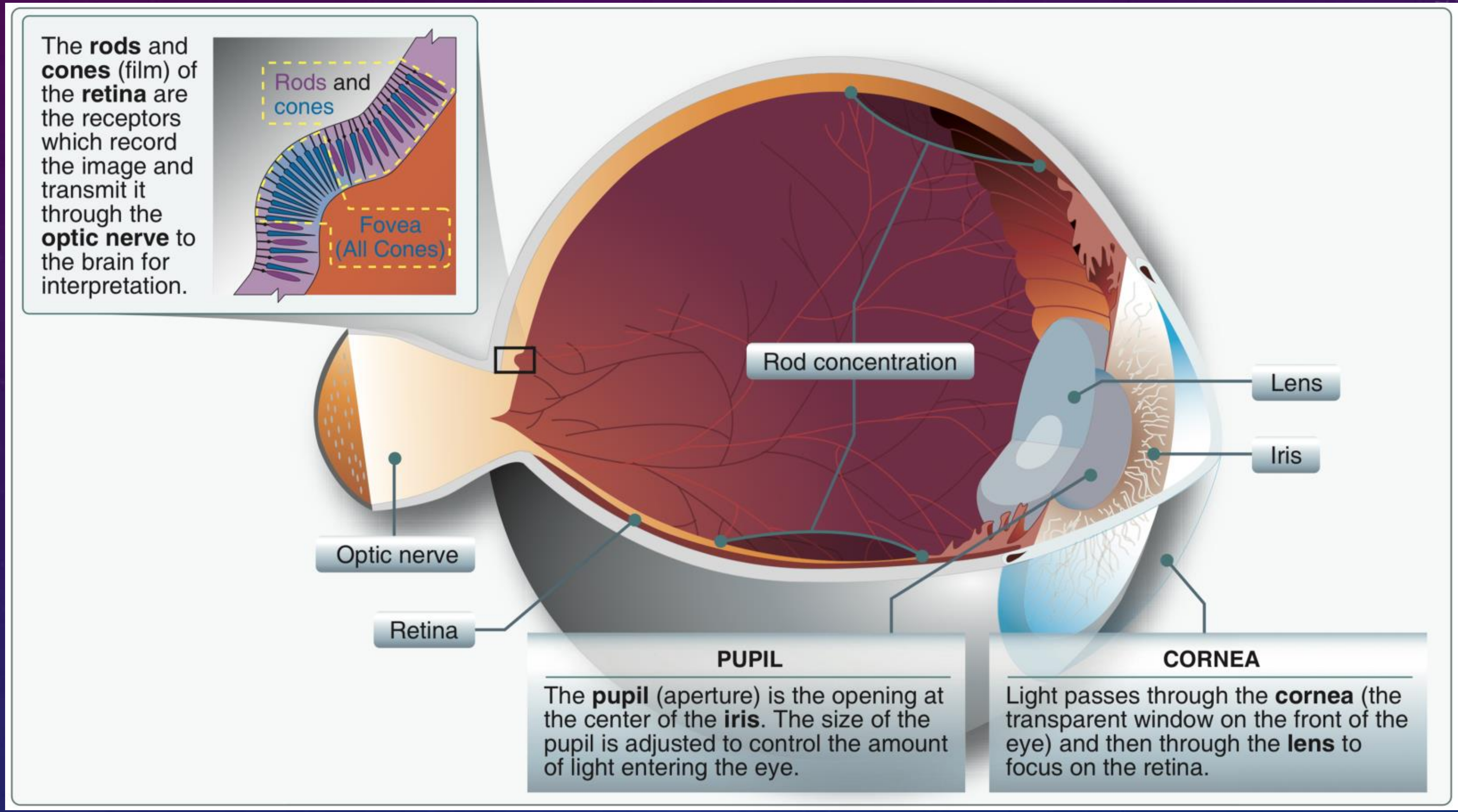
- Pilots must be aware of and know how to compensate effectively for the following:
  - Physical deficiency or self-imposed stress, such as smoking, which limits night-vision capability
  - Visual cue deficiencies
  - Limitations in visual acuity, dark adaptation, and color and depth perception

HUMAN EYE ANATOMY

HUMAN EYE ANATOMY- GENERAL STATEMENTS

- Normal visual acuity, or sharpness, is 20/20. A value of 20/80 indicates that an individual reads at 20 feet the letters that an individual with normal acuity (20/20) reads at 80 feet away.
- The human eye functions like a camera. It has an instantaneous field of view, which is oval and typically measures 120° vertically by 150° horizontally. When both eyes are used for viewing, the overall field of vision measures about 120° vertically by 200° horizontally.
- The eye automatically adjusts for the light level experienced. During night flight, the “cockpit” and instrument lights should be as dim as possible. The eye can then adjust for the outside lighting conditions to better see outside. The dimmer the inside lighting is, the better the eye can adapt and allow you can see outside.

HUMAN EYE ANATOMY



- **The Process**

Light passes through the cornea, then through iris, then though the pupil, and finally the lens which focus the image on the retina. When the image hits the retina, rods and cones collect the image and pass it on through the optic nerve and into the brain.

HUMAN EYE ANATOMY

- **CORNEA**

Light passes through the **cornea** (the transparent window on the front of the eye) and then through the **lens** to focus on the retina.

- **IRIS**

The **iris** is a muscular curtain near the front of the eye, between the cornea and lens.

- **PUPIL**

The **pupil** (aperture) is the opening at the center of the **iris**. The size of the pupil is adjusted to control the amount of light entering the eye.

- **LENS**

The **lens** is composed of transparent, flexible tissues which focuses the light and images on your retina.

HUMAN EYE ANATOMY

- **Rods**

Concentrated outside the fovea area, the rods are the dim light and night receptors. The number of rods increases as the distance from the fovea increases. Rods sense images only in black and white.

Focal points behind the pupil, are responsible for most peripheral vision. Images that move are perceived more easily by the rod areas than by the cones in the fovea. If you have ever seen something move out of the corner of your eye, it was most likely detected by rod receptors.

In low light, the cones lose much of their function, while rods become more receptive. The eye sacrifices sharpness for sensitivity. The ability to see an object directly in front of you is reduced, and much depth perception is lost, as well as judgment of size. The concentration of cones in the fovea can make a night blindspot at the center of vision. How well a person sees at night is determined by the rods in the eyes, as well as the amount of light allowed into the eyes. The wider the pupil is open at night, the better night vision becomes.

HUMAN EYE ANATOMY

- **Cones**

Cones are concentrated around the center of the retina. They gradually diminish in number as the distance from the center increases. Cones allow color perception by sensing red, blue, and green light. Directly behind the lens, on the retina, is a small, notched area called the fovea. This area contains only a high concentration of cone receptors. The best vision in daylight is obtained by looking directly at the object. This focuses the image on the fovea, where detail is best seen. The cones, however, do not function well in darkness, which explains why color is not seen as vividly at night as it is during the day.

HUMAN EYE ANATOMY- SUMMARY

- Vision is primarily the result of light striking a photosensitive layer, called the retina, at the back of the eye. The retina is composed of light-sensitive cones and rods. The cones in the eye perceive an image best when the light is bright, while the rods work best in low light. The pattern of light that strikes the cones and rods is transmitted as electrical impulses by the optic nerve to the brain where these signals are interpreted as an image.
- Diet and general physical health have an impact on how well a person can see in the dark. Deficiencies in vitamins A and C have been shown to reduce night acuity. Other factors, such as carbon monoxide poisoning, smoking, alcohol, and certain drugs can greatly decrease night vision. Lack of oxygen can also decrease night vision as the eye requires more oxygen per weight than any other part of the body.

NIGHT INDUCED ILLUSIONS AND PROCEDURES

DEFINITION

- Illusions give false impressions or misconceptions of actual conditions; therefore, pilots must understand the type of illusions that can occur and the resulting disorientation. Although the visual system is the most reliable of the senses, some illusions can result from misinterpreting what is seen; what is perceived is not always accurate. Even with the outside references and the display of flight instruments, pilots must be on guard to interpret information correctly.

RELATIVE-MOTION ILLUSION

- Relative motion is the falsely perceived self-motion in relation to the motion of another object. The most common example is as follows. An individual in a car is stopped at a traffic light and another car pulls alongside. The individual that was stopped at the light perceives the forward motion of the second car as his or her own motion rearward. This results in the individual applying more pressure to the brakes unnecessarily. This illusion can be encountered during flight in situations such as formation flight, or UAS operations from a moving vehicle.

REVERSIBLE PERCEPTION ILLUSION

- At night, an aircraft or helicopter may appear to be moving away when it is actually approaching. If the pilot of the manned aircraft has the same assumption as the UAS pilot, and the rate of closure is significant, by the time each pilot realizes his or her own error in assumption, it may be too late to avoid a mishap. This illusion is called reversible perspective, and is often experienced when a pilot observes another aircraft or helicopter flying a parallel course. To determine the direction of flight, the pilot should observe the other aircraft's position lights. Remember the following: red on right returning; that is, if an aircraft is seen with the red position light on the right and the green position light on the left, the observed aircraft is traveling in the opposite direction.

FLICKER VERTIGO

- Flicker vertigo is technically not an illusion; however, as most people are aware from personal experience, viewing a flickering light can be both distracting and annoying. Flicker vertigo may be created by rotor blades or propellers interrupting direct sunlight at a rate of 4 to 20 cycles per second. Flashing anticollision strobe lights, especially while the aircraft is in or near the clouds, can also produce this effect. One should also be aware that photic stimuli at certain frequencies could produce seizures in those rare individuals who are susceptible to flicker-induced epilepsy.

PREFLIGHT PROCEDURES AND POSSIBLE ILLUSIONS

- Aircraft preflight inspection is a critical aspect of flight safety. It must comply with the appropriate checklists and procedures. Preflight should be scheduled as early as possible in the flight planning sequence, preferably during daylight hours, allowing time for maintenance assistance and correction. If a night preflight is necessary, a flashlight with an unfiltered lens (white light) should be used to supplement lighting. On gas powered UAS oil and hydraulic fluid levels and leaks are difficult to detect with a blue-green or red lens. Displays are checked ensuring they are clean and relatively free of scratches. Slight scratches are acceptable for day flight but may not be for night flight.

PREFLIGHT PROCEDURES AND POSSIBLE ILLUSIONS

- All UAS operating between sunset and sunrise are required to have operable navigation (position) lights. Turn these lights on during the preflight to inspect them visually for proper operation. Between sunset and sunrise, these lights must be on any time the UAS is operating.
- One of the first steps in preparation for night flight is becoming thoroughly familiar with the UAS' displays, instrumentation, and control layout. It is recommended that a pilot practice locating each instrument, control, and switch, both with and without supplementary lights. Since the markings on some switches and components may be difficult to read at night, be able to locate and use these devices, and read the markings in poor light conditions. Before powering the UAS on, make sure all necessary equipment and supplies needed for the flight, such as charts, notepads, additional displays, and flashlights, are set up, accessible, and ready for use.

COLLISION AVOIDANCE AT NIGHT

- Because the quantity and quality of outside visual references are greatly reduced, a pilot or VO tends to focus on a single point (usually the UAS), or instrument, making him or her less aware of the other traffic around. Make a special effort to devote enough time to scan for traffic. Effective scanning is accomplished with a series of short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. If the pilot detects a dimly lit object in a certain direction, the pilot or VO should not look directly at the object but scan the area adjacent to it (this is called off-center viewing).
- This will decrease the chances of fixating on the light and allow focusing more on the objects (e.g., tower, aircraft, ground lights). Short stops of a few seconds in duration in each scan will help to detect the light and its movement. A pilot can determine another aircraft's direction of flight by interpreting the position and anticollision lights, as previously described. When scanning, pilots/VOs should also remember to move their heads, not just their eyes. Physical obstructions can cover a considerable amount of sky, and the area can easily be uncovered by a small head movement.

VISUAL DEFICIENCIES

VISUAL DEFICIENCIES

- **Night Myopia**

At night, blue wavelengths of light prevail in the visible portion of the spectrum. Therefore, slightly nearsighted (myopic) individuals viewing blue-green light at night may experience blurred vision. Even pilots with perfect vision find that image sharpness decreases as pupil diameter increases. For individuals with mild refractive errors, these factors combine to make vision unacceptably blurred unless they wear corrective glasses. Another factor to consider is “dark focus.” When light levels decrease, the focusing mechanism of the eye may move toward a resting position and make the eye more myopic. These factors become important when pilots rely on terrain/environmental features during unaided night flights. Practicing good light discipline is very important and helps pilots to retain their night adaptation. Keeping lighting on dim allows the pilot to better identify details, unmarked hazards such as towers, and unimproved landing sites with no hazard lighting.

VISUAL DEFICIENCIES

- **Light Intensity**

A simple exercise that shows the difference in light contrast would be to go out to a very dark road and turn the dash board lights down very low or off and let your eyes adjust to the ambient light level. Then, turn the dash board lights up and note how the outside features disappear. The same concept applies to lighting in the operations area and screen brightness, and being able to see the surrounding terrain and obstacles. Special corrective lenses can be prescribed to pilots who experience night myopia .

Additional note: UAS controller video downlink displays, crew stations, cell phone use can all be factors which contribute to this deficiency.

LIGHT INTENSITY

Effects of dimming display and surrounding lighting during night flight to better see surrounding terrain.

VISUAL DEFICIENCIES

- **Hyperopia**

Hyperopia is also caused by an error in refraction. In a hyperopic state, when a pilot views a near image, the actual focal point of the eye is behind the retinal plane (wall), causing blurred vision. Objects that are nearby are not seen clearly; only more distant objects are in focus. This problem, is referred to as farsightedness.

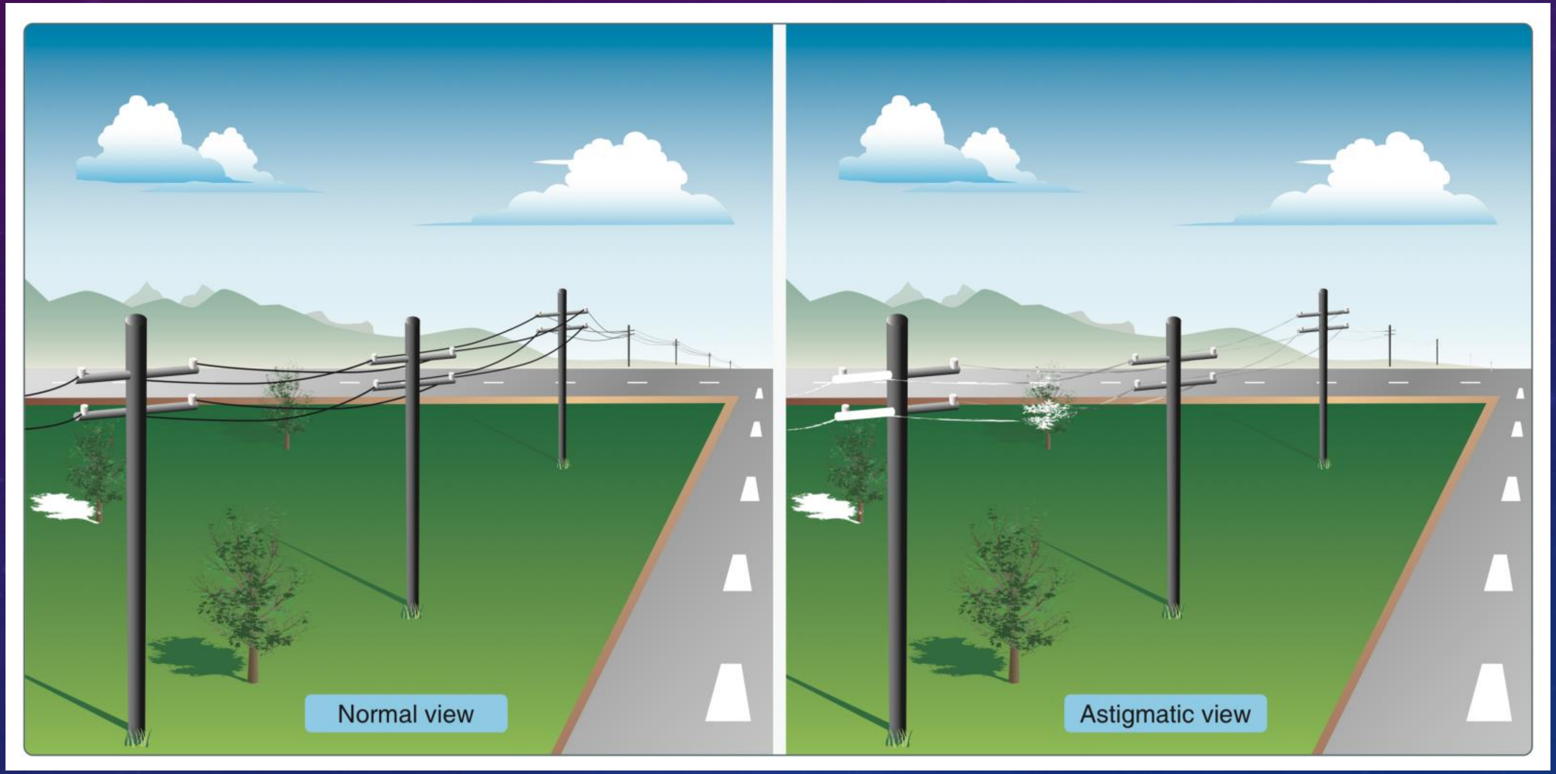
Additional note: This could happen when UAS controller displays or switches are placed very closely in the vision field. Close examination of UAS components in preflight could also cause this deficiency.

VISUAL DEFICIENCIES

- **Astigmatism**

An unequal curvature of the cornea or lens of the eye causes this condition. A ray of light is spread over a diffused area in one meridian. In normal vision, a ray of light is sharply focused on the retina. Astigmatism is the inability to focus different meridians simultaneously. If, for example, astigmatic individuals focus on power poles (vertical), the wires (horizontal) are out of focus for most of them.

ASTIGMATISIM EFFECT



Example of a view that might be experienced by someone with astigmatism.

VISUAL DEFICIENCIES

- **Presbyopia**

This condition is part of the normal aging process, which causes the lens to harden. Beginning in the early teens, the human eye gradually loses the ability to accommodate for and focus on nearby objects. When people are about 40 years old, their eyes are unable to focus at normal reading distances without reading glasses. Reduced illumination interferes with focus depth and accommodation ability. Hardening of the lens may also result in clouding of the lens (cataract formation). Aviators with early cataracts may see a standard eye chart clearly under normal daylight but have difficulty seeing under bright light conditions. This problem is due to light scattering as it enters the eye. This glare sensitivity is disabling under certain circumstances. Glare disability, related to contrast sensitivity, is the ability to detect objects against varying shades of backgrounds. Other visual functions decline with age and affect the aircrew member’s performance:

- Dynamic acuity
- Recovery from glare
- Function under low illumination
- Information processing

VISUAL DEFICIENCIES- SUMMARY AND IMPORTANCE

- The visual sense is especially important in collision avoidance and depth perception. A pilot's vision sensors are the eyes, even though they are not perfect in the way they function. Due to the structure of the human eye, illusions and blindspots occur. The more pilots understand the eye and how it functions, the easier it is to compensate for these illusions and blindspots.

FLIGHT MONITORING METHODS

NIGHT SCANNING

- Good night visual acuity is needed for collision avoidance. Night scanning, like day scanning, uses a series of short, regularly spaced eye movements in 10° sectors. Unlike day scanning, however, off-center viewing is used to focus objects on the rods rather than the fovea blindspot. When looking at an object, avoid staring at it too long. If staring at an object without moving the eyes, the retina becomes accustomed to the light intensity and the image begins to fade. To keep it clearly visible, new areas in the retina must be exposed to the image. Small, circular eye movements help eliminate the fading. Also, move the eyes more slowly from sector to sector than during the day to prevent blurring.

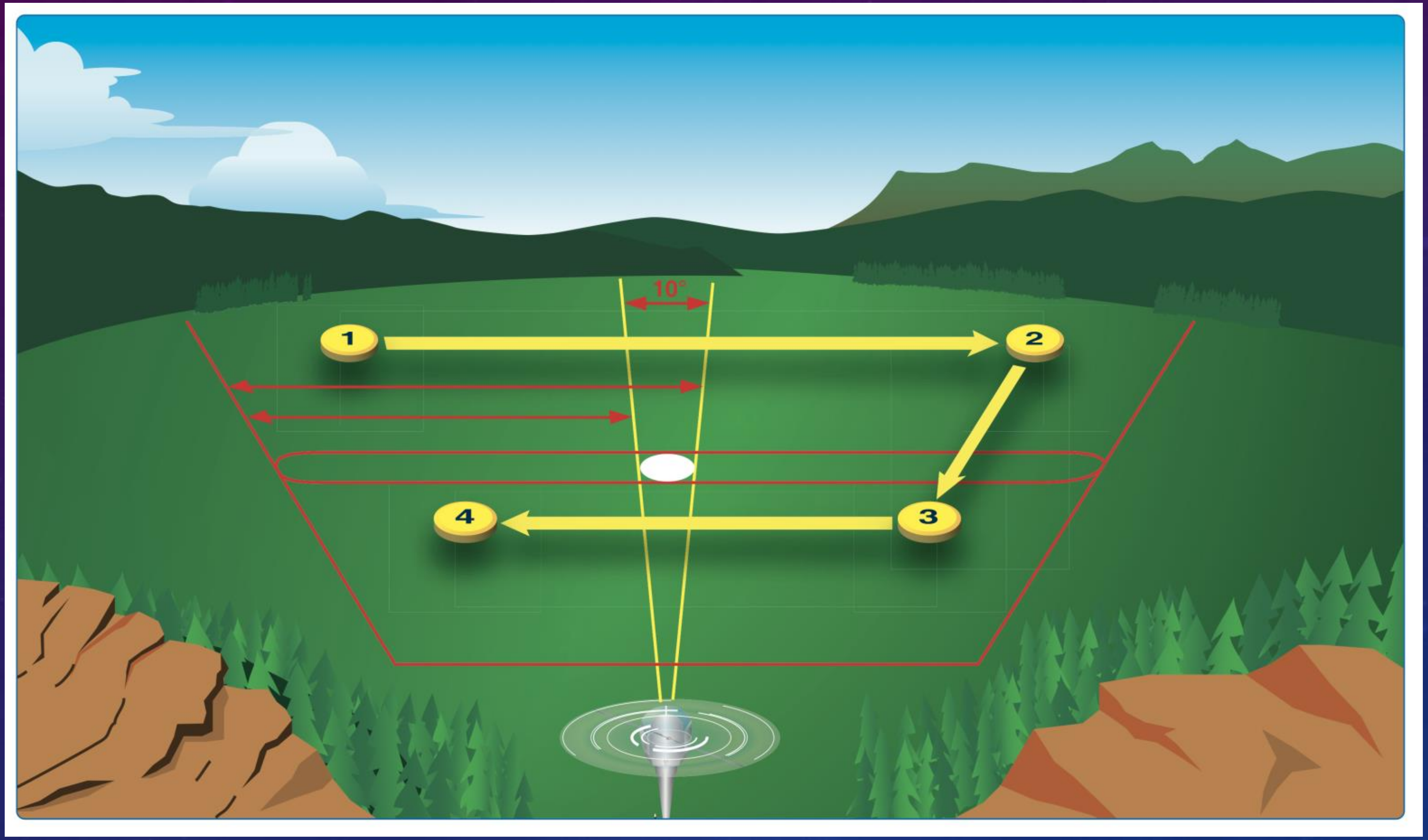
NIGHT SCANNING

Off-center vision technique.

NIGHT SCANNING

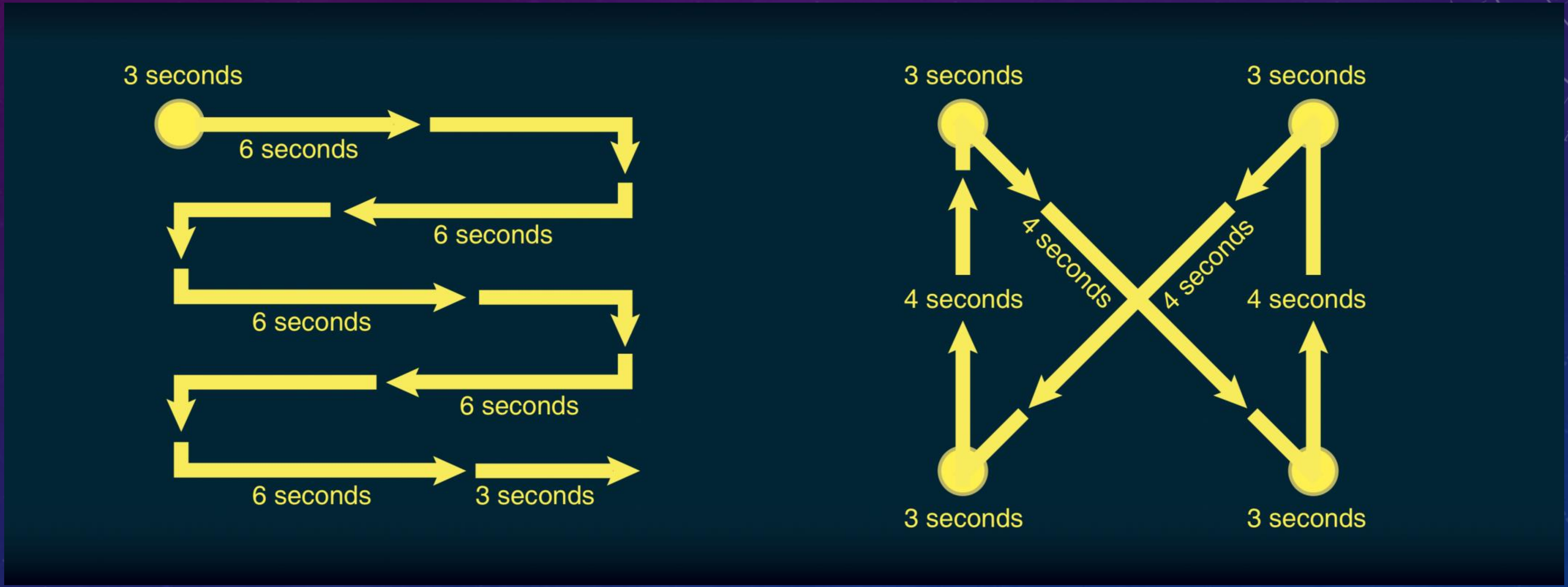
- During daylight, objects can be perceived at a great distance with good detail. At night, range is limited and detail is poor. Objects along the flight path can be more readily identified at night when pilots use the proper techniques to scan the terrain. To scan effectively, pilots look from right to left or left to right. They should begin scanning at the greatest distance at which an object can be perceived (top) and move inward toward the position of the aircraft (bottom). The following figure hows this scanning pattern. Because the light-sensitive elements of the retina are unable to perceive images that are in motion, a stop-turn-stop-turn motion should be used. For each stop, an area about 30 degrees wide should be scanned. This viewing angle includes an area about 250 meters wide at a distance of 500 meters. The duration of each stop is based on the degree of detail that is required, but no stop should last more than two or three seconds. When moving from one viewing point to the next, pilots should overlap the previous field of view by 10 degrees. This scanning technique allows greater clarity in observing the periphery. Other scanning techniques, as illustrated in the next figure, may be developed to fit the situation.

NIGHT SCANNING



Scanning pattern.

NIGHT SCANNING



Scanning pattern.

OBSTRUCTION DETECTION

- Obstructions having poor reflective surfaces, such as hanging wires and small tree limbs, are difficult to detect. The best way to locate these hidden features is by looking for their support structures. Preflight preparation should involve the pilot scanning the area for obstructions during the daytime (if applicable), or using applications like Google Earth and documents like current hazard maps to determine known locations of possible hidden or difficult to see features.

AIRCRAFT LIGHTING - FAA UAS COA REQUIREMENTS

- “The sUAS must be equipped with lighted anti-collision lighting visible from a distance of no less than 3 statute miles. The intensity of the anti-collision lighting may be reduced if, because of operating conditions, it would be in the interest of safety to do so. Additionally, in order to comply with § 91.209, the aircraft must have position lighting that enables determination of location altitude, attitude, and direction of flight.”

  (FAA UAS COS Lighting Requiments. This was stated previously but has been restated here for reference to the next slide.)

AIRCRAFT LIGHTING- GENERAL FAA REQUIREMENTS

- In order to see other aircraft more clearly, regulations require that all aircraft operating during the night hours have special lights and equipment. The requirements for operating at night are found in Title 14 of the Code of Federal Regulations (14 CFR) part 91.
- Position lights enable a pilot to locate another aircraft, as well as help determine its direction of flight. The approved aircraft lights for night operations are a green light on the right cabin side or wingtip, a red light on the left cabin side or wingtip, and a white position light on the tail. In addition, flashing aviation red or white anti-collision lights are required for night flights. These flashing lights can be in a number of locations

(For small UAS operations under the Blanket COA the lighting requirements detailed earlier in this presentation are regulatory, not to be confused with those requirements of FAR part 91 which are stated here.)

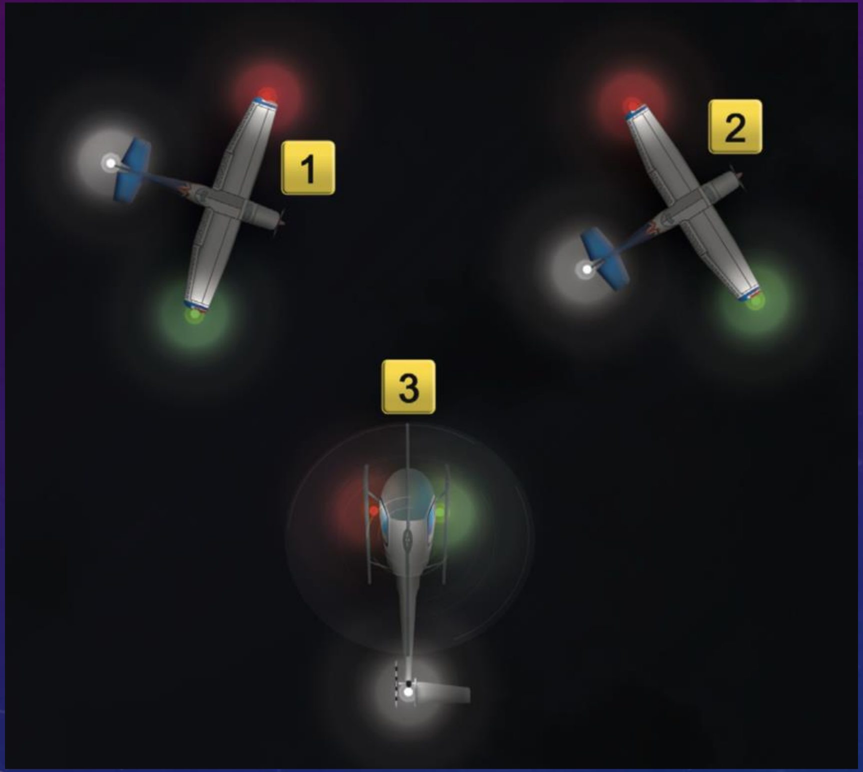
AIRCRAFT LIGHTING

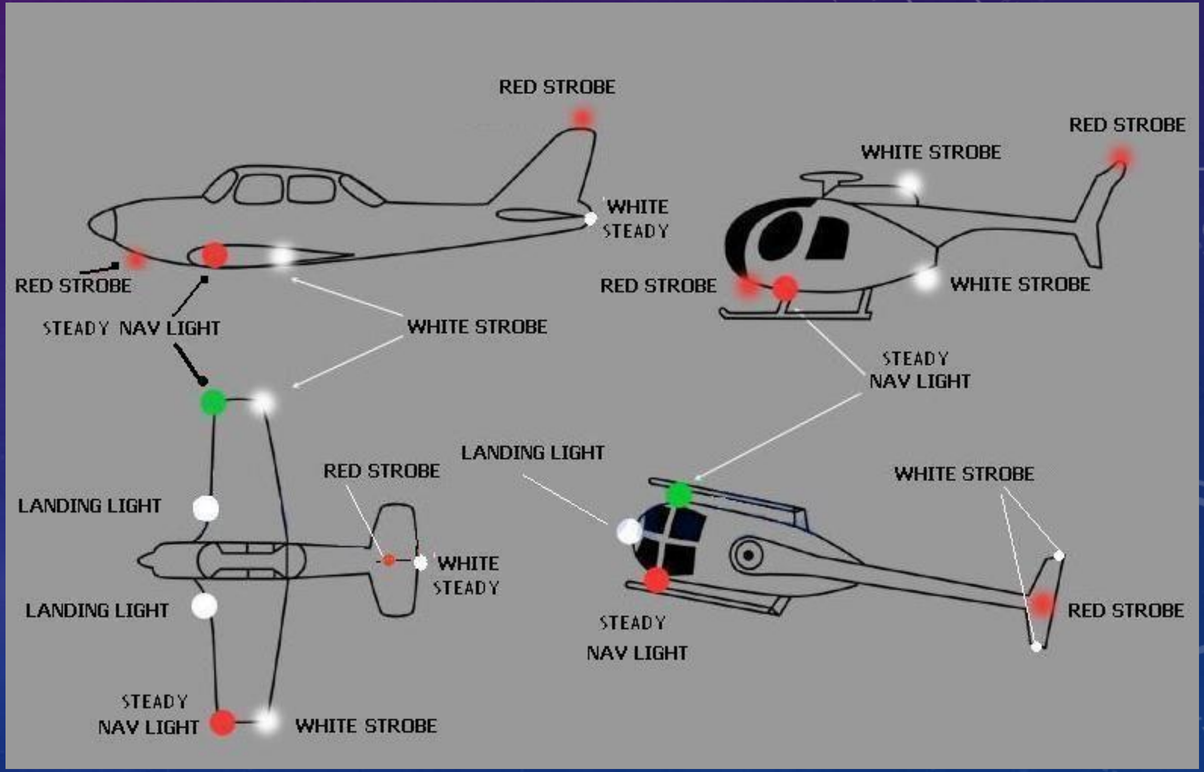
- The UAS used for initial multirotor PIC training has the following lighting system.
- Note the different types of lighting systems and how the lights on this UAS enable the pilot to understand the orientation.

AIRCRAFT LIGHTING

- The following example shows examples of fixed wing and helicopter aircraft lighting. By interpreting the position lights on other aircraft, the pilot in aircraft 3 can determine whether the aircraft is flying in the opposite direction or is on a collision course. If a red position light is seen to the right of a green light, such as shown by aircraft 1, it is flying toward aircraft 3. A pilot should watch this aircraft closely and be ready to change course. Aircraft 2, on the other hand, is flying away from aircraft 3, as indicated by the white position light.

AIRCRAFT LIGHTING





SUMMARY

- Knowledge of the basic anatomy and physiology of the eye is helpful in the study of UAS night operations. Adding to that knowledge a study of visual illusions gives the pilot and VO ways to overcome those illusions. Techniques for preflight, takeoff, collision avoidance, and night approach and landings help teach crewmembers safer ways to conduct flight at night.
- If you have any questions, please feel free to contact the DO or any CFI for additional information

NEXT STEPS

- Congratulations! You have now completed the ground portion of the required UAS night flight training program. The next steps require and in person training event and flight which will consist of the application of night topics discussed in this presentation and is in place to give you initial familiarity in UAS nigh operations. Upon successful completion of that night flight training event a checkride can be schedule in order to receive full flight privileges.

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