

360 Cameras, January 2017

This is a high-level summary of 360 cameras available on the market as of early January 2017. The focus of this article is to give consumers simple recommendations about real products that are actually available and usable in the field.

Information in this article by no means constitutes official endorsement from me nor from Facebook. Camera preferences are based largely on use-case targets and subjectivity, and one should always make purchase decisions based on personal requirements.

General Notes

Before getting into specific camera models, it might be useful to think about what's important when considering a 360 camera:

- **Use cases.** The intended use cases will dictate most of the requirements of your 360 camera. Think about the scenario(s) in which you will be using the camera. Here are some questions to get started:
 - Will you be shooting in a casual / dynamic environment or a scripted environment?
 - Do you have a lot of camera movement and/or subject movement?
 - How far away will your closest subject be?
 - How reliable do you need the camera to be?
- **Form factor.** 360 cameras come in 3 main form factors:
 - **Standalone.** These cameras work without being connected to any other devices (e.g., smartphones, computers, networks), but have varying levels of on-camera controls. Some have literally no controls other than a record button and rely on connected devices to change settings.
 - **Fully standalone.** Some 360 cameras have full (but rudimentary) interfaces with a small screen and a few buttons to change camera settings. This is rare, but is very useful.
 - **Wi-Fi / network connected.** These cameras can typically be started and stopped using a button, but need to be connected to a smart device or computer via Wi-Fi or wired network to change settings. Most existing consumer 360 cameras exist in this category. Reliability of connectivity varies widely by camera model.
 - **Direct-connect (smartphone accessory).** These cameras must be physically connected to a smartphone, usually via the Lightning or USB port. They either have onboard storage for media or shoot directly to the phone's camera roll. Direct connections are more

convenient and reliable than Wi-Fi, but introduce camera-positioning challenges for considered (non-casual) shooting.

- **In-camera stitching.** Some cameras stitch in-camera, allowing for very low-spec phones to be used. This improves battery life and prevents phones from getting hot during use.
- **Phone-based stitching.** Some cameras stitch on the phone, which might require higher-spec phones to be used. Phones will get hot (overheating is possible), and battery life will shorten.
- **Target distribution media.** Where is the final 360 going to be shared, and in what viewing format?
 - **Feed vs headset.** Is the target the Facebook feed only? Is it a Gear VR headset? 360 videos and stills images targeted at headset viewing need to be higher in resolution and in general, need to be more stably mounted (people get sick if the camera moves).
 - **2D-360 vs 3D-360.** Do you need 3D (stereoscopic) output? 3D is difficult to produce and is very expensive. Great 3D enhances immersion dramatically, and bad 3D can drive viewers away from the format for good.
- **Sharing workflow and required turn-around time.** How long do you have between shooting and sharing? If your camera doesn't stitch in-camera, it will take time to stitch. Stitching time varies from roughly real time (1 minute of video = 1 minute of stitching) to ~150x real time or longer (1 minute of video = 2.5 hours of stitching). Stitching software can run in-camera, on smartphones, on computers, and in the cloud.
- **Post-processing tolerance.** Do you have the right computing power, software tools, and editing expertise to do manual stitching and editing of 360 content? If not, are you OK posting footage straight from camera or working through a production partner?
- **Output quality.** Do you need the final 360 media to be perfect? Stitching quality is highly variable, and there are tradeoffs between stitching quality and post-processing time (and cost).
- **Livestreaming.** Do you need live 360 streaming support?
- **Ambient temperature.** Some cameras will overheat when recording long clips, especially when used in warmer temperatures. Cameras that connect directly to smartphones also need to worry about smartphones overheating or turning off due to extreme cold.
- **Price.** Prices range from \$100 - \$60,000+. Typical consumer cameras are \$100-\$500. Prosumer and enthusiast cameras are \$2000-5000. Serious productions typically use cameras from \$300-\$60,000+. Most of the cost of a serious production is in post production.

Realistically-usable 360 cameras as of right now

This list of cameras is taken from my own experience in testing cameras and from talking to many 360 content creators ranging from individuals sharing casual content all the way to production companies working on large 360 productions and live events. Obviously, there is a lot of subjectivity here; if I missed something, please let me know.

For consumers

For video: if you want **headset compatibility for videos**, the [Samsung Gear 360](#) (\$278 street, **Samsung S6/S7 or Windows computer required**) and [Nikon KeyMission 360](#) (\$500 street) are the only viable consumer choices. They both shoot in 4K (30 fps for Samsung, 24 fps for Nikon) and can be used without being connected to a smartphone.





Samsung Gear 360 (top); Nikon KeyMission 360 (bottom)

The Samsung has a **full, on-camera interface** for changing camera settings, while the Nikon needs to be connected to a smartphone for settings changes. Connecting the Nikon to a smartphone is not a straightforward process, and connection reliability is low. The Samsung requires a Samsung S6/S7 or Windows machine to stitch video, which is much slower than realtime. Conservatively, I'd budget 5 minutes of processing time for every minute of video shot (not including file transfer time). Note that a Samsung S6 is not able to stitch 4K footage from the Gear 360—an S7 or Windows machine is necessary.

The Nikon **stitches in-camera**—the videos are ready to use right after capture, but the video quality is worse than the Samsung's. If you need a super fast turnaround for upload, the Nikon is worth considering, but it comes at the cost of a worse user experience. I recommend the Nikon only if the end user *needs* to be successful with the camera (i.e., it's part of their job). Otherwise, friction in the user experience has the potential to cause users to not use the camera.

For stills, the [Ricoh Theta S](#) (\$305 street) is the **best combination of quality and usability**. It stitches 14-megapixel stills on camera so images are ready to be shared via mobile app or computer after they are shot. The built in IMU records orientation, and the mobile app automatically levels shots when they are copied via Wi-Fi (the Ricoh desktop stitcher does not do this). The Ricoh Theta S has **best-in-class stitching** with almost no stitching artifacts, and is also resistant to flare from the sun and other bright point-light sources. The **Samsung Gear 360** is also a decent stills camera, with higher-resolution output (30 megapixels), but images must be stitched using a Samsung S7 or a Windows computer, and the camera is extremely prone to flare.



Ricoh Theta S: the gold standard for consumer 360 stills

If you need very high resolution 360 stills, the [Panono](#) (\$2450 street) generates by far the highest-quality output for an integrated, single-moment 360 camera (as opposed to panoramic capture rigs, which can't freeze action). It takes still images at 16K (108 megapixels), and uses Panono's free cloud service for stitching.



The Panono: a 108-megapixel 360 stills camera

The [LG 360 CAM](#) (\$110 street) is the **best intro camera** because it is inexpensive and pretty good. It works very much like the Ricoh Theta S, but is a fraction of the cost. Its 16-megapixel stills are decent, and it shoots better video than the Ricoh. It is also the **first consumer camera to shoot and encode spatial audio**.

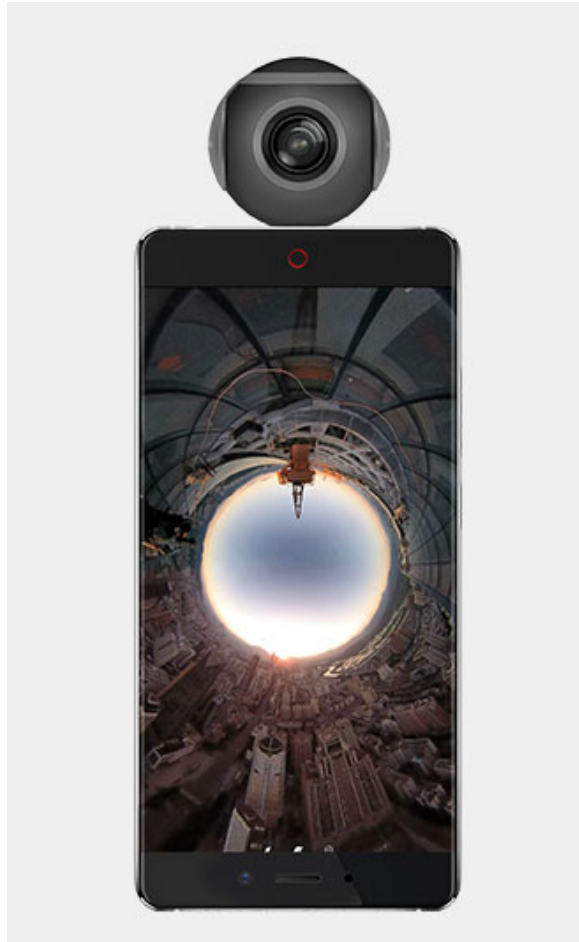


LG 360 Cam: inexpensive, supports spatial audio

If you want **fast sharing** and are ok with having your hand in every picture, and if you don't care about headset viability of video, get a camera that **attaches directly to a smartphone** via the Lightning or USB port. The [Insta360 Nano](#) (\$199 street) is an iPhone accessory camera that **connects directly to the phone's Lightning port**. The Insta360 can also be used as a standalone 360 camera, although it's conspicuously missing a tripod socket. The upcoming [Giroptic iO](#) (\$249 street; Mar/Apr availability) has better Ux and stitches in-camera, but isn't really available yet. Insta360 will soon ship an Android-compatible product called the [Insta360 Air](#) (\$150 street; micro-USB and USB-C versions; Mar availability). **No direct-attach camera is good (yet) for stills.**



The Insta360 Nano attaches directly to iPhones and can also be used standalone



The Insta360 Air attaches directly to Android devices and to computers via USB



The Giroptic iO connects to iPhones and features best-in-class Ux

Note about cameras that connect directly to phones: Almost every photographer who shoots 360 and actually tries to create content ends up putting the camera on a stick or tripod or light stand. It is possible to do this with phone-connected cams, but it's not as easy and is potentially risky for phones (typical phone holders aren't designed to be used on moving sticks).

For regular content creation with minimal post-production

There isn't much at the moment in the way of all-in-one cameras that are shipping and well supported. Unless you go with a production team (who will obviously support all the gear they bring), I think the current realistic options are the following:

Samsung Gear 360: 4K consumer camera. Sample use: [The New York Times](#), for their daily 360 videos (Samsung-supported, per disclosures in the content). Perfect for FB feed presentation, and meets the minimum bar for headset viewing (but not in low light situations).

Nikon KeyMission 360: 4K consumer camera with in-camera stitching. Sample use: [Associated Press journalists](#). Videos are stitched in-camera, allowing for sharing and editing immediately. However, the camera's smartphone connectivity problems could impact real-world usability in the field.

For media partners who can do some post production

ImagineVision [Z CAM S1](#) (\$2,500 street). 6K/30 and 4K/60 video output. Works very well with off-the-shelf stitchers like [AutoPano Video Pro](#), and will also eventually have their own stitcher based on Facebook's Surround 360 stitcher. They are currently shipping to crowdfunding backers slowly and are ramping up for higher-volume production. Represents a great value for mid-range camera rigs, but service and support quality is unknown (company is China-based with no USA representation).



ImagineVision Z Cam S1

[GoPro Omni](#) (\$5,000 street). The Omni is as integrated a solution as can be represented by a rig comprised of multiple cameras. It can generate 8K video output as well as 66-megapixel still images, but **stitching requires real knowledge** of 360 post-production workflow. The extra 2 cameras over typical 4-camera systems introduces an additional 8 seams that need to be handled in stitching. Also, managing 6 separate GoPro cameras is painful even though there is a single power source and built-in synchronization (e.g., you need a tool to get into the camera frame).



GoPro Omni: a 6-GoPro synchronized solution

Working with a production company

If you work directly with a specialized production companies, you don't have to worry about the hardware being used to power productions and/or livestreamed events. Cameras that are used tend to be higher end (but are not always). From discussions with production companies, I hear of the following cameras often being used:

- [Nokia OZO](#) (\$45,000)
 - The most popular camera used for Live 360 events, mostly because it is production friendly (image quality is OK, but is not considered to be good). Output is partial 3D, but most production companies only use a subset of the OZO's cameras, outputting 2D (and mostly for live events). The OZO is used not for its output quality, but rather because it is production-friendly. Extensive post-production workflow required.
- [Jaunt](#) (rental). Extensive post-production workflow required.
- **Samsung Gear 360** (\$278 street) for pickup / highly dynamic shots
- Custom rigs (\$highly variable). External stitching required, with extensive post-production workflow required. Typical examples:
 - multi Go-Pro w/custom lenses
 - multi BlackMagic
 - multi Sony a7s II (low light)

- multi Z CAM E1 (small Micro Four Thirds)

For Live 360

Standalone cameras are fairly limited for Live 360 applications. Most of the big events are currently done using specialized production partners not because cameras do not exist, but because the livestream has to be reliable and successful. All high-stakes live production is done this way, and adding 360 to the equation doesn't make things simpler.

In the consumer camera category, the only cameras that can livestream without a computer or additional live-broadcast hardware are the **Insta360 Nano** and upcoming **Insta360 Air** and **Giroptic iO**. These cameras attach directly to iPhones and Android devices and can livestream in 360 to YouTube and custom RTMP destinations. Facebook Live 360 has been announced and is being showcased via specific events; there isn't yet any information about general availability.

In the high end, any number of custom solutions exist, mostly using computers to stitch and broadcast to RTMP addresses, managed by specialized production companies. Many high-end livestreams use the [Nokia OZO](#) (\$45,000) and hundreds of thousands of dollars of broadcast equipment.

The [VideoStitch Orah 4i](#) (\$3,595) has the potential to enable high-quality live 360 in a plug-n-play solution at up to 4K/30. The Orah 4i features a single cable from the camera that runs to a stitching box, which streams over Ethernet and broadcasts a Wi-Fi hotspot for web control. Intel's keynote at CES 2017 featured an [Orah 4i on a drone](#) broadcasting live to 250 journalists, who were watching using Oculus Rifts.



The Orah 4i is a plug-n-play 4K live 360 solution

Production-quality live 360 for important events is likely to stay in the domain of dedicated, specialized production companies. Reliability is not something that any standalone hardware can ever guarantee.

Spatial Audio

Spatial audio support is still essentially non-existent in the 360 camera space. The **LG 360 Cam** is the first consumer camera that supports spatial audio (encoding first-order ambisonics, a basic format supported by both Facebook and YouTube). The [Zoom H2n Handy Recorder](#) (\$160 street) a standalone audio recorder, records spatial audio (first-order ambisonics). Its output can be multiplexed into videos in post using **FB360 Encoder** (part of [Facebook's 360 Spatial Workstation](#)). Note that first-order ambisonics can only be rotated using specialized tools like **Facebook's 360 Spatial Workstation**, so if you use the **LG 360 Cam** or **Zoom H2n**, you should try to orient the recorder as you'd like it to be reproduced in the final 360 video. Spatial audio is still difficult for normal consumers to incorporate into content. All big productions produce spatial audio in post, and a proper discussion about spatial audio is beyond the scope of this document.

Note that some 360 cameras feature multiple microphones, which is not the same as supporting spatial audio. Spatial audio is complicated in both capture and encoding,

and using multiple microphones is not sufficient. Many of these companies are looking to enable spatial audio at some point in the future, which might or might not be possible depending on camera design.

The future

The 360 camera landscape is changing *extremely* quickly. If you're reading this document months after the publish date, please consider it to be outdated.