APPENDIX 2

Guidelines for conducting a camera study of nesting raptors

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A2.1 Introduction to cameras in raptor nests

Logistical challenges in the remote breeding range of Gyrfalcons have limited the application of cameras as a primary method to study nesting biology (Jenkins 1978, Poole 1988, Poole and Boag 1988, Poole and Bromley 1988, Tømmeraas 1989, Booms and Fuller 2003). Difficulties associated with the widespread nature of remote nest locations have complicated our ability to gather enough data from which to draw statistically sound inferences. Recent developments in camera technology have alleviated many of these difficulties, as exemplified in a recently successful camera-based study of nesting Gyrfalcon diet at a scale not achieved previously (Robinson 2016). Specifically, new camera technology provides relatively low-cost, compact, and light units that are adaptable to various installation schemes. These cameras are also weatherproof, have long lasting battery life, and large memory card capabilities. These aspects enable researchers to deploy more camera units in one breeding season, thus increasing sample sizes and statistical power. Based on recent and successful camera-based studies of Arctic nesting raptors (Anctil and Franke 2013, Franke et al. 2013, 2016, Anctil et al. 2014, Robinson et al. 2015, Robinson 2016), we present guidelines on camera model selection, installation, and camera programming procedures that are broadly applicable to studies of nesting raptors at remote locations.

A2.2 Selecting a camera model

Selecting the appropriate camera model is the starting point for conducting a camera study. The primary goal is to select a unit that will confidently achieve research objectives, a decision that is largely based on a trade-off between cost and camera capabilities. Thoughtful consideration of this trade-off relative to project objectives before selecting a model will increase the success of the camera study. Additionally, after considering camera specifications essential for research objectives, an understated approach is to consult researchers that have used cameras as a technique to monitor nesting raptors for additional considerations pertaining to specific research goals.

A2.3 Video vs. photography

Traditionally, the application of video units on a remote nesting species such as the Gyrfalcon has been limited due to the logistical issues of unit deployment and maintenance (Jenkins 1978, Poole 1988, Poole and Boag 1988, Poole and Bromley 1988, Tømmeraas 1989, Booms and Fuller 2003). Alternatively, new motion-activated photography models are compact and light, allowing for easy transport to nest sites, as well as relatively simplified deployment while on rope at cliff nests. Because motion-activated units are compact and have an internal battery source they are both water and weatherproof, a key consideration for monitoring Arctic nesting raptors such as Gyrfalcon that experience a great deal of snow and rain during the nesting period.

Although motion-activated photography units hold many benefits over current video set-ups, the decision between these different unit types should be made regarding research objectives, and the cost or benefit of using one unit over the other. Video units can capture continuous imagery, and in some cases audio, to better capture behavior and other aspects of life in the nest for a truncated period. At present, motion-activated cameras may be a better option for studies such as diet quantification due to their high performance and lower cost. However, recent technological advances have produced motion-activated video units that capture video as well as images and may be the best option to capture all necessary data, given the unit is within project budget. Because of the continued advances in technology, it is essential to explore all options of current available technology to further advance the utility of this method for monitoring nesting birds.

A2.4 Camera specifications

Additional considerations when selecting a camera model involve camera specifications such as model design attributes, camera durability, lens attributes, image quality in variable light conditions, programming options, camera software, mounting options, and battery and memory card attributes.

Physical characteristics of camera units can strengthen their utility for capturing quality nest images. Cameras that are designed with a diversity of mounting options increase the ability to successfully install the unit at nest sites. Arctic raptors nest in a variety of situations. A camera that is capable of mounting on a stake, a wall mount, or in the ground will simplify installation at nest sites and strengthen the ability to use all nests available for study. Camera durability and performance at temperature extremes are key attributes for utility in Arctic studies. Because much of the nesting season in the Arctic faces harsh weather and precipitation, camera units must be able to withstand these conditions.

Lens attributes are a necessary consideration for successful implementation of camera studies in Arctic nesting raptors. Lens attributes include image resolution, focal length, and depth of field. It is important to consider the image resolution capabilities of camera units because high image quality is necessary for research objectives such as identification of individuals (e.g., through leg band reading) or prey deliveries. For studies investigating aspects such as frequency of incubation bouts, feeding frequency, and hatch and fledge dates, image resolution may be less of a priority.

Camera focal length is also a key consideration. It is prudent to determine whether the focal length is fixed or variable, because working with most raptor nests requires installation at varied distances and may require adjustment of the focal length to ensure optimal photo quality. Additionally, with a limited depth of field comes a limited range in which to obtain a quality photo. Familiarity with focal length and depth of field of camera units will strengthen the ability to capture quality images.

Camera units that capture quality images in variable light conditions (i.e., low light caused by cloudy weather, dawn or dusk, or even at night) are necessary to maximize data collection. Although daylight is nearly continuous during the Arctic breeding season, weather can cause low light situations, and in turn poor image quality. Birds may remain active and provision young in low light conditions such as in poor weather or at night, which emphasizes the need for a camera that is capable of capturing quality images in these conditions to limit data loss, increase data quality, and maximize data collection.

To obtain images in low light, or at night, camera units use a flash to light a subject. Camera models may use a traditional flash of visible light (e.g., incandescent flash), and thus may cause added disturbance to the birds each time the motion-sensor is triggered. Options that employ infrared LED flashes are preferred, because they are essentially invisible to the birds and do not cause added disturbance.

Some models possess menu-driven programming that is adaptable to various situations and may better achieve research goals. However, programming options only increase the utility of cameras at nest sites if implemented correctly. If cameras are improperly programmed, there may be data loss or decreased sampling. Simpler units that lack programming complexities may be appropriate for studies with straightforward sampling goals. Because of this, researchers should consider research objectives and the appropriate camera technology to best achieve their goals. In cases where programming options are necessary, researchers need to familiarize themselves with the programming prior to camera installation at nest sites. Camera programming includes options for the motion-activation such as flexible scheduling and a sensor start delay, sensitivity to motion, motion-trigger speed, motion detection bands in field of view, frame-rate and photo frequency, and the ability to program set time-lapse photographs in the event of a motion-sensor failure to ensure a minimum capture of photo data. If implemented correctly, flexible programming increases both efficiency and quality of data collection.

Along with programming options, additional aspects of a camera's software can strengthen its utility in nests. Many camera images record metadata that may be useful for study objectives. These include time, date, temperature, and moon phase, for example, recorded with each photo and in many cases shown in the image. Consider models with this attribute to increase the breadth of data provided by each individual photograph. Other considerations involving camera software include the ability to update firmware. The ability of a camera's firmware to follow updates provided by the camera company increases camera performance and lifespan.

Selecting camera models with versatile battery requirements and long-lasting capabilities decreases maintenance and nest disturbance, and increases confidence in successful data collection. In the past, camera studies involving video setups were powered by car batteries that needed to be changed regularly and were also heavy and cumbersome, limiting their utility for large scale studies (Booms and Fuller 2003). Battery requirements for motion-activated cameras vary, but some units can take a variety of battery types such as AA Alkaline, NiMH rechargeable, or Lithium. These battery types vary in price, as well as in performance. A camera that is versatile in its battery requirements allows the researcher to adapt to specific performance needs. Relatively cheap alkaline batteries can be used for short duration studies at moderate temperatures, but studies conducted at low temperatures and for long periods should use the more expensive lithium batteries. Lithium batteries used in a recent Gyrfalcon diet study (Robinson 2016) were replaced midway during the brood-rearing period (20–30 days) as a conservative measure, however the batteries may have performed for the entire brood rearing period (B. W. Robinson unpubl. data). Regardless of the choice of battery type for use in cameras, it is important to ensure that the battery terminals on the camera unit as well as the batteries are clean and free of corrosion. Previous studies have experienced camera failures and loss of data from neglecting to clean units and rechargeable batteries, thus proactive maintenance is always prudent.

In the future, units that use solar panels with a battery backup may be a useful alternative. At present, the use of solar panels as the main power source may require camera modifications, which is an important consideration in selecting a camera model because some models support modifications whereas others do not. Additionally, the installation of solar panels at nests may increase installation time and disturbance.

Memory card capabilities also represent a key area for consideration when selecting a camera model. If it is critical to capture rapid fire photographs when motion is detected, such as in diet studies, it is necessary to select a model capable of using memory cards with a high transfer rate, such as SDHC models used for handheld digital cameras. Camera units also dictate the memory capacity capabilities; for instance many units cannot use memory cards exceeding 32 GB. A complete understanding of the number of photos taken between camera servicing is important when choosing camera models, because memory card capacities are often the limiting factor in data collection (B. W. Robinson, unpubl. data). Additionally, many memory card types and brands do not work well in some camera units, an issue that emphasizes the importance of testing camera and card combinations in mock trials prior to their deployment at nests.

A2.5 Deploying cameras at nests

A2.5.1 Camera installation

Both camera installation and programming consist of trade-offs that are important to consider in the context of research objectives. To ensure successful use of camera equipment it is necessary to develop a familiarity with camera installation and programming prior to fieldwork through multiple mock installation exercises. The time spent conducting mock installation exercises can prevent failure of camera installation, ensure effective camera placement, increase installation efficiency, and ultimately decrease the possibility of data loss. Consider the guidelines listed herein during installation, however understanding aspects of the cameras such as depth of field, field of view, and the nuances of installation will ensure success of research objectives.

Proper installation is perhaps the most critical aspect for capturing useful images of prey deliveries for quantifying diet. There are many considerations when installing cameras, such as nest status, nest site characteristics, the camera's point of view, lighting issues, the amount of daylight and working hours, and research objectives. However, the proximate consideration for camera installation is whether to install a camera, or not. Researchers should have a clear protocol for when it is appropriate to enter nests for camera installation, and what conditions to avoid. This protocol should be developed considering temperature, precipitation, cloud cover, time of day, and nest status.

Nest status (i.e., egg laying, incubation, or brood rearing) is a necessary consideration because each stage varies in sensitivity to the disturbance of nest entry and camera installation. Avoid nest entry near hatch, a time when nest survival is most sensitive because hatching eggs or small nestlings lack thermoregulatory ability and are particularly susceptible to wind, rain, or direct sunlight (T. Booms, pers. comm). The recommended time for camera installation in Gyrfalcon nests is mid-incubation, when the adults have developed strong fidelity to the nest site and the eggs are hardy, withstanding exposure for relatively long periods (B. W. Robinson, unpubl. data). Avoid installation during any inclement weather such as precipitation, temperatures below freezing, and high winds, because these factors compound the negative effects of exposure on eggs and nestlings, which in turn decreases the length of time that adults can leave nest contents unattended. Install cameras on calm and sunny days at midday, or the hour when temperatures reach the daily high, however consider that direct sunlight can also be detrimental to eggs and nestlings.

Consider adult behaviors and installation time to limit nest disturbance and exposure. Recent Gyrfalcon nest camera installations took an average 60 minutes from nest entry to exit (B. W. Robinson, unpubl. data). Adult behaviors appear variable in western Alaska, where individuals may return within a range as wide as 15 minutes to four hours following camera installation (B. W. Robinson, unpubl. data). With installation duration in mind, assess individual adult behaviors and adapt installation procedures accordingly, i.e., more aggressive adults may return to the nest sooner whereas timid adults may stay away for longer periods following disturbance which will increase the duration of nest exposure (B. W. Robinson, unpubl. data).

Along with considering weather when entering nests, it is prudent to assess the ability to access the nest prior to the attempt. Whether nest entry will require climbing equipment or not, and the potential route of entry should be assessed from afar using a scope before approaching the nest cliff and flushing the adults into the air. This will save time in setting up anchors and nest entry, and limit the amount of disturbance to the adults and nestlings. Assess potential hazards to both the climber and the birds, such as loose rocks or debris. Do not rappel from directly above the nest to avoid knocking anything onto nestlings and eggs. Monitor the possibility of rope rub from above to limit wear on the rope, and further avoid falling material that could threaten the climber and the nest. At the initiation of the descent into the nest, make noise to alert the incubating/brooding adult of your presence. This will reduce the likelihood of surprising the bird, which is important because a flushing bird may damage eggs or knock them from the nest bowl.

Camera placement is a key consideration during installation, because improper placement can hinder camera performance and data collection. To aim the camera properly and obtain the best image quality, options such as the use of a laser pointer or a portable card reader with an LCD screen (e.g., tablet) can ensure proper placement. However, it is necessary to have a familiarity with the camera's field of view before installation because it will increase the ability to properly place the camera in an efficient and timely manner to achieve the best image quality and limit nest disturbance. Unless the direction of the camera is a specific research goal, aim the camera towards nest edge and away from the subject. This will lessen the amount of "false camera triggers" caused by nestling movement and capture prey deliveries when the adult is entering the nest.

Consider potential problems associated with nest site characteristics that may limit camera performance. For instance, install the camera to capture all areas that mobile young may climb to in the late nesting period. When possible, avoid nests with accessible topography for mobile nestlings, such as ledges behind the camera out of reach of the lens. Ideal camera placement is 1 m above and 2–3 m away from the nest (adapted from Anctil et al. 2014 and A. Franke pers. comm.), however nest site characteristics usually do not allow for ideal placement. Consider complications with lighting that may arise at the nest site, such as areas of dark shadow and bright light on sunny days, or direct sunlight shining on the camera lens. Whenever possible, aim the camera facing north to minimize the risk of overexposing images from direct sunlight. Also, installing the camera 1 m above the nest provides a downward angle, which also reduces the likelihood of overexposed images. Assess the potential for vegetation to grow in front of the camera lens and limit the view of the nest. Grass can grow rapidly in the Arctic, and has caused complications in past Gyrfalcon camera studies.

The amount of daylight and working hours of the camera are also major considerations. For study of raptors that breed in the Arctic, assume a 24-hour working period for cameras because of the challenge of added day length and essentially continuous subject activity.

There are a variety of camera installation options depending on the camera models that are used for monitoring nests. Creativity and innovation are encouraged so long as new methods are tested before implementation in occupied nests. Cameras can be attached to cliffs, or when situations allow they can be mounted to a stake that is placed in the ground. Cliff mounted cameras can be installed by attaching cameras to the cliff on a wall mount. This is done through pre-drilling holes with a battery powered hammer drill and masonry drill bit to attach a wall mount bracket to the cliff side with concrete anchor screws. The use of a hammer drill as well as masonry drill bits will ensure effective and efficient installation, because hammer drills are designed to effectively bore into hard surfaces such as stone, and masonry drill bits are more durable than traditional bits, and less likely to dull or break during installation. Using each will limit installation time and in turn nest disturbance.

When rock is soft, use of a drill bit that is smaller than the anchor screws increases the stability of the mount. However, in areas with harder rock it is important to assess the need to match drill bit diameter with anchor diameter to avoid breaking the anchor screw during installation. For example, in recent camera installations in Gyrfalcon nests involving the attachment of Reconyx PC800 motion-activated photography units to Reconyx wall mount brackets, a 5/32-inch (4 mm) masonry drill bit was used with a hammer drill to ensure effective and efficient bore holes for the installation of the wall mount. 3/16-inch (4.75 mm) concrete anchor screws were placed in soft rock to strengthen the mount stability. For harder rock, 5/32-inch (4 mm) concrete anchor screws were used to avoid breaking the screws during installation. Planning for such situations in advance will enhance the success of installation and increase the strength of the mount. Again, the importance of repeated mock installation exercises prior to camera installation at occupied nest sites cannot be overstated.

In cases where power tools are not available, or a lack of electricity for charging batteries at field camps limits the use of these tools, researchers can use other installation options such as cement glue or epoxy for mounting cameras. The use of these options requires thorough tests of the glue before implementation at nests. Additionally, the amount of time it takes for glue to set is critical to limit duration of nest entry and nest disturbance.

Fall protection measures may be a useful consideration in areas where rock is brittle, or simply to ensure that the camera will not be damaged in the event of a mount failure. Such options can be explored prior to fieldwork, but may involve a tether attached to a second mount bracket installed in the same manner as the primary mount bracket.

Camera maintenance at installation and subsequent visits must be considered. Placing anti-moisture packs inside the camera at installation can limit the impacts of moisture that may get inside the camera. Anti-moisture packs can also reduce the presence of moisture on the lens caused by humidity and heat. Other useful maintenance measures are to check and clean the camera lens and battery terminals on every visit. To ensure maximum camera life, check the service agreement for camera models because some companies offer to refurbish units after each field season.

In summary, due to the variety of camera installation options, consider multiple techniques specific to nesting situations and camera types prior to fieldwork, and consult other researchers that have used similar models in similar situations.

A2.5.2 Camera programming

Camera models vary in their programming versatility. Proper programming consists of both a familiarity of the options available for the model and an understanding of what imagery is needed to best achieve project goals. Motion-activated cameras may be programmable to offset overuse of the camera and limit problems associated with prematurely exceeding memory card capacity, while still capturing the images necessary for the study. The following guidelines are based on previous implementation of motion-activated cameras in Gyrfalcon nests for a diet study (Robinson 2016).

It is important to strike a balance between limiting excess photos while ensuring that the appropriate data are captured. To achieve this, it is possible to calculate the number of images a camera will take before exceeding the memory capacity. Once the number of photos is known for a given card size (e.g., 32GB), it is then possible to calculate how programming may influence the number of photos taken over the course of the study period to ensure that the maximum amount of sampling can occur without exceeding the memory capabilities.

We recommend the following programming for camera implementation in nests requiring a minimum 20–25 days between visits, as derived from a diet study that used Reconyx PC 800 motion-activated photography units in Gyrfalcon nests (Robinson 2016). We again emphasize that a clear vision of project objectives combined with field testing prior to implementation be the proximate factors for decisions regarding the appropriate programming in any study. Our camera programming recommendations are as follows: medium to medium-high motion-activation sensitivity, 30-second motion-activation sleep period, recurring time-lapse photo at 30-minute intervals, and subjective start delay (dependent on nest stage at camera installation).

Allow less sensitive programming for those nests with little distance between subject and camera, because motion activation sensitivity increases with proximity to subject. Because of the balance between camera overuse and the need to capture appropriate data resolution, consider a combination of sequential photos (e.g., two continuous photos at trigger) at a slightly less liberal sensitivity setting of medium or medium-high depending on nest site characteristics and the camera's proximity to the nest.

The ability to program a rest period for the motion sensor following a trigger can be helpful to limit prematurely reaching the memory capacity of the card. For example, after motion is detected and photos are taken, the motion sensor will deactivate for a period (e.g., 30 seconds). The decision of the length of the sleep period should be made regarding the confidence that the initial trigger and photos captured the necessary information, and how often a given event needs to be sampled. For example, in diet studies that aim to identify prey items delivered to nestlings, the appropriate length of delay will be related to the average length of feeding bouts and how many photos will be necessary from one feeding event to ensure that the item is identifiable.

Scheduling a time-lapse photo option independent of motion-activation ensures that a minimum number of photos, and thus data, will be recorded in the event of a motion-activation failure. A programmed recurring photo taken every 30 minutes achieves this goal, while not providing a large tax on memory card capacity.

Programmable daily sleep periods may also be useful in some studies. Cameras may be programmed to shut down for a scheduled period such as nightly hours of darkness, or anticipated times of subject inactivity, conserving battery and memory card life. Research objectives will dictate the use of this feature, however in most raptor nest studies in the Arctic, subject activity is nearly continuous and the use of such programming is not advised.

Finally, some camera models have programming options that allow a delay in the start of camera activation. Nesting studies can use estimated hatch dates and start delay to ensure that the entire nest period is captured without overuse of the camera, limiting restraints of battery life and memory card capacity.

A2.6 Summary

Cameras represent an excellent method to monitor and quantify aspects of nesting biology such as diet. New technology increases the feasibility of camera studies through increased sample size and reduced nest disturbance, because modern cameras require shorter installation times and reduce logistical challenges associated with camera maintenance. We recommend the use of sophisticated motion-activated photography models with versatile programming options, because they provide a relatively inexpensive yet effective option for the study of remotely nesting raptors such as the Gyrfalcon.

The implementation of cameras at nest sites consists of trade-offs that are important to consider in the context of research objectives. To ensure the successful implementation of cameras, it is essential to develop a familiarity with installation and programming prior to fieldwork. Nest sites characteristics are variable, and each location presents different challenges for installation. Consider the guidelines herein when installing cameras, however the ability to assess complications specific to each nest and to adapt camera programming and installation accordingly will ensure the success of research objectives.

Table A2.1. Itemized considerations for implementation of motion-activated camera units to monitor nesting raptors. Importance column rates the importance for

Feature	Feature Range	Importance
Motion Detection	Y/N	1
Detection Zone (degrees)	35–150 degrees	3
Trigger Speed (seconds)	.3–1 seconds	1
Recovery Time (seconds)	1–10 seconds	1
Detection Range (variable in ft/m)	40–80 ft.	3
Time-lapse	Y/N	1
Multi-shot	Y/N	1
Image Resolution (megapixels)	3–12 mp	D
Effective Focal Length (in/mm)	~ 3″–infinity (variable / lens exchange)	1

consideration of each category for successful implementation of cameras at nest sites (1 = more important, 3 = less important, D = dependent on research objectives).

Description	Considerations
Ability of camera to capture images when motion is detected in field of view.	Essential for most behavioral studies.
Detection angle is the angle of the detection circuit. Coupled with the detection range, the detection angle comprises the detection zone.	The bigger the detection zone, the more likely it is that movement will be captured. The detection zone may be "factory-set" or may contain variable settings that are adaptable to specific nest situations, increasing versatility and effectiveness.
Trigger speed measures how quickly an image is taken after camera is triggered.	Quicker triggers are more likely to capture images of fast movements. Consider this pertaining to research objectives and the primary data needed from each image.
Recovery time determines how soon after taking an image the camera will be ready to trigger again.	Low recovery time will decrease the images obtained during quick movement. Consider this pertaining to research objectives, as adult visits to nests may be rapid in cases of delivering prey to older nestlings.
Detection range is the maximum distance at which the camera can detect movement.	Consider this related to nest site characteristics. Some nests have broad areas where mobile nestlings may perch later in the nestling period. If the distance between these perch areas and the camera are greater than the detection range, data loss may occur.
Programmable setting that provides motion-independent images at set time intervals, in addition to images captured by motion detection.	Motion-independent programming may be important in the event of motion detection failure to ensure that a minimum number of images are captured.
The capability to capture multiple images per motion trigger.	Potential to fill memory capacity increases with multiple images.
Overall quality of image - higher quality image = larger file size.	Consider resolution in relation to research objectives. More detailed photographs may provide more information, however are larger and may create memory limitations.
Specific distance where images will be sharpest and highest quality.	Cameras may be programmable in focal length, which will increase effectiveness at nest sites with variable characteristics.

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Table A2.1 (continued from previous page)

Feature	Feature Range	Importance
Field of View (degrees)	42–150 degrees	3
Video Quality (megapixels)	480–720p, 1080 HD	D
Camera Flash	Infrared, Incandescent	2
Power Source	Internal, External	D
Battery Size	AAA, AA, C, D	N/A
Battery Type	Alkaline, Lithium, NiMh	D
External Power Input Jack	Y/N	2
Memory Card	16–32 GB	D

Description	Considerations
Complete view that is captured by the camera, including vertical and horizontal view.	A familiarity of the camera's field of view will ensure effective camera placement. Cameras with a limited field of view will be effective in nests that are small and restricted; however, many nest sites may be large and on open cliff sides with accessible topography for older nestlings. A camera with a wide field of view will ensure that mobile birds will be captured in images.
Resolution quality range for units with video capabilities. Generally, larger numbers indicate higher quality.	Consider project objectives related to video resolution. Lower quality images may capture necessary information and may be the better option because lower resolution videos are smaller files and will lessen the possibility of memory card issues.
Built-in camera flash to light up subject in low light conditions such as at night or during weather events. Incandescent captures color photographs, infrared captures black/white photographs.	Consider that the use of a traditional incandescent flash may be disruptive to nesting birds, whereas infrared is essentially non-visible and may lessen disturbance.
Internal sources rely on batteries such as D, C, AA or AAA. External sources may be car batteries, or solar panels attached to car batteries or directly to camera units.	Internal sources generally require less maintenance, are less cumbersome, and shorten installation time. External sources may offer increased battery life and reduced nest visits.
Specific to camera type and requirements.	Size may dictate installation time, and may cause difficulties with transport to nest sites.
Dictates capacity and functionality under temperature variables.	Lithium batteries are the most efficient and have the widest operating temperature range, however are difficult to ship.
Ability to use external DC power source (e.g., auxiliary battery, solar array, etc.)	Can provide the ability to adapt camera power source to solar supply, or an external backup battery unit.
Removable storage for camera data.	Follow camera manufacturer card recommendations. Some cameras may have compatibility issues. Higher performance cards are more expensive. Consider research objectives to maintain a balance between camera performance and cost.

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