IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

GENTEX CORPORATION and INDIGO TECHNOLOGIES, LLC, Plaintiffs, THALES VISIONIX, INC., Involuntary Plaintiff, v. FACEBOOK, INC. and FACEBOOK TECHNOLOGIES, LLC, Defendants.	Case No.: 6:21-cv-00755-ADA **JURY TRIAL DEMANDED**

PLAINTIFFS' AMENDED DISCLOSURE OF PRELIMINARY INFRINGEMENT CONTENTIONS

Pursuant to the Court's Order Governing Proceedings, Plaintiffs Gentex Corporation and Indigo Technologies, LLC (collectively, "Gentex") hereby serve their amended disclosure of preliminary infringement contentions.

These infringement contentions are preliminary. Discovery has not yet begun, and Gentex's investigation is ongoing. The parties have not discussed proposed constructions for, and the Court has not yet construed, any of the asserted claims. Gentex specifically reserves its right to supplement these disclosures—including by asserting additional claims, accusing different or additional functionality, and accusing additional and/or different products—based on information obtained as the case progresses. Gentex also reserves the right to amend its infringement contentions and asserted claims based on any proceedings before the U.S. Patent & Trademark Office regarding the asserted patents.

I. CHARTS SETTING FORTH WHERE IN THE ACCUSED PRODUCT(S) EACH ELEMENT OF THE ASSERTED CLAIMS IS FOUND.

As set forth in detail in Gentex's Complaint and the Exhibits attached thereto (Dkt. No. 1), Gentex alleges that Defendants Facebook, Inc. and Facebook Technologies, LLC (collectively, "Facebook") have infringed and continued to infringe, directly and indirectly, literally or under the doctrine of equivalents, one or more claims of U.S. Patent Nos. 6,757,068 (the"'068 patent"), 7,301,648 (the "'648 patent"), 8,224,024 (the "'024 patent"), 6,922,632 (the "'632 patent"), and 7,725,253 (the "'253 patent") (collectively, the "Asserted Patents") by making, using, selling, offering to sell, and/or importing their Oculus Rift S, Oculus Quest, and Oculus Quest 2 products (collectively, with their respective related instructions, systems, services, and software, the "Accused Products").

Gentex attached as Exhibits 1-5 to its October 22, 2021 Disclosure of Preliminary Infringement Contentions ("Preliminary Infringement Contentions") claim charts identifying the manner in which the Accused Products infringe each element of the asserted claims. These claim charts are based on a reasonable investigation of publicly available information currently available to Gentex. These preliminary infringement contentions are intended to serve a notice function, and do not constitute an exhaustive explanation of all theories Gentex may present in this case. Gentex reserves the right to amend, revise, alter, or otherwise modify these charts as this case progresses, including to incorporate new information obtained during the course of discovery (such as information that is not currently publicly available).

Exhibit 1 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-2, 4-5, 7-9, 11-20, 23-33, 35, 41, 45-48, 50, and 54-59 of the '068 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

Exhibit 2 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-5, 8-11, 16-18, 20-32, 35, 37-38, and 40-44 of the '648 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

Exhibit 3 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claim 1 of the '024 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claim is found, to the best of Gentex's current knowledge and information.

Exhibit 4 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-8, 11-26, 28-36, 44-45, 47-55, 57-61, and 66-69 of the '632 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

Exhibit 5 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-4 and 6-9 of the '253 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

The Court has not yet conducted claim construction proceedings. Depending on any constructions by the Court as to the Asserted Claims, and/or positions that Facebook or its expert witness(es) may take concerning claim interpretation, infringement, and/or validity issues, the charts in Exhibit 1–5 and the disclosures referenced therein may be of greater or lesser relevance, and different disclosures relating to the Accused Products may be implicated. Given this uncertainty, the charts may reflect alternative applications of the claims to the Accused Products. Nothing stated herein shall be construed as an admission or a waiver of any particular construction of any claim term.

II. THE PRIORITY DATE TO WHICH EACH ASSERTED CLAIM IS ENTITLED

Gentex contends that the Asserted Claims of the ’068 patent are entitled to a priority date no later than January 28, 2000, the date of the filing of Provisional Application No. 60/178,797, to which the ’068 patent claims priority.

Gentex contends that the Asserted Claims of the ’648 patent are entitled to a priority date no later than January 28, 2000, the date of the filing of Provisional Application No. 60/178,797, to which the ’648 patent claims priority.

Gentex contends that claim 1 of the ’024 patent is entitled to a priority date no later than July 14, 2005.

Gentex contends that the Asserted Claims of the ’632 patent are entitled to a priority date no later than June 13, 2001.

Gentex contends that the Asserted Claims of the ’253 patent are entitled to a priority date no later than June 13, 2001.

Gentex’s investigation is ongoing, and not all materials related to the conception and reduction to practice of the Asserted Claims are in its possession. Gentex reserves the right to amend its contentions regarding the priority dates of the Asserted Claims, including to identify and establish earlier dates, based on information learned as the case progresses.

III. DOCUMENTS EVIDENCING THE CONCEPTION AND REDUCTION TO PRACTICE FOR EACH CLAIMED INVENTION

Gentex produced a copy of the file histories for the Asserted Patents with its Preliminary Infringement Contentions. Gentex is concurrently producing certain documents evidencing conception and reduction to practice of the inventions claimed in the ’024, ’632, and ’253 patents with Bates numbers GNTX0001534–GNTX0001604. Gentex is working with and will continue to work with the relevant third parties to locate any additional documents evidencing conception and reduction to practice of the claimed inventions and to produce them promptly.

IV. A COPY OF THE FILE HISTORY FOR EACH PATENT IN SUIT

Gentex has produced a copy of the file histories for each of the Asserted Patents with Bates numbers GNTX0000031–GNTX0000904.

Dated: December 22, 2021

Respectfully submitted,

/s/ Adam D. Harber

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Exhibit 4

Gentex Corporation and Indigo Technologies, LLC (collectively, "Gentex") presently contend that Facebook, Inc. and Facebook Technologies, LLC (collectively, "Facebook") infringe claims 1-8, 11-26, 28-36, 44-45, 47-55, 57-61, and 66-69 (the "Asserted Claims") of U.S. Patent No. 6,922,632, directly and/or indirectly, either literally or under the doctrine of equivalents. This chart sets forth Gentex's preliminary infringement contentions relating to the Asserted Claims and the accused products, i.e., the Oculus Rift S, Oculus Quest, and Oculus Quest 2 (collectively, the "Accused Products"). In the event Facebook releases new products or services that infringe the '632 patent, or further investigation reveals that other products or services infringe the '632 patent, Gentex reserves the right to update these contentions as appropriate under the Order Governing Proceedings.

These contentions articulate the structure and acts that constitute direct and/or indirect infringement of the '632 patent and identify specifically where each element of each asserted claim is found within each Accused Product. Exemplary references to publicly available information concerning the Accused Products is provided where appropriate. Exemplary references to specific Accused Products are not intended and should not be read to exclude Accused Products not exemplified. On information and belief, the Accused Products are materially the same with respect to the claims of the '632 patent discussed below, except the contentions below regarding hand tracking, which is performed by the Oculus Quest and Oculus Quest 2, but based on present information, is not performed by the Oculus Rift S. This disclosure is not intended to describe all acts of direct, induced, or contributory infringement Facebook has and continues to commit by making, using, selling, providing, developing, installing, testing, deploying, and/or directing the use of the Accused Products by customers and end users. The parties have not engaged in any discovery. The parties also have not discussed proposed constructions for, and the Court has not yet construed, any of the claims of the '632 patent. As a result, and consistent with the Order Governing Proceedings, Gentex reserves the right to modify, amend, or otherwise supplement these initial infringement contentions as discovery and the pre-trial phase of the litigation proceed and as additional information comes to light, including with respect to which claims Gentex is asserting, the infringement analysis for one or more of the claims, and whether and how limitations of one or more claims are met literally or under the doctrine of equivalents.

U.S. Patent 6,922,632	
Claim Limitation	**Accused Products**
Claim 1	
(1pre) A method for tracking an object comprising:	Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method, as set forth below. For example, Facebook uses, and encourages users to use, a method for tracking an object (e.g., the user's hand(s) and/or Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

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See, e.g., *Compare Headsets*, https://www.oculus.com/compare/?products=quest%2Cquest-2 (hereinafter "*Compare Headsets*").

Oculus Quest
All-In-One VR Gaming

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

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Oculus Quest 2

Advanced All-In-One VR Gaming

Starting At **$299 USD***

BUY NOW

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

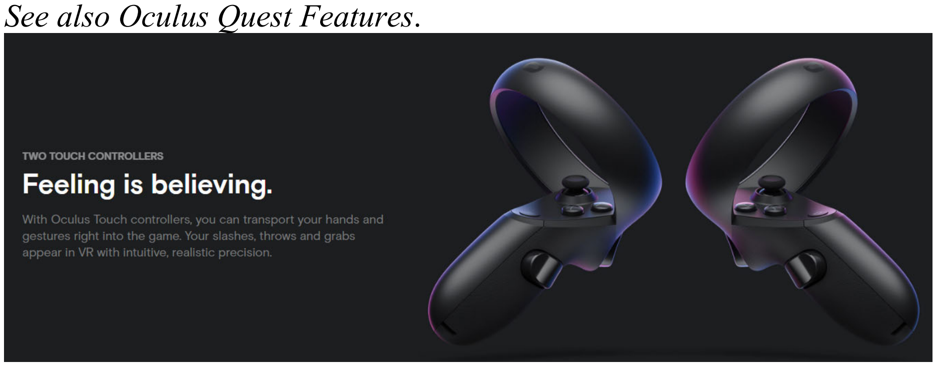
Oculus Rift S
PC-Powered VR Gaming

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

See also Oculus Quest Features.



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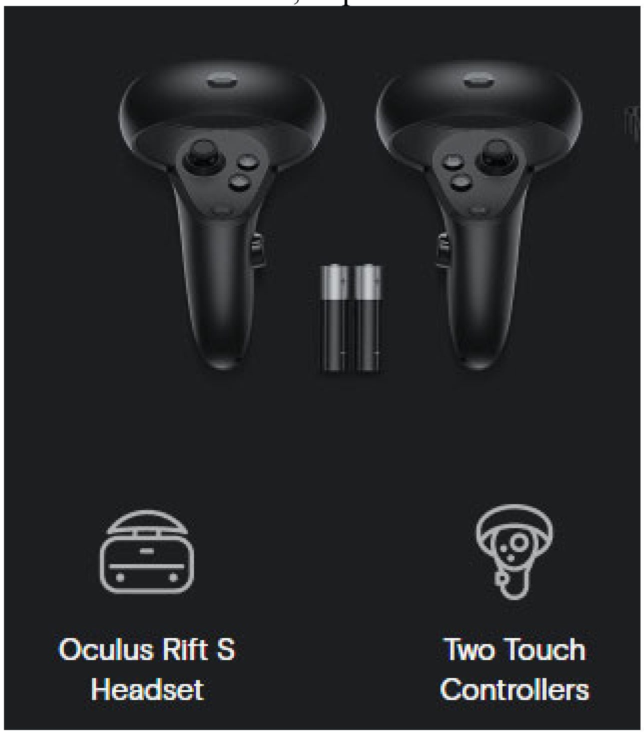
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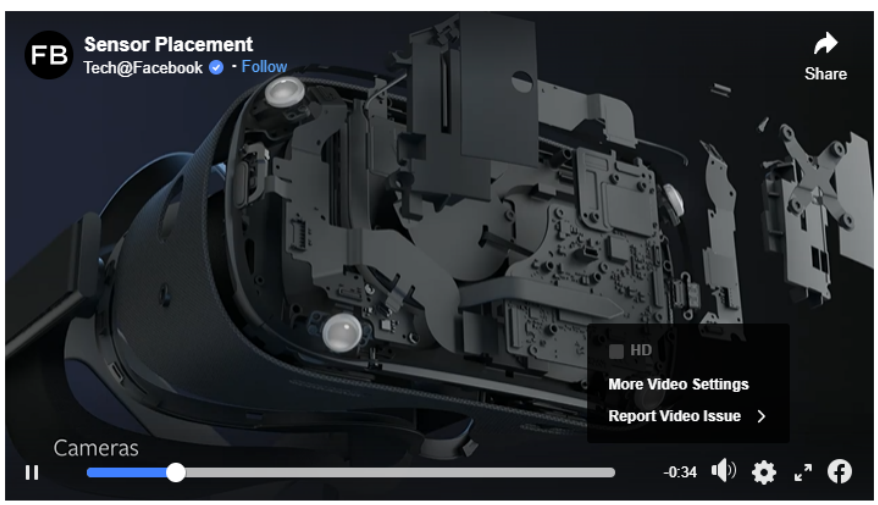
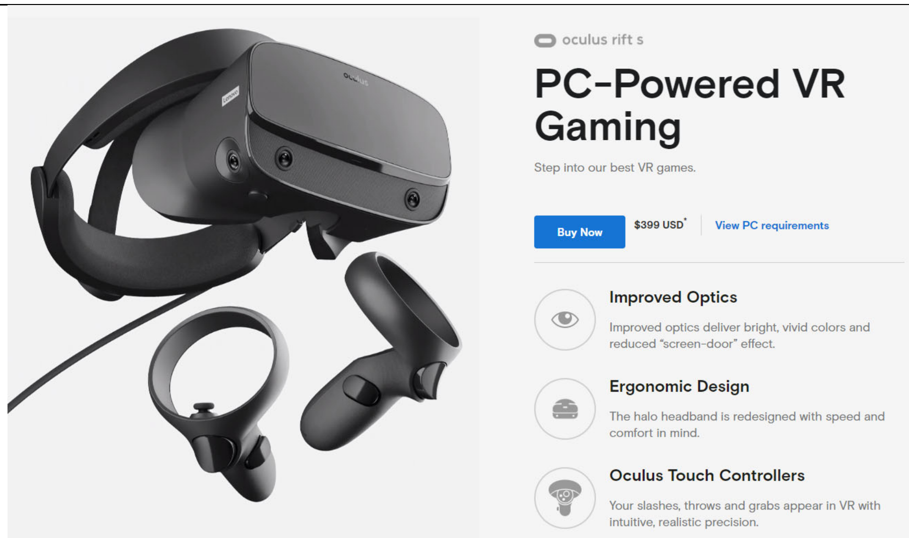
<tr><td>(1a) coupling a sensor subsystem to an estimation subsystem, said sensor subsystem enabling measurement related to relative locations or orientations of sensing elements;</td><td>Facebook encourages, directs, or promotes users to couple a sensor subsystem to an estimation subsystem, wherein the sensor subsystem enables measurement related to relative locations or orientations of sensing elements, and Facebook performs such step itself. For example, the Accused Products include a sensor subsystem (e.g., the cameras and/or inertial measurement units (“IMUs”), such as accelerometers and gyroscopes, within the headset, and/or the IMUs within the Oculus controller(s)) that is coupled to an estimation subsystem (e.g., the Oculus Insight tracking system). The sensor subsystem enables measurement related to the relative locations or orientations of sensing elements (e.g., the positions and orientations of the user’s hand(s) and/or the Oculus controller(s) relative to the headset). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest Features, https://web.archive.org/web/20200901154027if_/https://www.oculus.com/quest/features/ (hereinafter “Oculus Quest Features”).</td></tr>
</table>

See also Tech@facebook, *From the Lab to the living room: The story behind Facebook's Oculus Insight technology and a new era of consumer VR* (Aug. 22, 2019), https://tech.fb.com/the-story-behind-oculus-insight-technology/, Sensor Placement at 0:15 (hereinafter "*From the Lab*").



See also Oculus Rift S.



See also Oculus Blog, *Powered by AI* (Aug. 22, 2019), https://ai.facebook.com/blog/powered-by-ai-oculus-insight/ (hereinafter "*Powered by AI*").

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also Oculus for Developers, Oculus Device Specifications, https://developer.oculus.com/learn/oculus-device-specs/ (hereinafter "*Oculus for Developers*").

	Oculus Quest 2
	• Panel Type: Single Fast-Switch LCD, 1832×1920px per eye
	• Supported Refresh Rate: 72Hz (default), can be configured to 60Hz in some cases
	• Default SDK Color Space: Rec.2020 gamut, 2.2 gamma, D65 white point
	  • CIE 1931 xy color-primary values:
	    • Red : (0.708, 0.292)
	    • Green: (0.17, 0.797)
	    • Blue : (0.131, 0.046)
	    • White: (0.3127, 0.3290)
	• USB Connector: 1x USB-C
	• Tracking: Inside out, 6DOF
	
	See also id.
	
	3DOF vs 6DOF
	The Oculus Go headset comes with 1 3 Degree-of-Freedom (DOF) controller to track controller orientations. However, the Oculus Go headset will not track controller positions in space. The Oculus Rift, Rift S, and Quest headsets are equipped with 2 6DOF controllers that support both orientation and positional tracking. The 6DOF capabilities allow you to integrate virtual hands to interact with VR environments.
	
	See also Ben Lang, *Quest Teardown Shows How Oculus Crammed Cooling & Cameras Inside* (July 17, 2019), https://www.roadtovr.com/oculus-quest-teardown-disassembly/ (hereinafter "Lang").

Image courtesy BadVR, Jad Meouchy

Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

See also Powered by AI.

To unlock the full potential of virtual reality (VR) and augmented reality (AR) experiences, the technology needs to work anywhere, adapting to the spaces where people live and how they move within those real-world environments. When we developed Oculus Quest, the first all-in-one, completely wire-free VR gaming system, we knew we needed positional tracking that was precise, accurate, and available in real time — within the confines of a standalone headset, meaning it had to be compact and energy efficient.

See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also Powered by AI.

At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

	"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski. Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset. Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up. "With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up. *See also* Oculus Quest 2, https://www.oculus.com/quest-2/.

See also Compare Headsets,
https://www.oculus.com/compare/?products=quest%2Cquest-2.

Oculus Quest
All-In-One VR Gaming

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See also David Heaney, Oculus Firmware Reveals New Touch Controllers, Referencing Improvements to Tracking, Finger Sensing, Haptics (Apr. 16, 2020), https://uploadvr.com/oculus-jedi-controller-driver-found/ (hereinafter “Heaney”).

More Precise Tracking

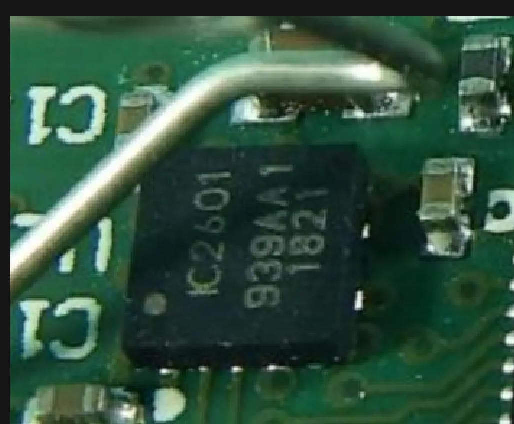
A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Heaney.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

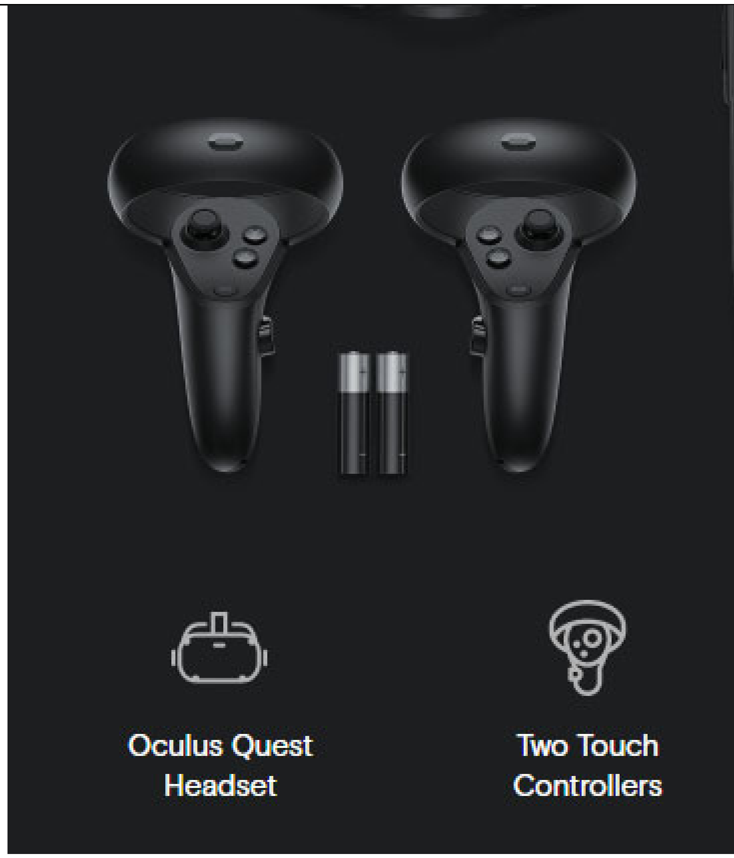
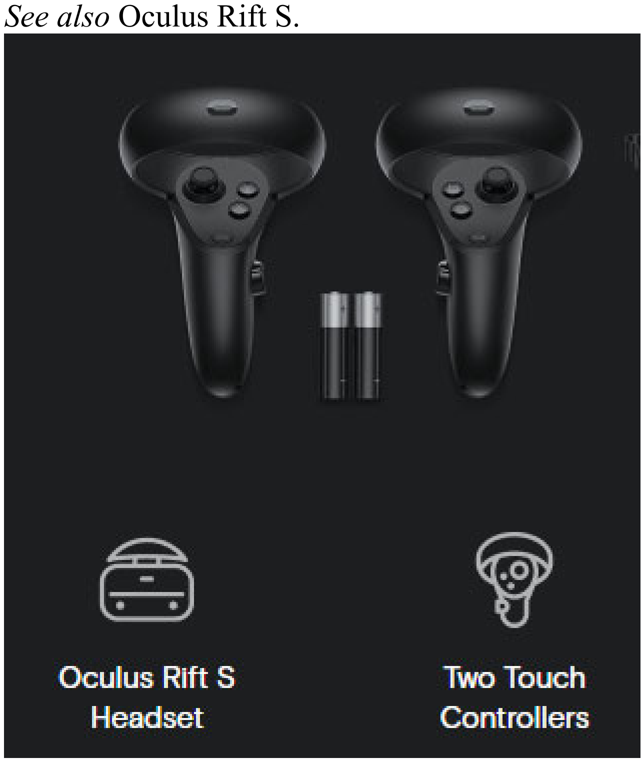
	FEATURES • 3-Axis Gyroscope with Programmable FSR of ±500dps, ±100dps, ±2000dps and ±4000dps • 3-Axis Accelerometer with Programmable FSR of ±4*g*, ±8*g*, ±16*g*, and ±32*g* • User-programmable interrupts • Wake-on-motion interrupt for low power operation of applications processor • 512 byte FIFO buffer enables the applications processor to read the data in bursts • On-Chip 16-bit ADCs and Programmable Filters • Host interface: 8 MHz SPI or 400k Hz Fast Mode I^2C • Digital-output temperature sensor • VDD operating range of 1.71 to 3.45V • MEMS structure hermetically sealed and bonded at wafer level • RoHS and Green compliant
(1b) accepting configuration data from the sensor subsystem;	Facebook encourages, directs, or promotes users to use the Accused Products to accept configuration data from the sensor subsystem, and Facebook performs such step itself. For example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and the headset in the Accused Products is configured using the applicable configuration data of the sensors in use at a given time. As a further example, the Accused Products enumerate the sensing elements available in the sensor subsystem, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), and configuration data regarding these sensing elements, including the characteristics of these sensing elements, is accepted from the sensor subsystem. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

Designing for Hands

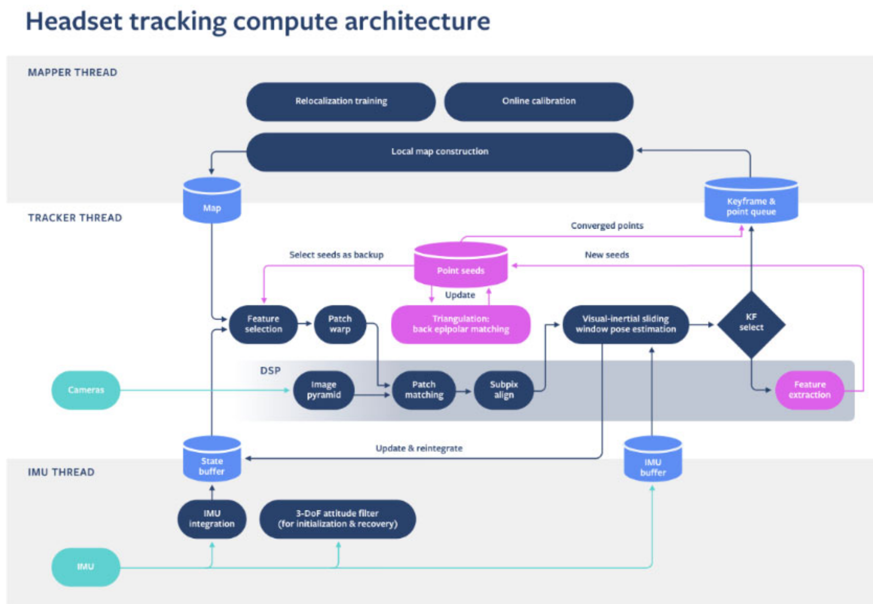
See also Hand Tracking Deep Dive.

See also id. at 4:00–10:00.

See also Oculus Quest.

	 *See also* Oculus Rift S.  *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology …** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also id.*



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.

See also From the Lab, Sensor Placement at 0:30.

See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Does the Quest have a single controller mode for any games?, Reddit, https://www.reddit.com/r/OculusQuest/comments/c1rwr1/does_the_quest_have_a_single_controller_mode_for/ (hereinafter "Reddit Single Controller Discussion").

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

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See also Expert Mode at 2:36.

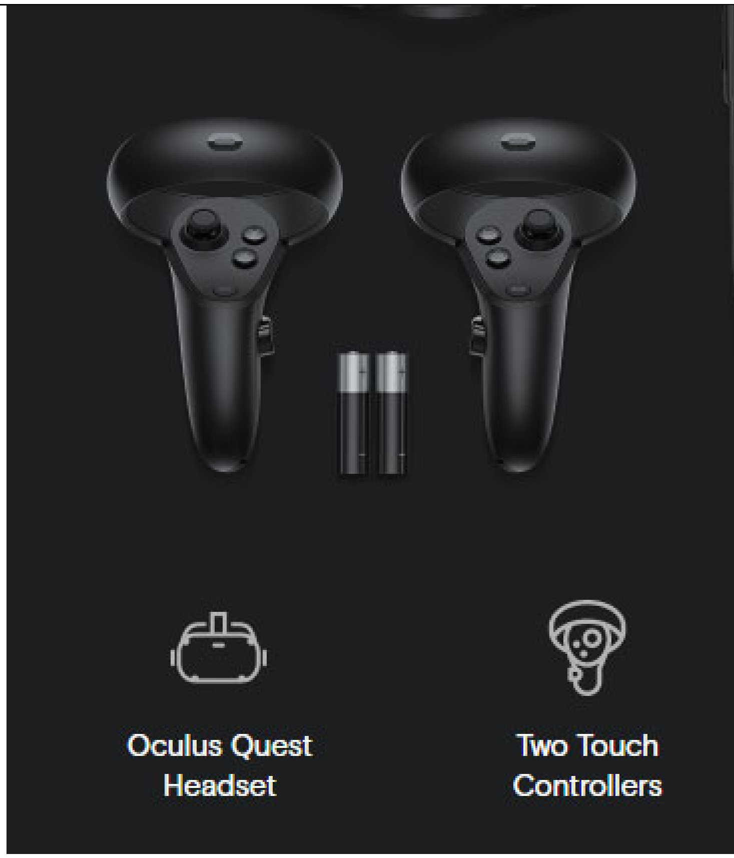
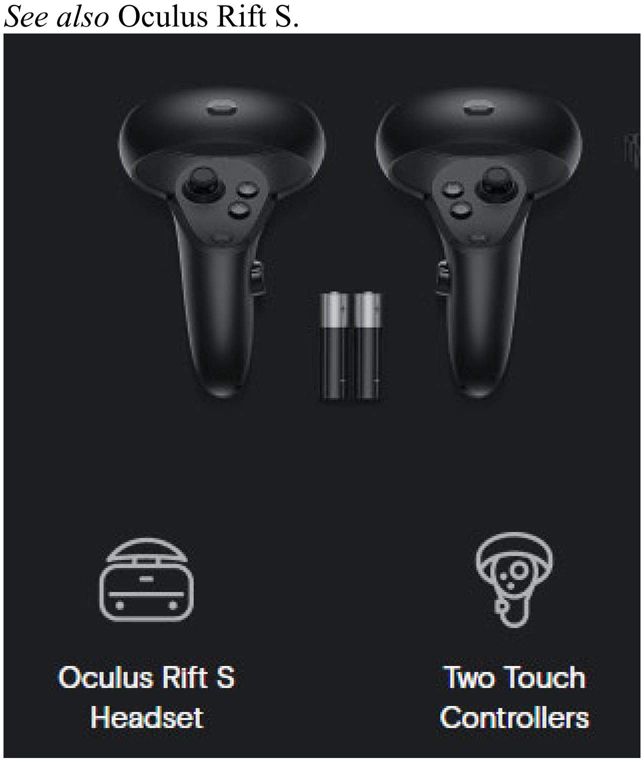
(1c) configuring the estimation system according to the accepted configuration data;	Facebook encourages, directs, or promotes users to use the Accused Products to configure the estimation system according to the accepted configuration data, and Facebook performs such step itself. For example, the Accused Products configure the estimation system (e.g., the Oculus Insight tracking system) based on the accepted configuration data (e.g., the configuration of the Oculus controller(s) and/or the available sensing elements). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

See also Oculus Quest.

	 *See also* Oculus Rift S.  *See also* Reddit Single Controller Discussion.

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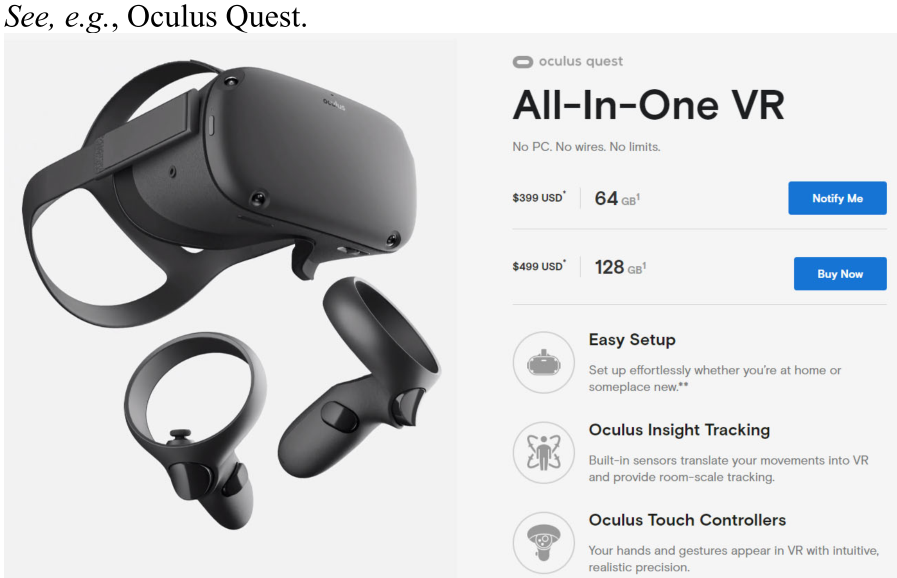
(1d) repeatedly updating a state estimate, including accepting measurement information from the sensor subsystem, and updating the state estimate according to the accepted configuration data and the accepted measurement data.	Facebook encourages, directs, or promotes users to use the Accused Products to repeatedly update a state estimate, including accepting measurement information from the sensor subsystem, and updating the state estimate according to the accepted configuration data and the accepted measurement data, and Facebook performs such step itself. For example, the Accused Products repeatedly update a state estimate (e.g., the position and orientation of the user's head, the user's hand(s), and/or the Oculus controller(s)), including accepting measurement information from the sensor subsystem (e.g., the headset in the Accused Products receiving data from the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers) and updating the state estimate (e.g., the position and orientation of the user's hand(s) and/or the Oculus controller(s)) according to the accepted configuration data (e.g., the configuration of the Oculus controller(s) and/or the available sensing elements) and the accepted measurement data (e.g., the sensor data received from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)). The Accused Products update the positional and orientation tracking parameters using the sensor data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.  *See also* Oculus Quest Features.

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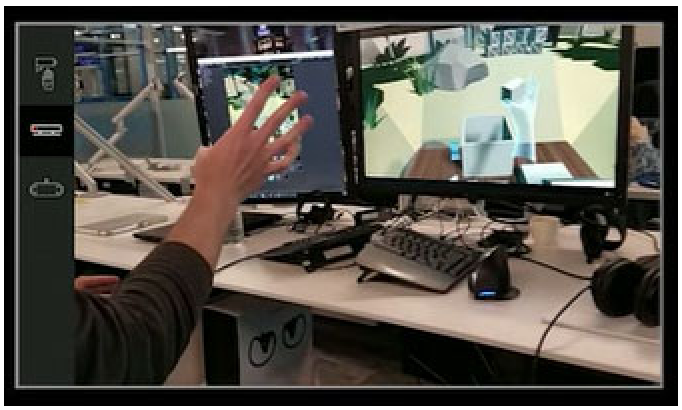
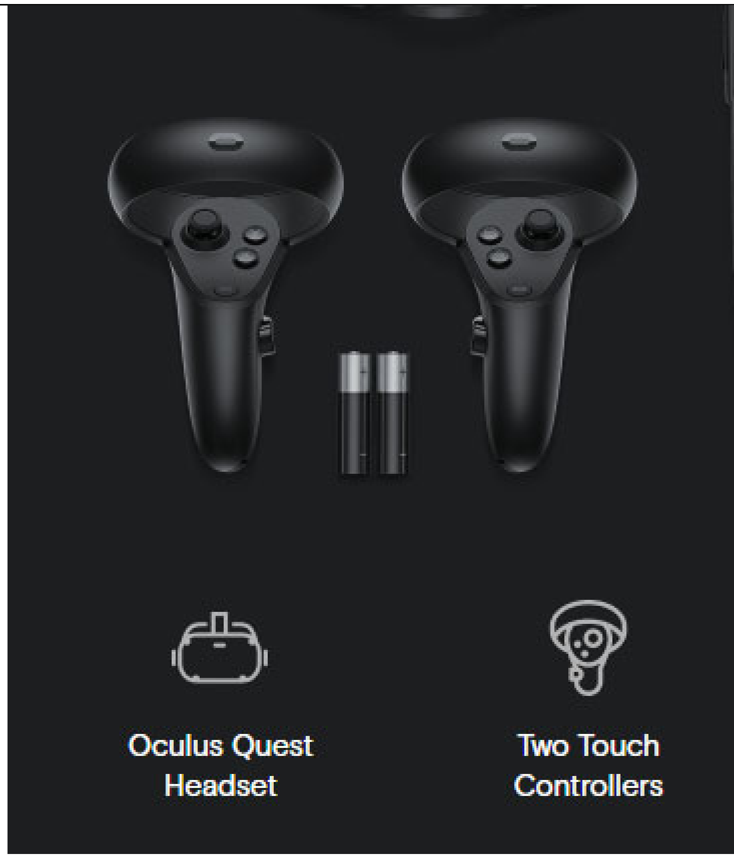
	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.



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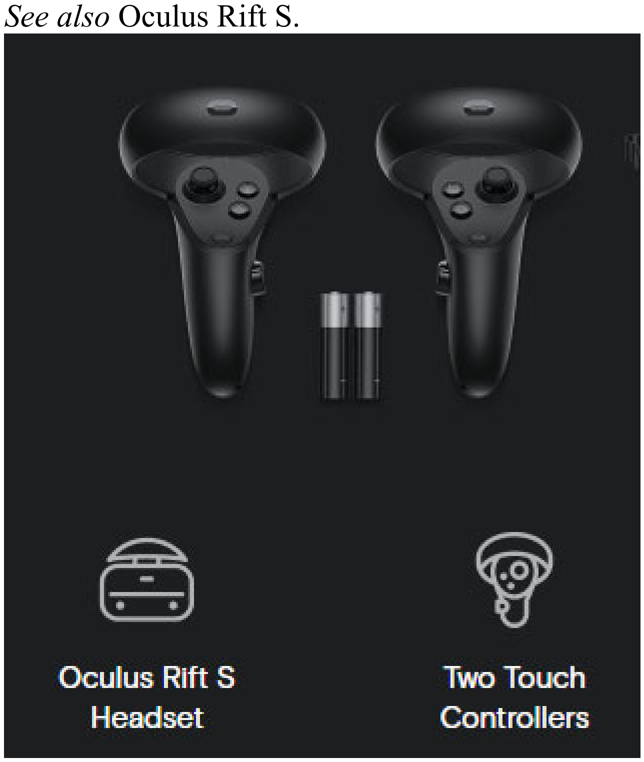

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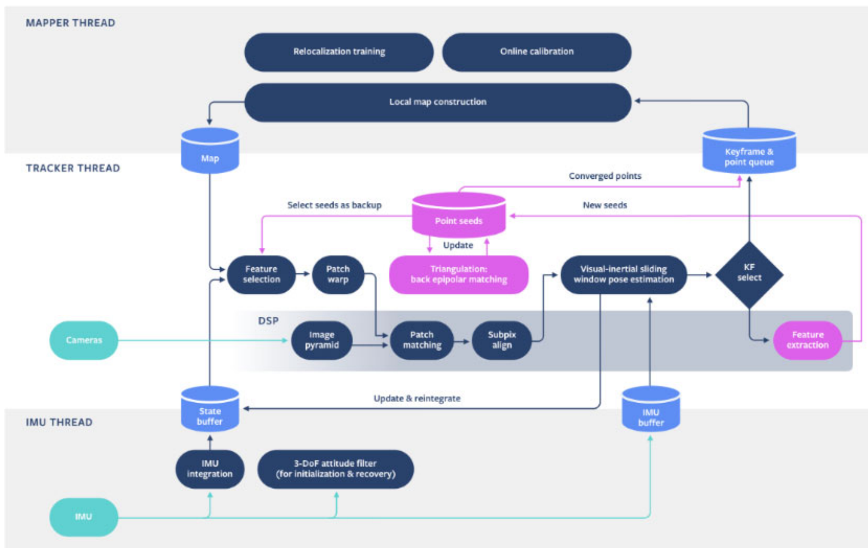
Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.

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See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

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See also id.

	The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer. Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.  The IMU in the current Touch controllers for Rift S and Quest *See also* ICM-20601 Specification.
Claim 2	
(2) The method of claim 1 wherein coupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements.	*See supra* claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which coupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements (e.g., software modules within the Oculus Insight tracking system operating on the Accused Products that receive data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

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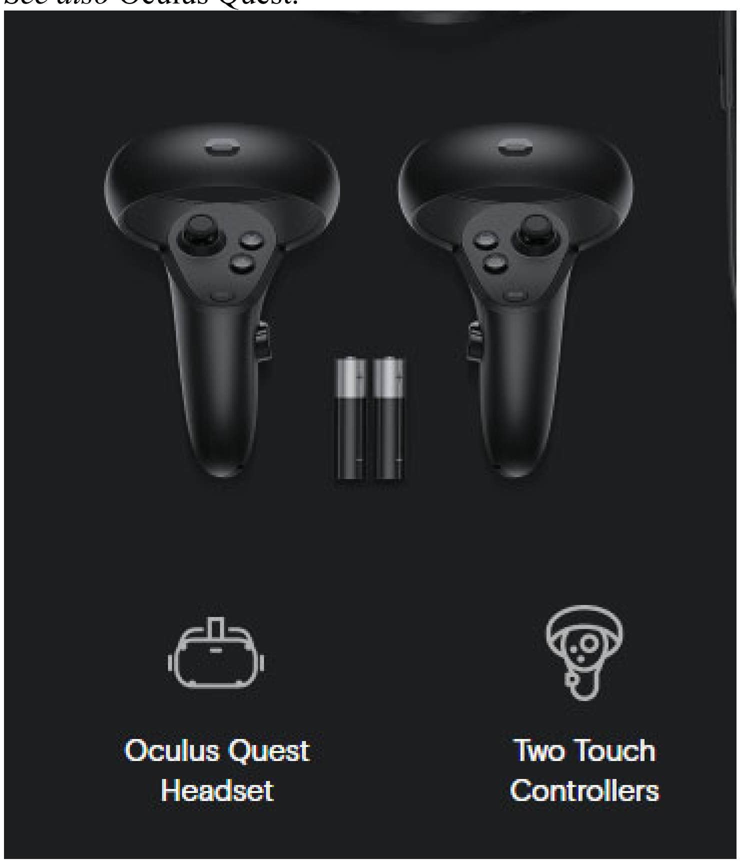

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	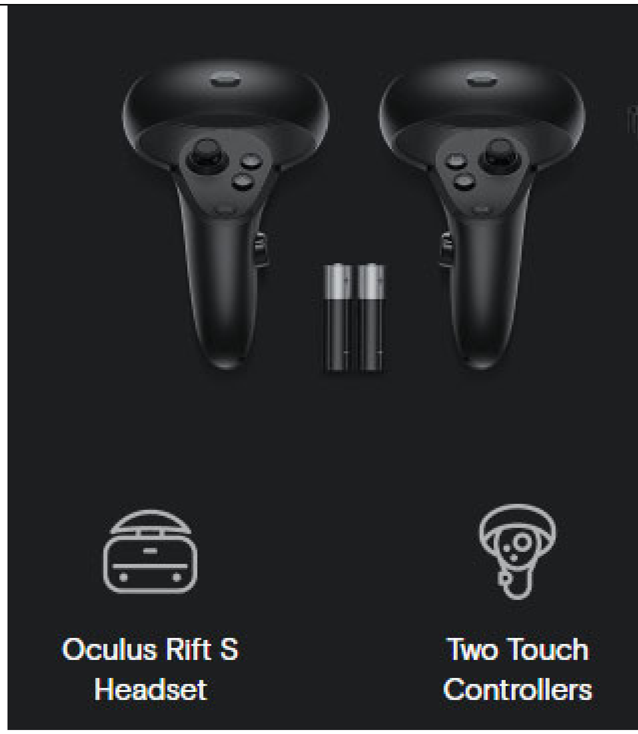 *See also* Reddit Single Controller Discussion.

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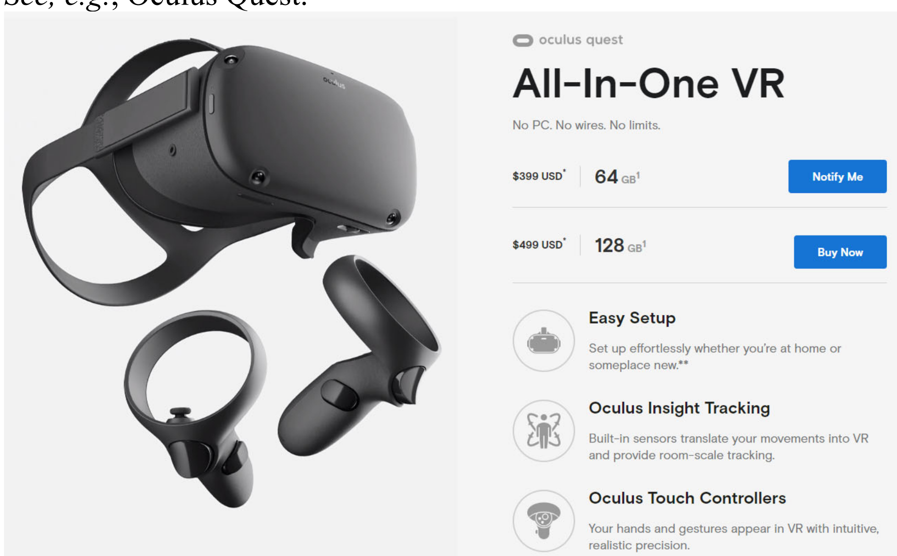
Claim 3	
(3) The method of claim 2 wherein each of the software modules provides a software interface for receiving information related to an expected sensor measurement and providing measurement information that depends on said received information.	*See supra* claims 1, 2. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 2 in which each of the software modules (e.g., software modules within the Oculus Insight tracking system operating on the Accused Products that receive data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)) provides a software interface for receiving information related to an expected sensor measurement (e.g., the predicted position of the user's hand(s) and/or the Oculus controller(s)) and providing measurement information that depends on said received information (e.g., estimating the position and orientation of the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.  *See also* Oculus Quest Features. 

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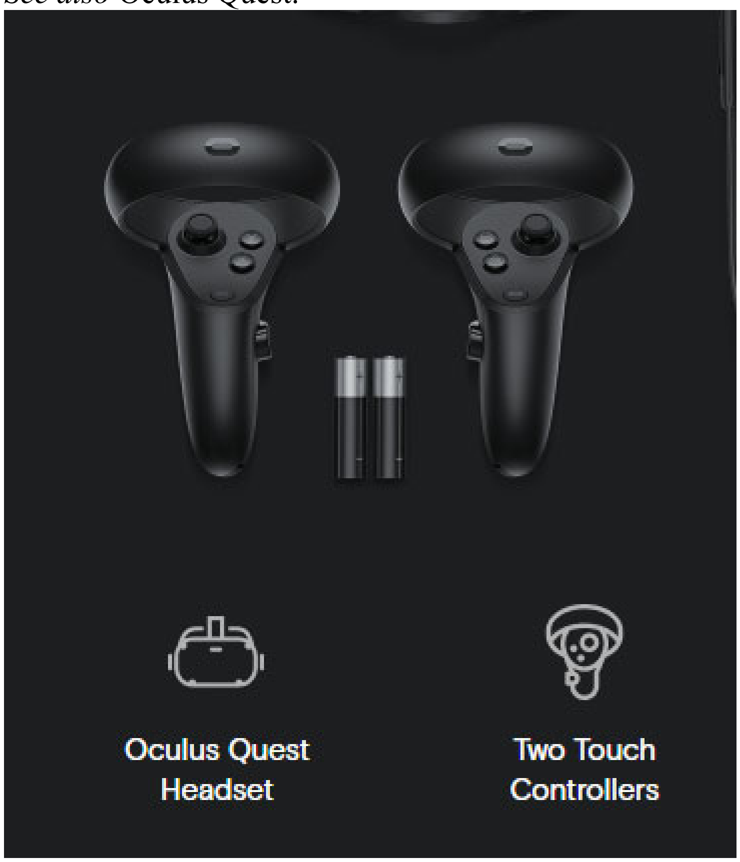
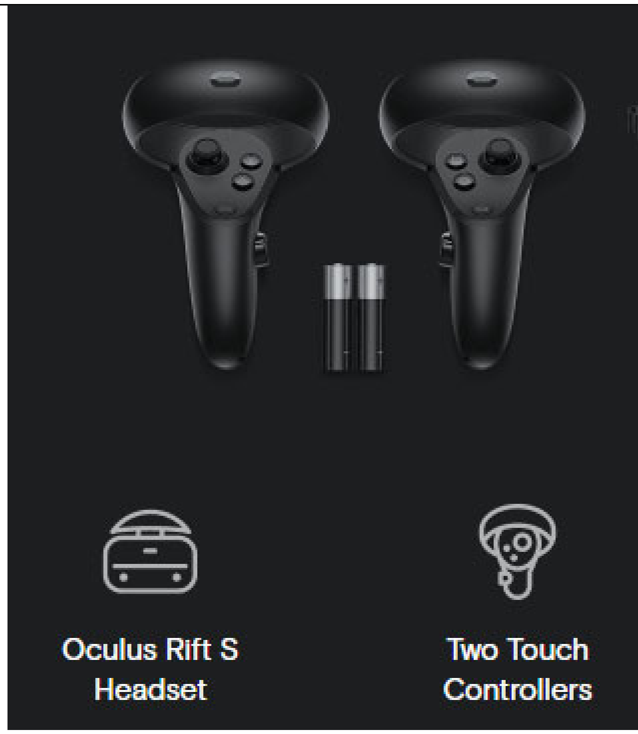
	 See also Oculus Quest.  *See also* Oculus Rift S.



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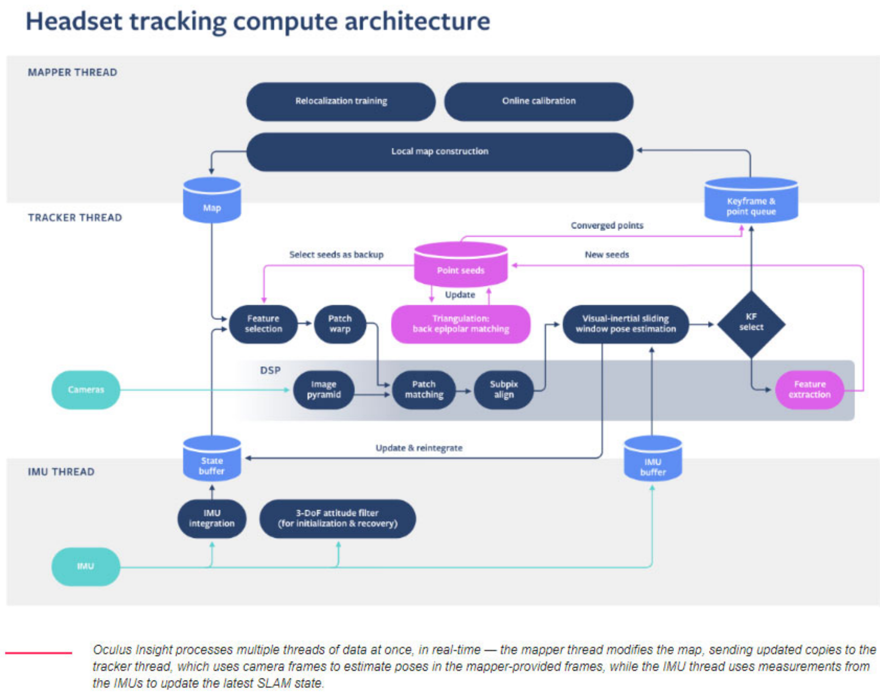

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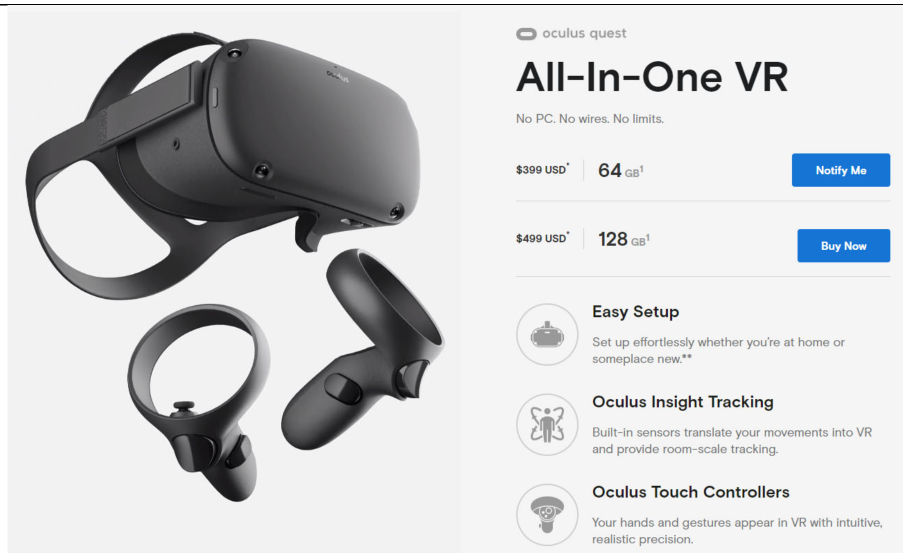
(4) The method of claim 3 wherein each of the software modules implements calculations that are independent of a representation of the state in the estimation subsystem.	*See supra* claims 1, 2, 3. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 3 in which each of the software modules (e.g., software modules within the Oculus Insight tracking system operating on the Accused Products that receive data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)) implements calculations that are independent of a representation of the state in the estimation subsystem (e.g., processing the data received from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), independent of the representation in the Oculus Insight tracking system of the position and orientation of the user's hand(s) and/or the Oculus controller(s)) and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.



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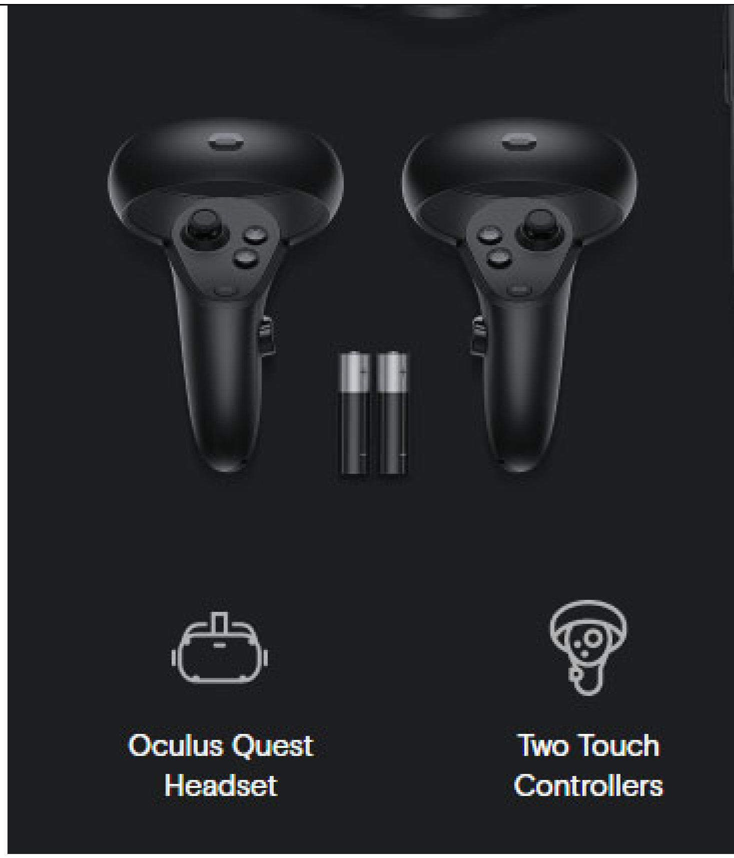

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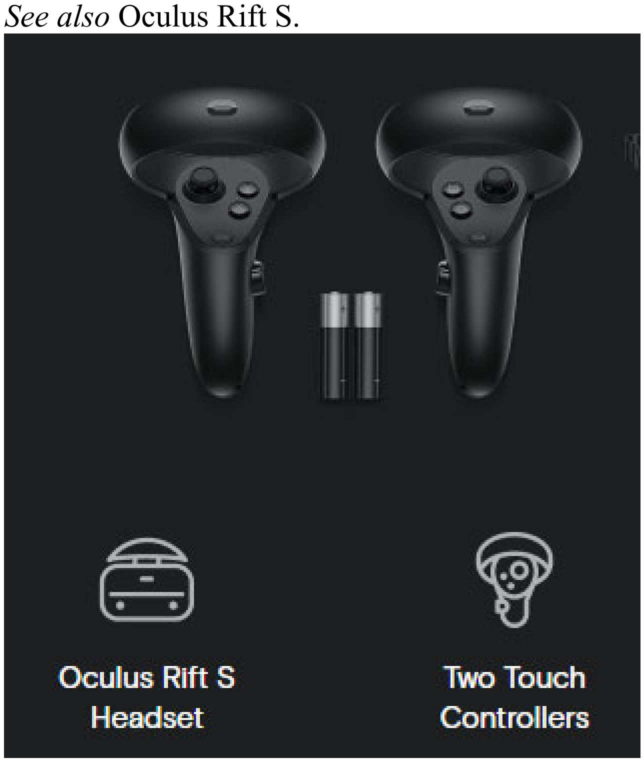

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	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

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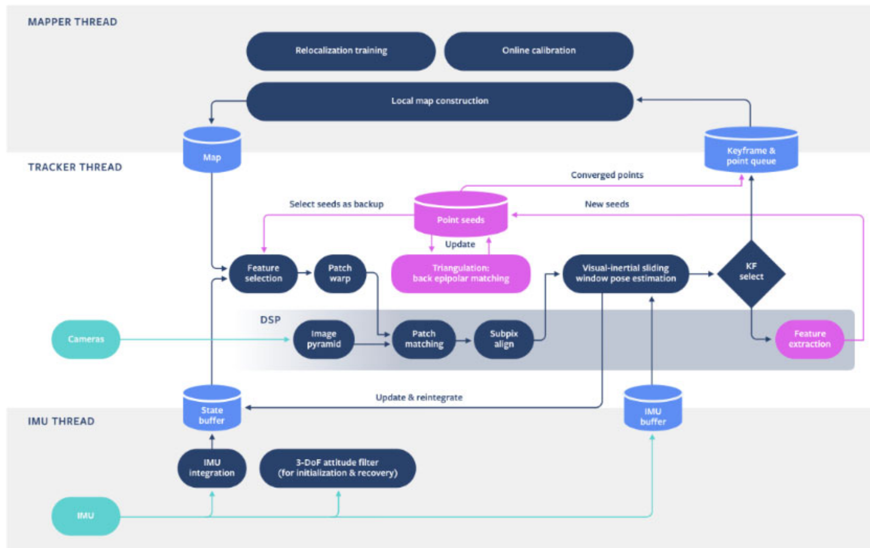
See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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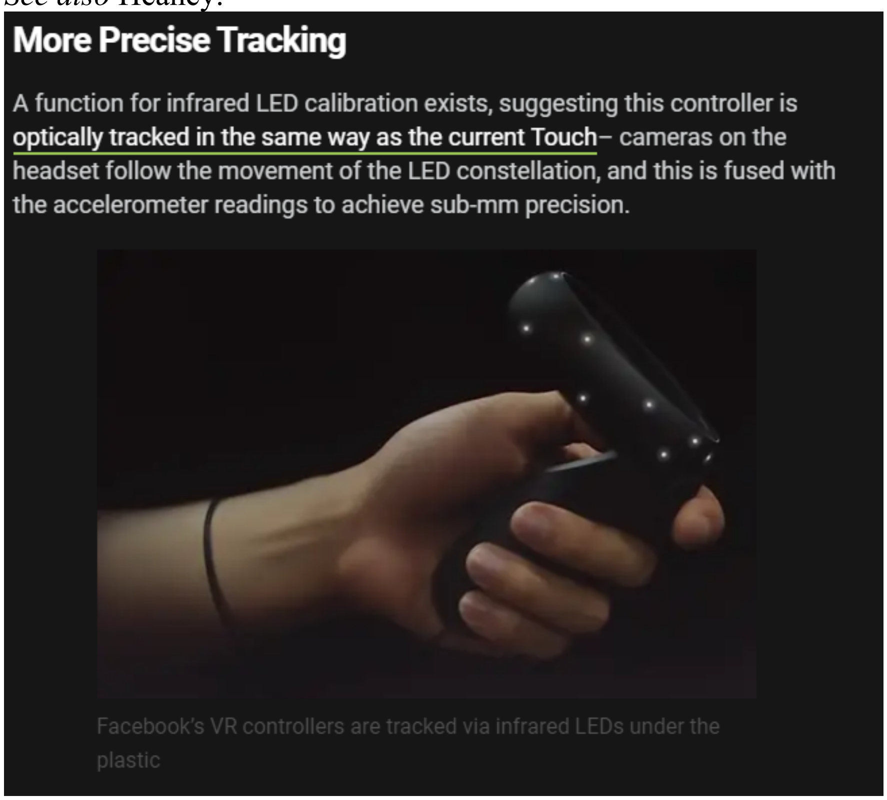

More Precise Tracking

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Facebook's VR controllers are tracked via infrared LEDs under the plastic

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<table>
<tr><td></td><td>The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.

The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.</td></tr>
<tr><td colspan="2">Claim 5</td></tr>
<tr><td>(5) The method of claim 1 wherein the state estimate characterizes an estimate of a location of the object.</td><td>See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the state estimate characterizes an estimate of a location of the object (e.g., the position of the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.</td></tr>
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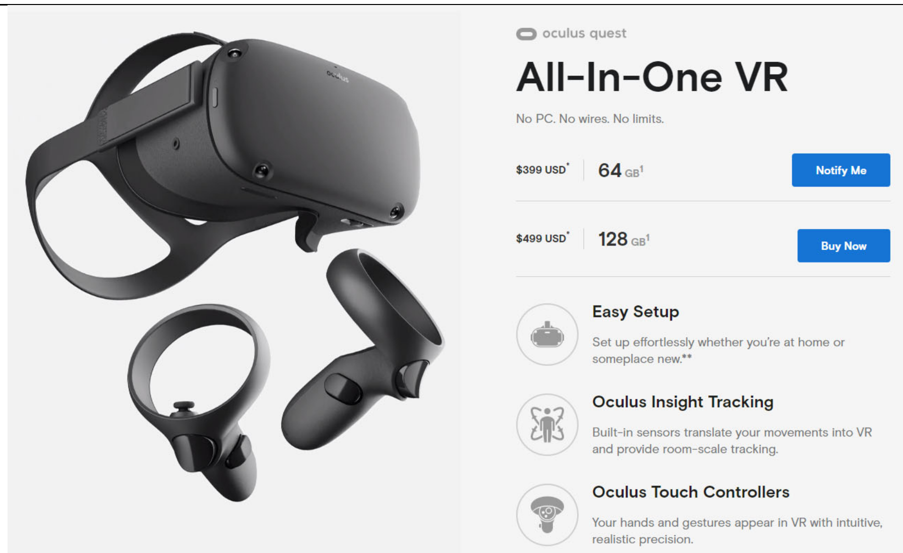

See also Oculus Quest Features.

See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

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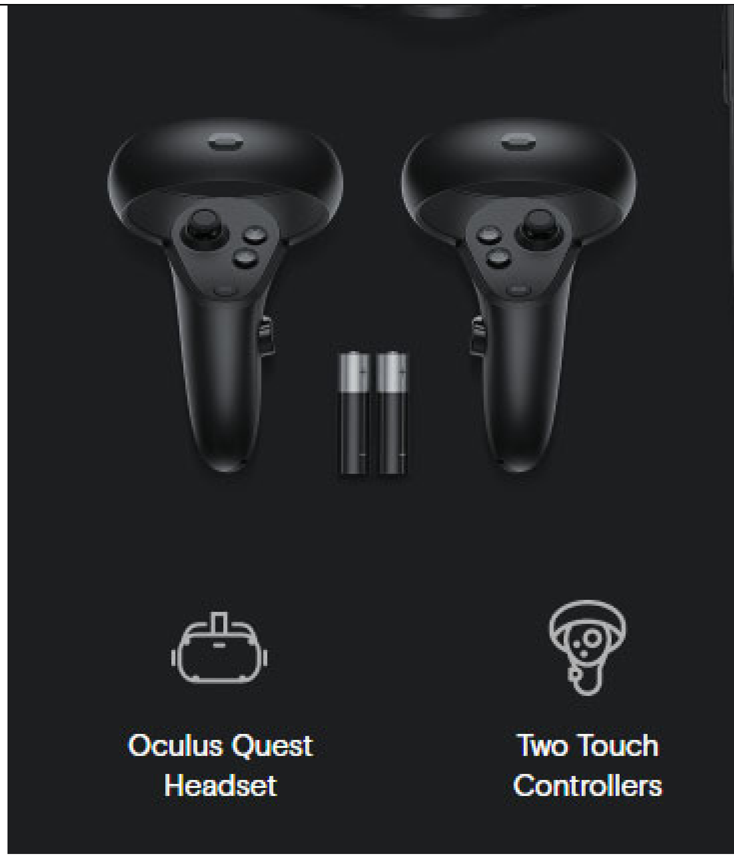
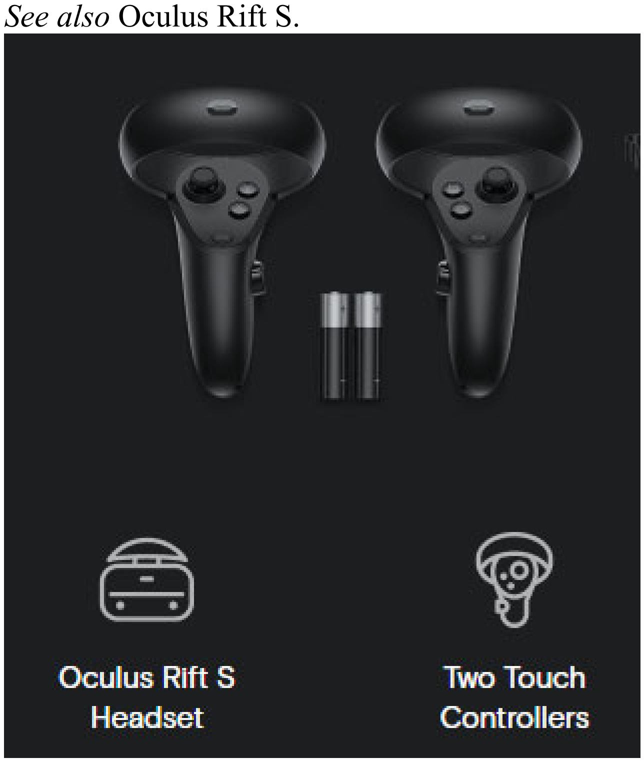
	 *See also* Oculus Rift S.  *See also From the Lab.*

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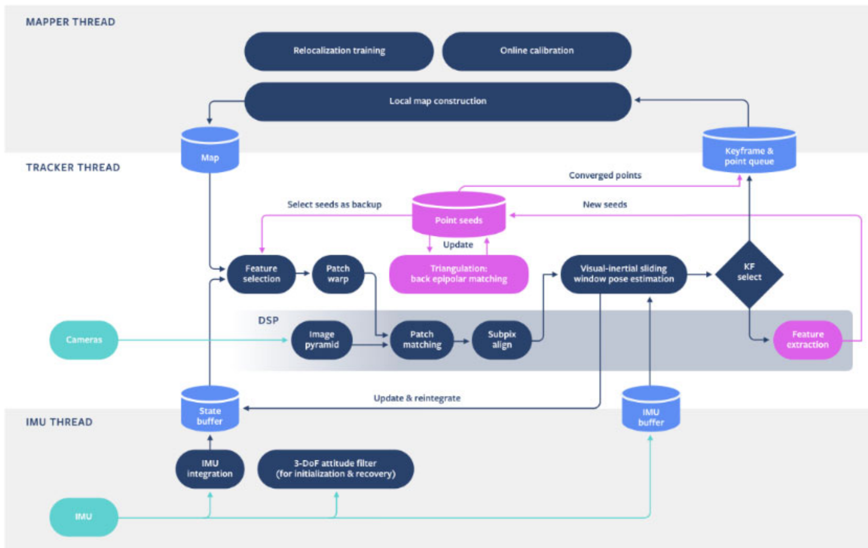
Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



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A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

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	The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer. Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.  The IMU in the current Touch controllers for Rift S and Quest *See also* ICM-20601 Specification.
Claim 6	
(6) The method of claim 1 wherein the state estimate characterizes configuration information for one or more sensing elements fixed to the object.	*See supra* claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the state estimate characterizes configuration information for one or more sensing elements fixed to the object (e.g., the configuration of the Oculus controller(s) and/or sensing elements), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

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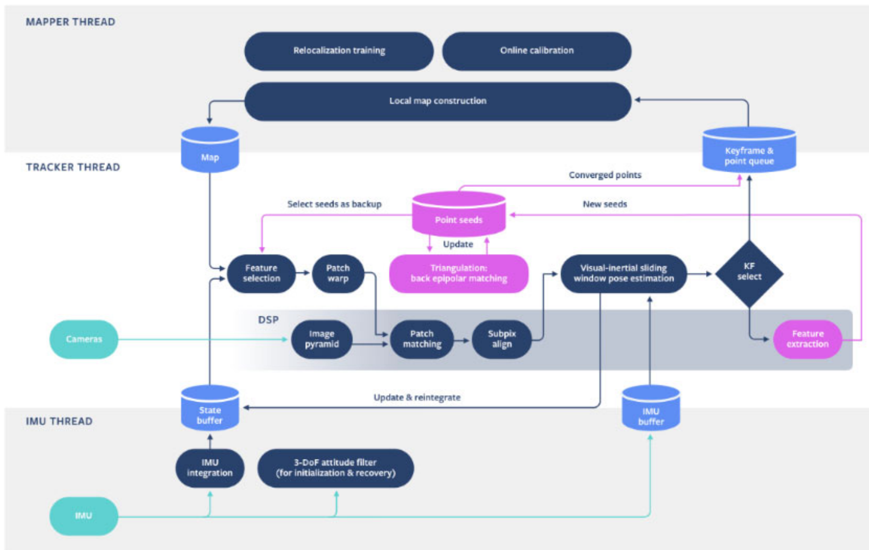

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Claim 7	
(7) The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes information related to position or orientation of said sensing elements relative to the object.	*See supra* claims 1, 6. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 6 in which the configuration information for the one or more sensing elements fixed to the object (e.g., the Oculus controller(s) and/or sensing elements) includes information related to position or orientation of said sensing elements relative to the object (e.g., the position and orientation of the IMUs and LEDs fixed to the Oculus controllers relative to the controller(s), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

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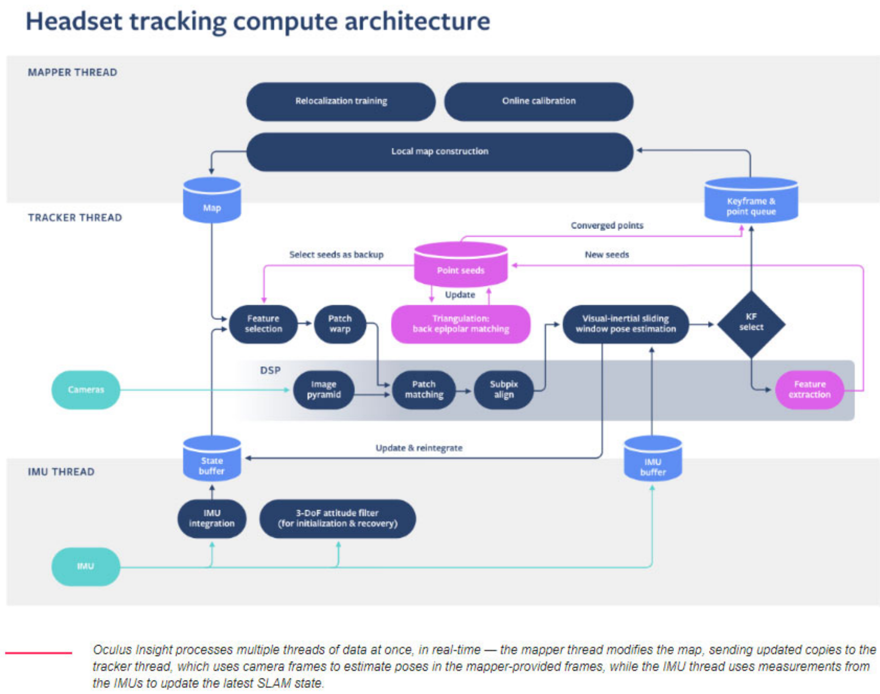

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Claim 8	
(8) The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes operational parameters for the one or more sensing elements.	*See supra* claims 1, 6. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 6 in which the configuration information for the one or more sensing elements fixed to the object (e.g., the configuration of the Oculus controller(s) and/or sensing elements) includes operational parameters for the one or more sensing elements (e.g., the number of Oculus controllers in use), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

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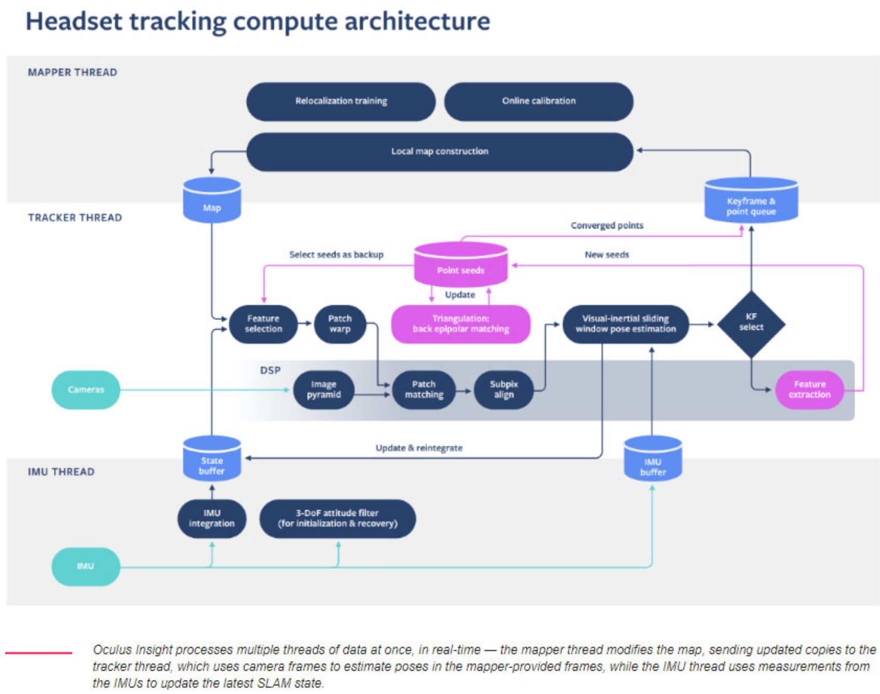

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See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

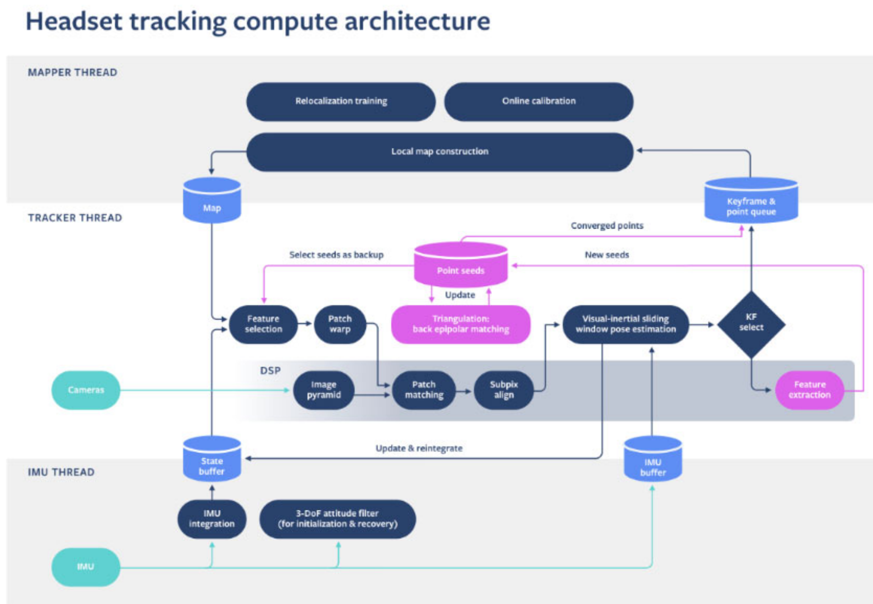
stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

Claim 11	
(11a) The method of claim 1 wherein repeatedly updating the state further includes: providing to the sensor subsystems information related to an expected sensor measurement; and	*See supra* claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which repeatedly updating the state further includes providing to the sensor subsystems information related to an expected sensor measurement (e.g., the predicted position of the user's hand(s) and/or the Oculus controllers), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See also* Hand Tracking Deep Dive at 4:00–10:00.  *See also id.* at 4:00–10:00.  *See also From the Lab*.

	Taking SLAM technology ... The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.* SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments. Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR. *See also id.*

<table>
<tr><td></td><td>

Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.</td></tr>
<tr><td>(11b) wherein accepting the measurement information from the sensor subsystem includes accepting information related to an actual sensor measurement.</td><td>See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which accepting the measurement information from the sensor subsystem includes accepting information related to an actual sensor measurement (e.g., the headset in the Accused Products receiving data from the cameras and IMUs in the headset and/or the IMUs in the Oculus controllers), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.</td></tr>
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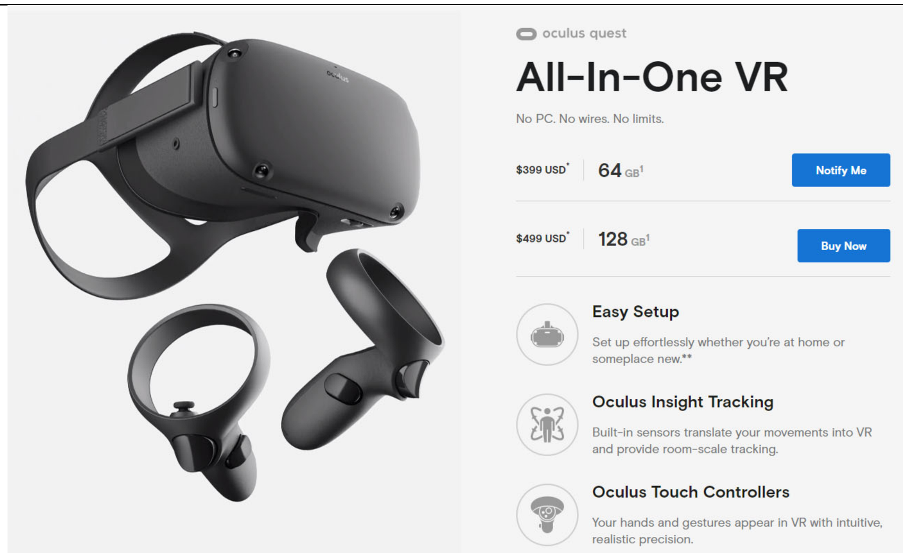

See also Oculus Quest Features.

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The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.

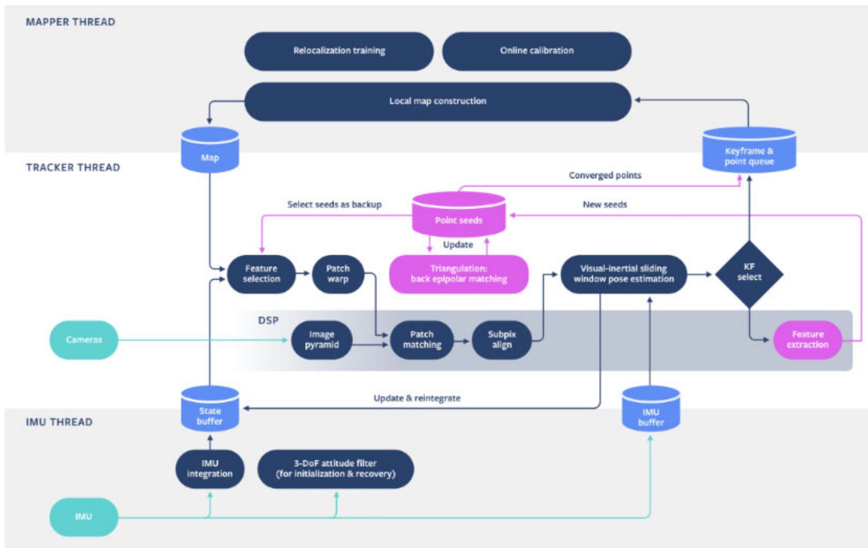
	Designing for Hands  *See also* Hand Tracking Deep Dive at 4:00–10:00.  *See also id.* at 4:00–10:00.  *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.

See also From the Lab, Sensor Placement at 0:30.

See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

	The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer. Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.  The IMU in the current Touch controllers for Rift S and Quest *See also* ICM-20601 Specification.
Claim 12	
(12) The method of claim 11 wherein providing the information related to an expected sensor measurement includes providing information related to a relative geometric configuration of two of the sensing elements.	*See supra* claims 1, 11. On information and belief and subject to discovery which has not yet occurred, Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which providing the information related to an expected sensor measurement includes providing information related to a relative geometric configuration of two of the sensing elements (e.g., the predicted positions of the user's hand(s) and/or the Oculus controller(s) relative to the headset), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial. *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology …** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

<table>
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SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

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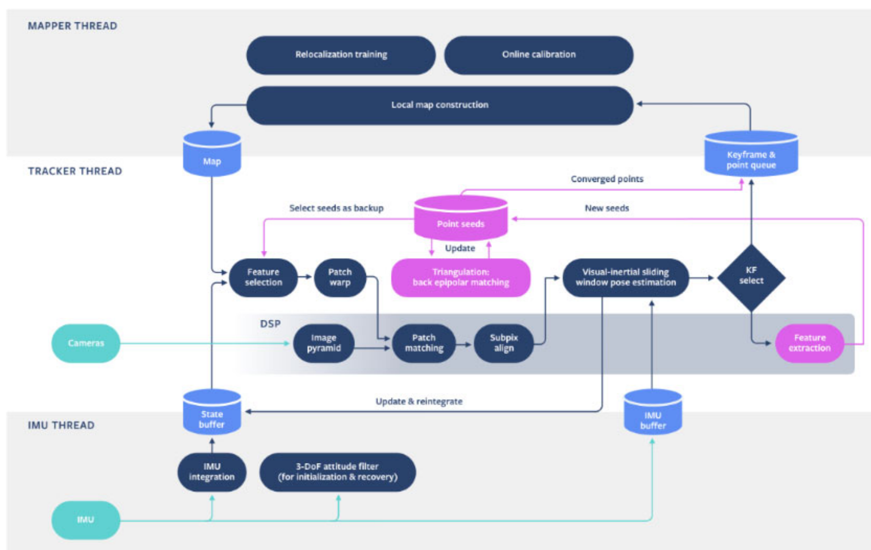
See also id.

Headset tracking compute architecture



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</td></tr>
<tr><td colspan="2">Claim 13</td></tr>
<tr><td>(13) The method of claim 12 wherein providing information related to a relative geometric configuration of the two of the sensing elements includes providing information characterizing a</td><td>See supra claims 1, 11, 12. On information and belief and subject to discovery which has not yet occurred, Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 12 in which providing information related to a relative geometric configuration of the two of the sensing elements includes providing information characterizing a relative location of said sensing elements (e.g., the predicted positions of the user's hand(s) and/or the Oculus controller(s) relative to the headset), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.</td></tr>
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There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

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See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also Powered by AI.

SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

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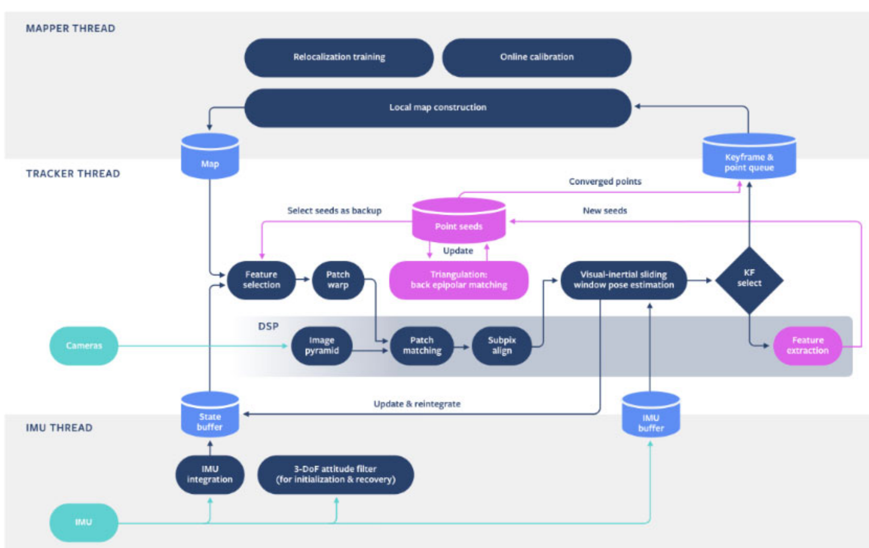
See also id.

Headset tracking compute architecture



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Claim 14	
(14) The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information enabling the estimation subsystem to calculate a difference between the actual measurement and the expected measurement.	*See supra* claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which accepting the information related to an actual sensor measurement includes accepting information enabling the estimation subsystem to calculate a difference between the actual measurement and the expected measurement, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), which enables the Oculus Insight tracking system to calculate a difference between the data received and the predicted movement of the user's hand(s) and/or the Oculus controller(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands. **Designing for Hands**  *See also* Hand Tracking Deep Dive at 4:00–10:00.

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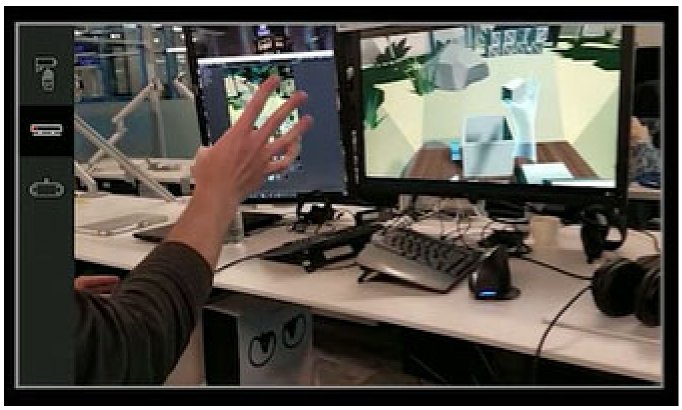

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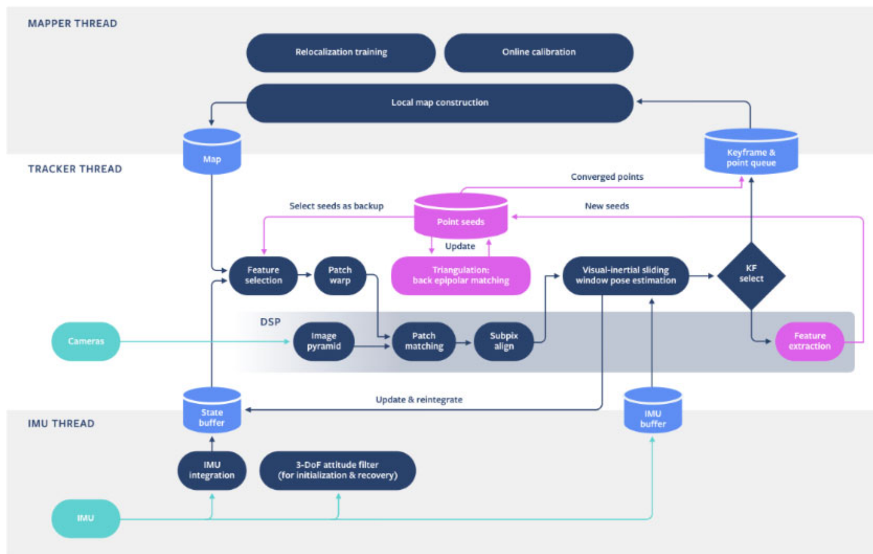
Headset tracking compute architecture



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</td></tr>
<tr><td colspan="2">Claim 15</td></tr>
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(15) The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information for correlating measurements and geometric relationships between sensing elements.

</td><td>

See supra claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which accepting the information related to an actual sensor measurement includes accepting information for correlating measurements and geometric relationships between sensing elements, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), where the data includes information for correlating measurements and geometric relationships between these sensing elements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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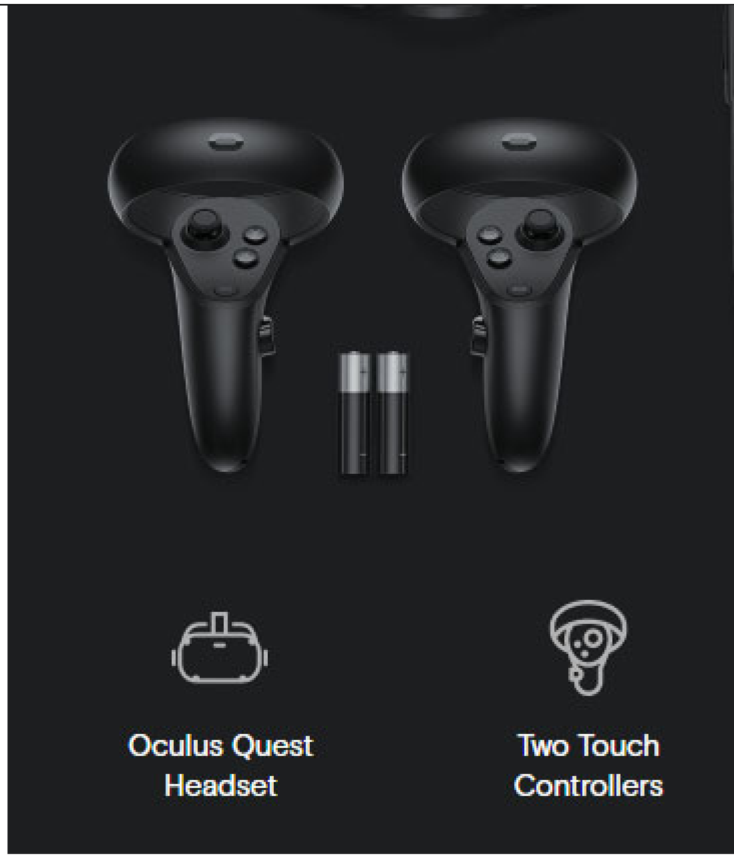
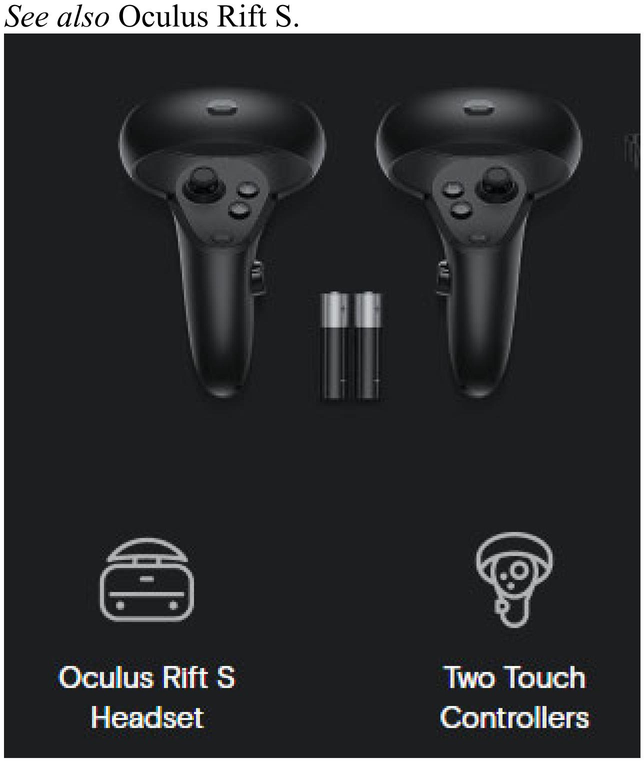


See also Oculus Rift S.



See also From the Lab.

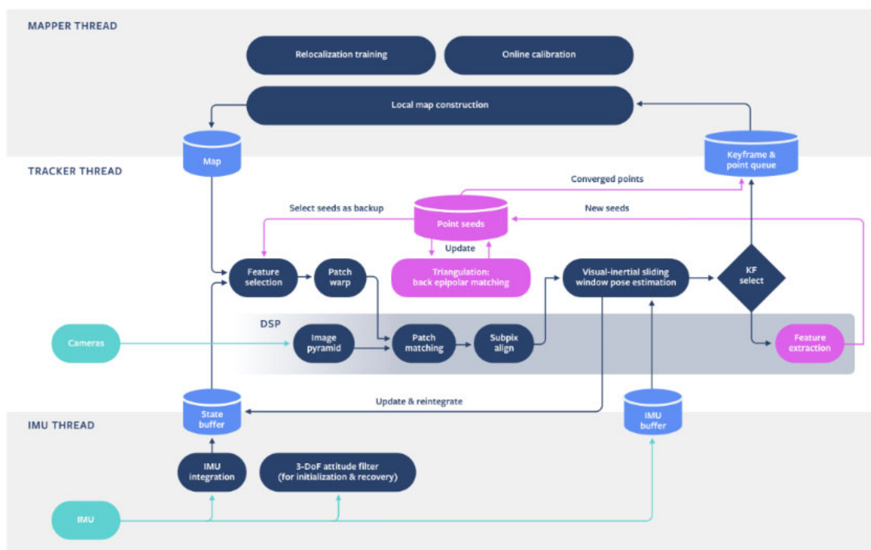
	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 16

(16) The method of claim 15 wherein the information for correlating measurements and geometric relationships between sensing elements includes a mapping between a relative pose of the sensing	*See supra* claims 1, 11, 15. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 15 in which the information for correlating measurements and geometric relationships between sensing elements includes a mapping between a relative pose of the sensing elements and a sensor measurement, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the data that the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s) includes information for correlating measurements and geometric relationships between the Oculus controllers and the IMUs within them, including a mapping between a relative position of the controllers and the data received. The

<table>
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<td>elements and a sensor measurement.</td>
<td>
Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand’s pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.
Designing for Hands


See also Hand Tracking Deep Dive at 4:00–10:00.


See also id. at 4:00–10:00.
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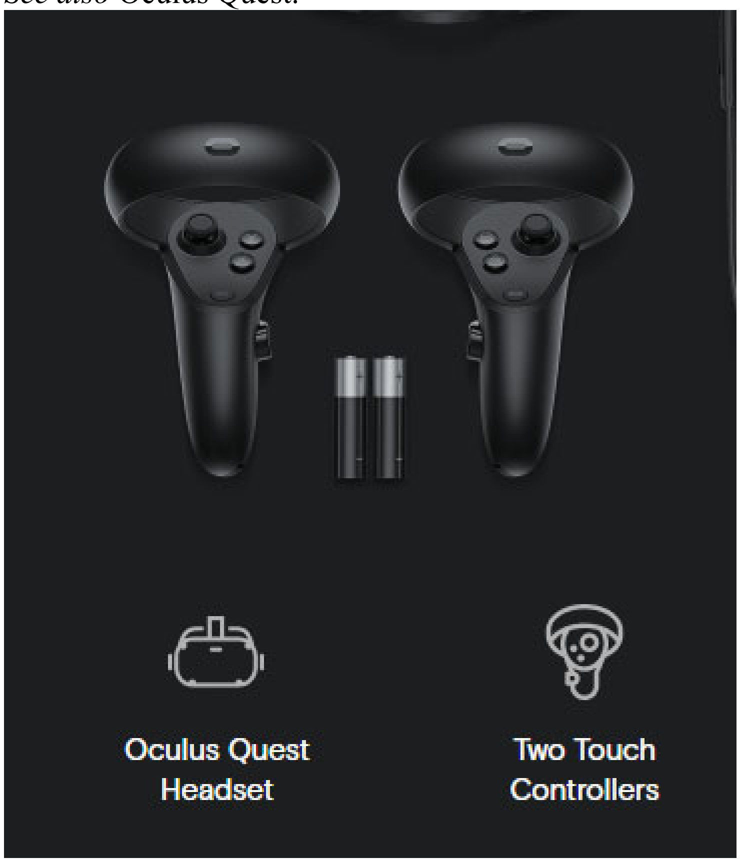
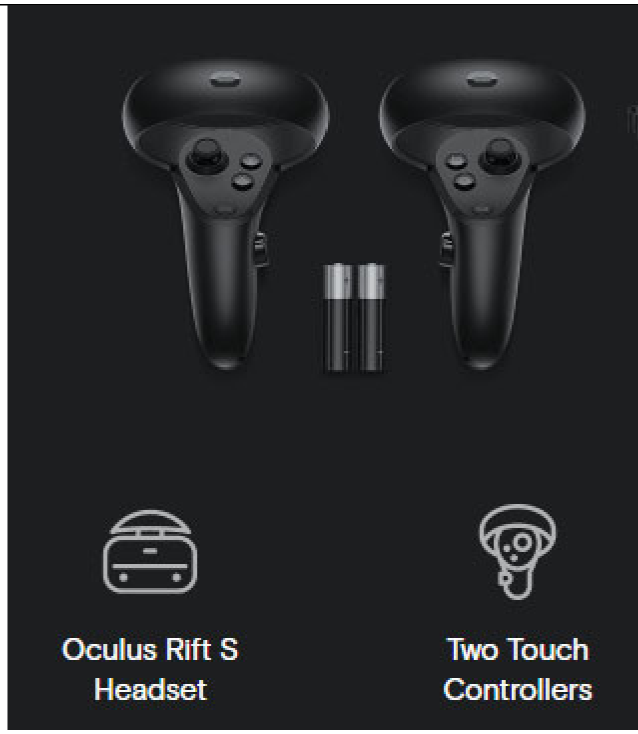
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



See also From the Lab.

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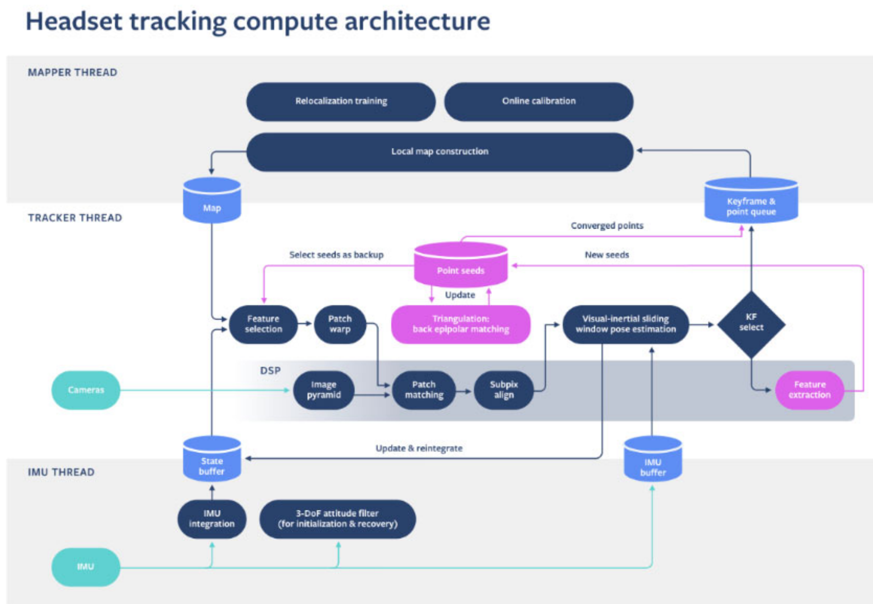


Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 17

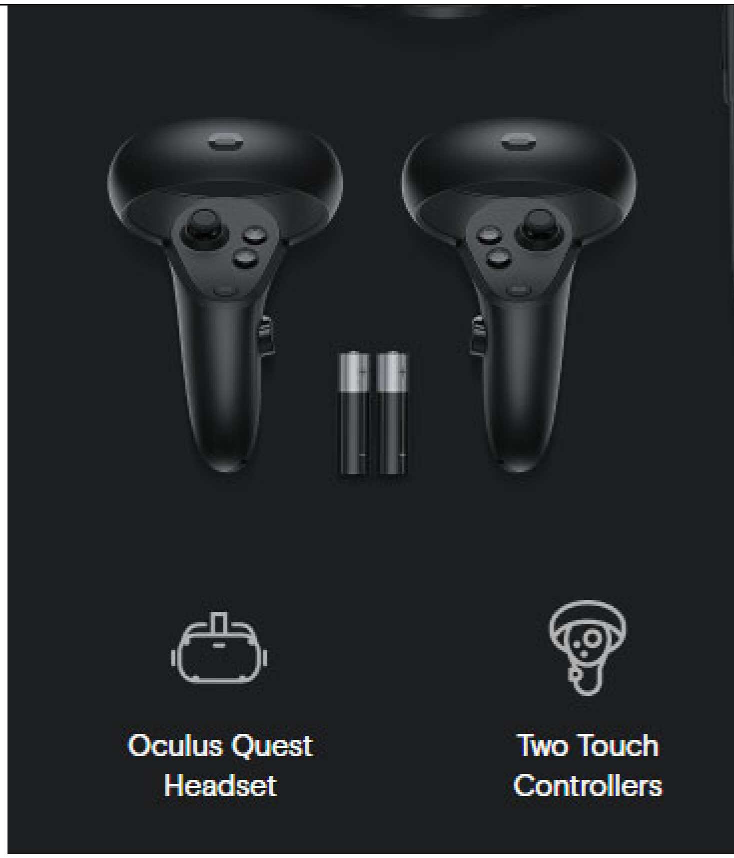
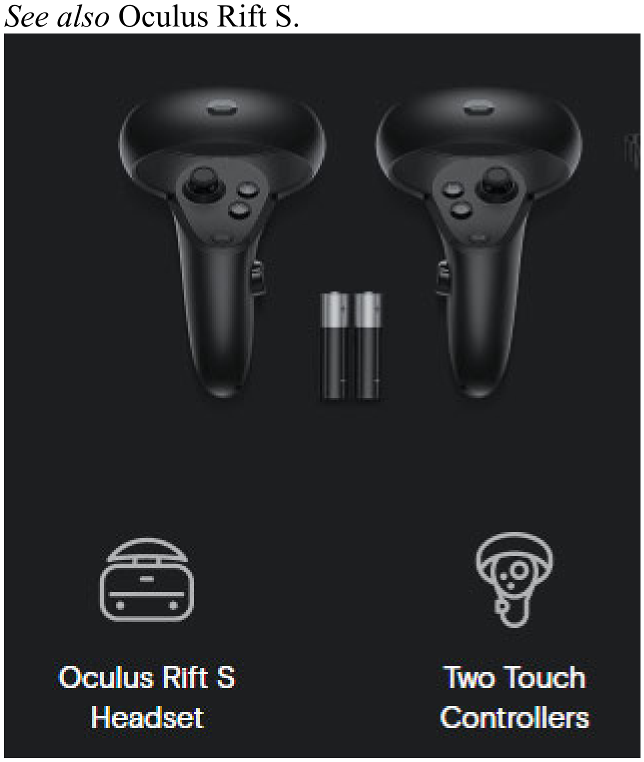
(17) The method of claim 16 wherein the mapping between the relative pose of the sensing elements and the sensor measurement characterizes a linear mapping.	*See supra* claims 1, 11, 15, 16. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 16 in which the mapping between the relative pose of the sensing elements and the sensor measurement characterizes a linear mapping. For example, on information and belief and subject to discovery which has not yet occurred, the data that the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives from the IMUs in the Oculus controllers includes information for correlating measurements and geometric relationships between these sensing elements, including a linear mapping between a relative position of these sensing elements and the data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

See also Oculus Quest.

	 *See also* Oculus Rift S.  *See also From the Lab.*

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

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To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also Powered by AI.

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SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

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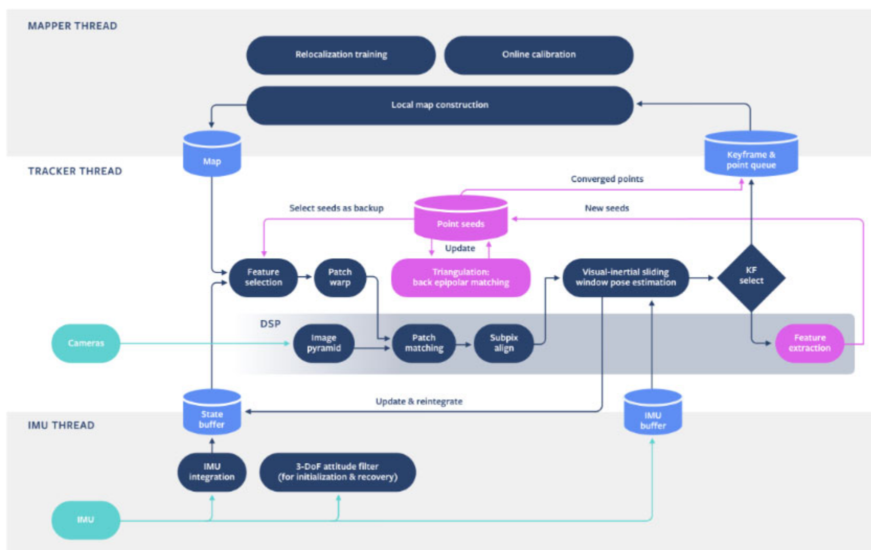
Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.
</td></tr>
<tr><td colspan="2">Claim 18</td></tr>
<tr><td>(18) The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information characterizing an uncertainty in the actual measurement.</td><td>See supra claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which accepting the information related to an actual sensor measurement includes accepting information characterizing an uncertainty in the actual measurement. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), including data characterizing the uncertainty in the actual measurement made by these sensing elements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused</td></tr>
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Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

See, e.g., Hand Tracking.

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See also Designing for Hands.

Designing for Hands

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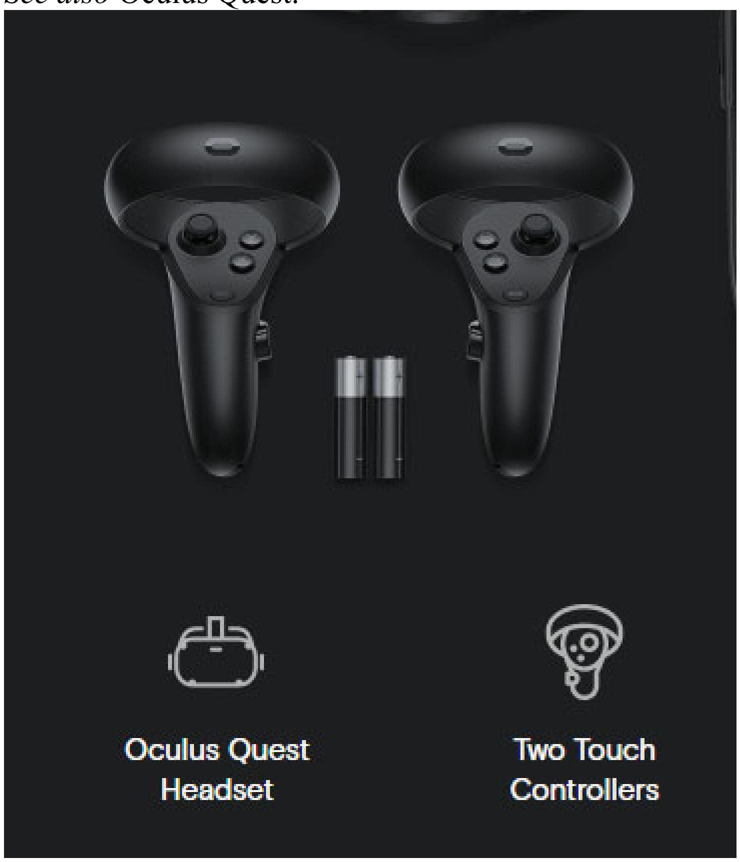
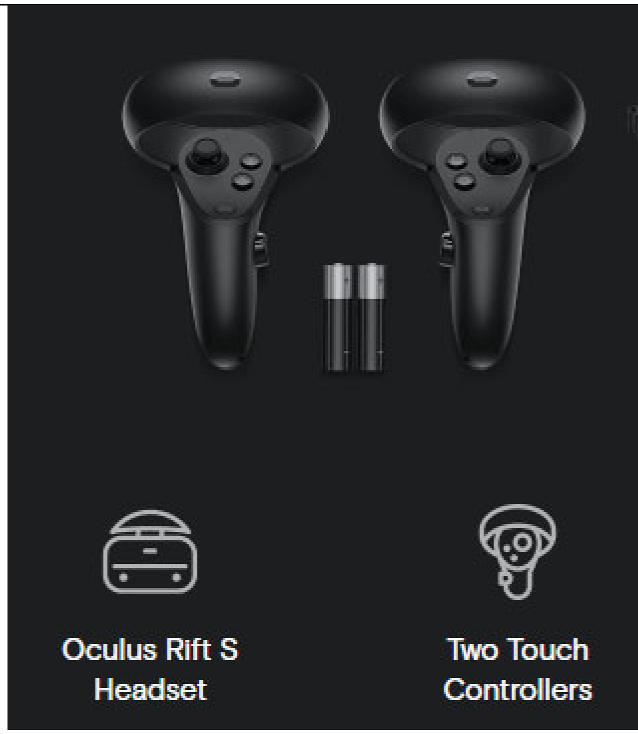
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



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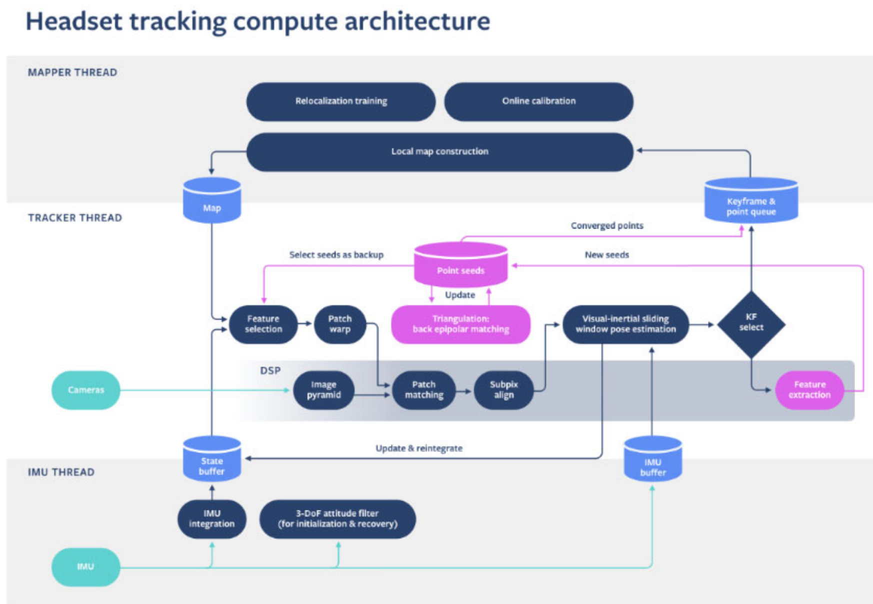

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Claim 19	
(19) The method of claim 18 wherein the information characterizing the uncertainty in the actual measurement includes parameters of a statistical distribution of an error of the actual measurement.	*See supra* claims 1, 11, 18. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 18 in which the information characterizing the uncertainty in the actual measurement includes parameters of a statistical distribution of an error of the actual measurement. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), including parameters of a statistical distribution of an error in the actual measurement made by these sensing elements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial. *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

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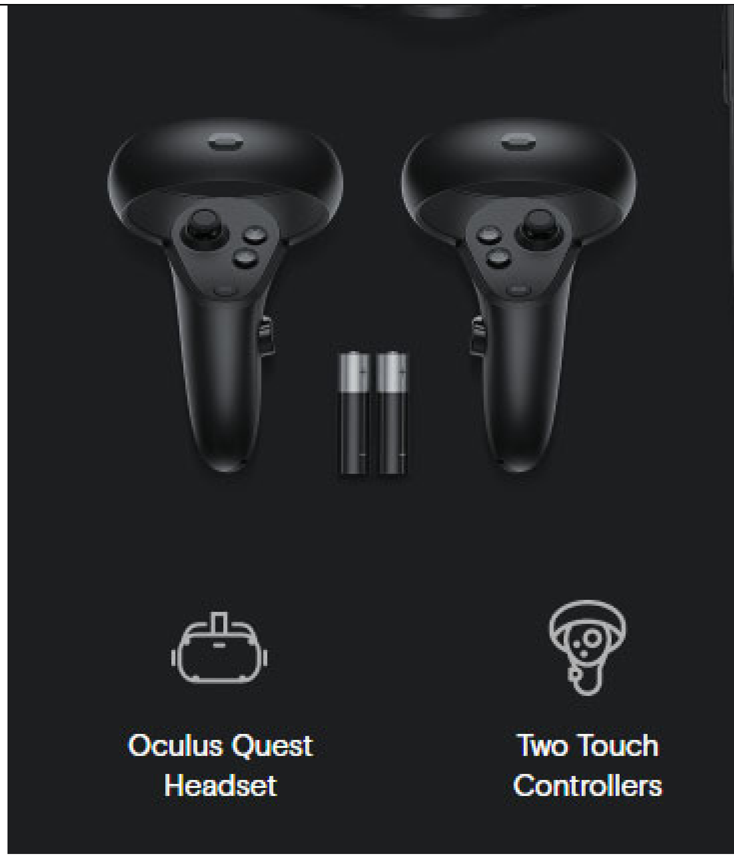
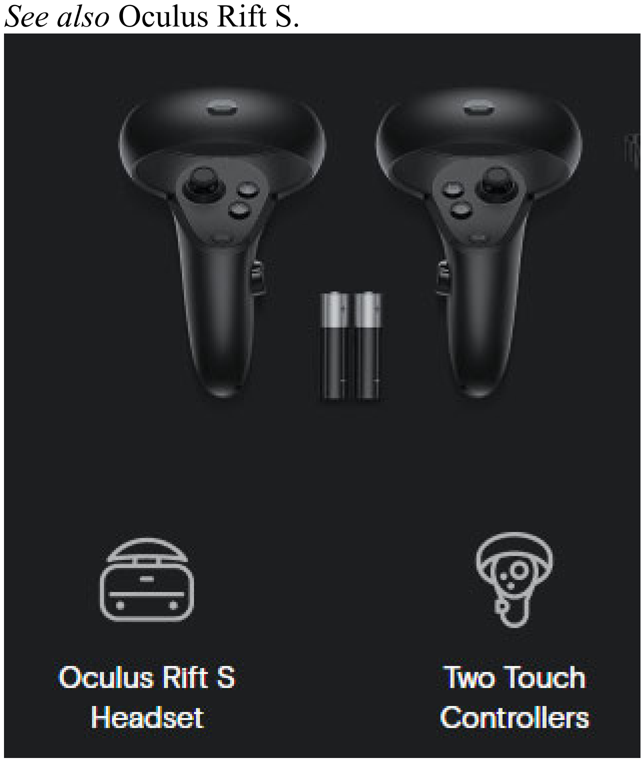
	 *See also* Oculus Rift S.  *See also From the Lab.*

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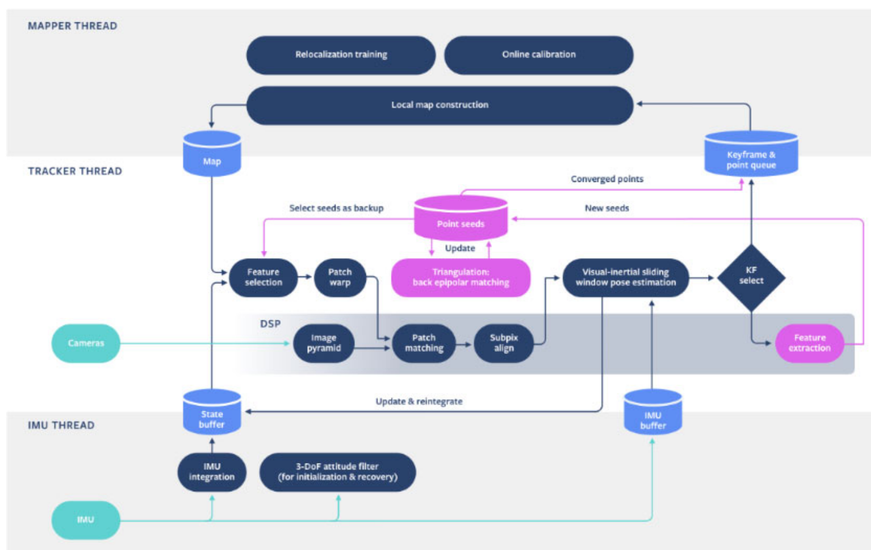
SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



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</td>
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See, e.g., *From the Lab*.

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See also Oculus Rift S.

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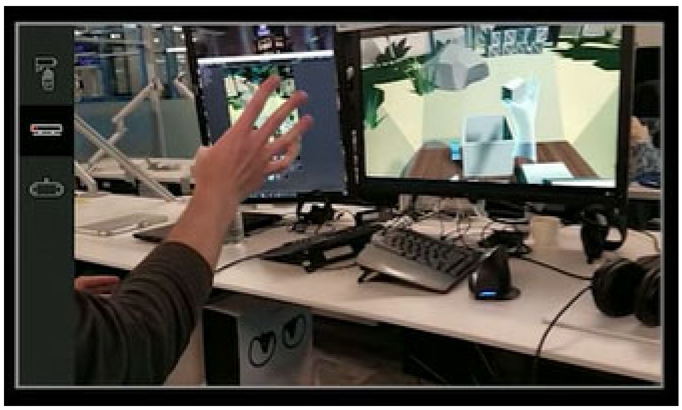
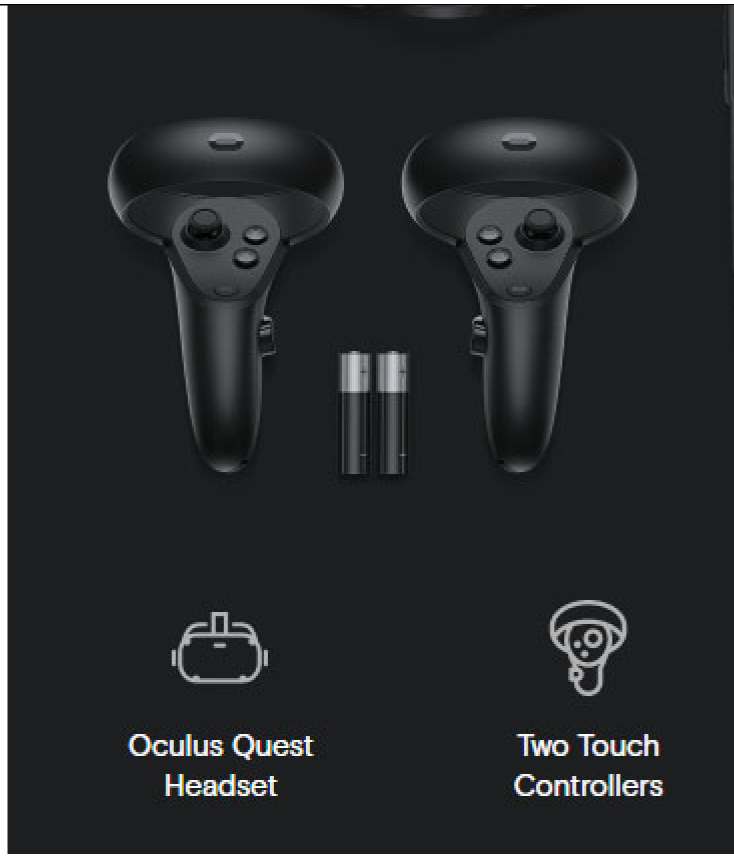
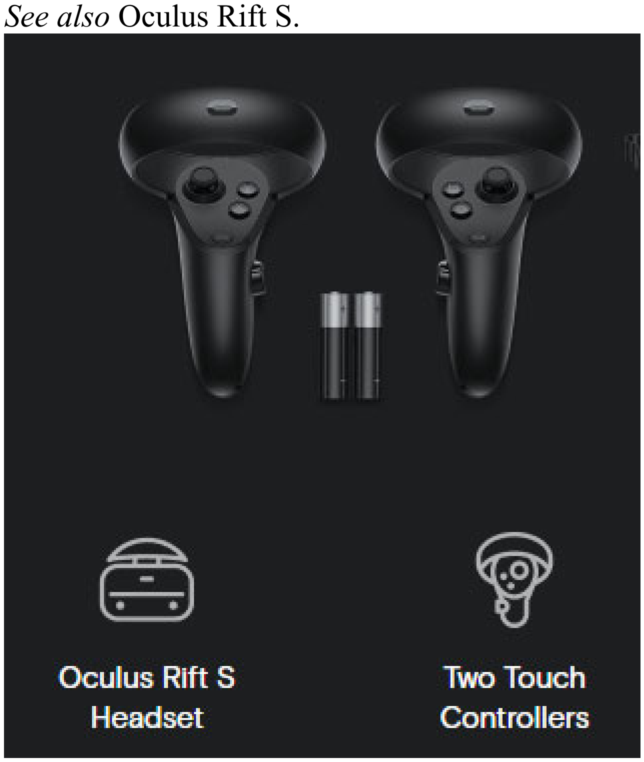
	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

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	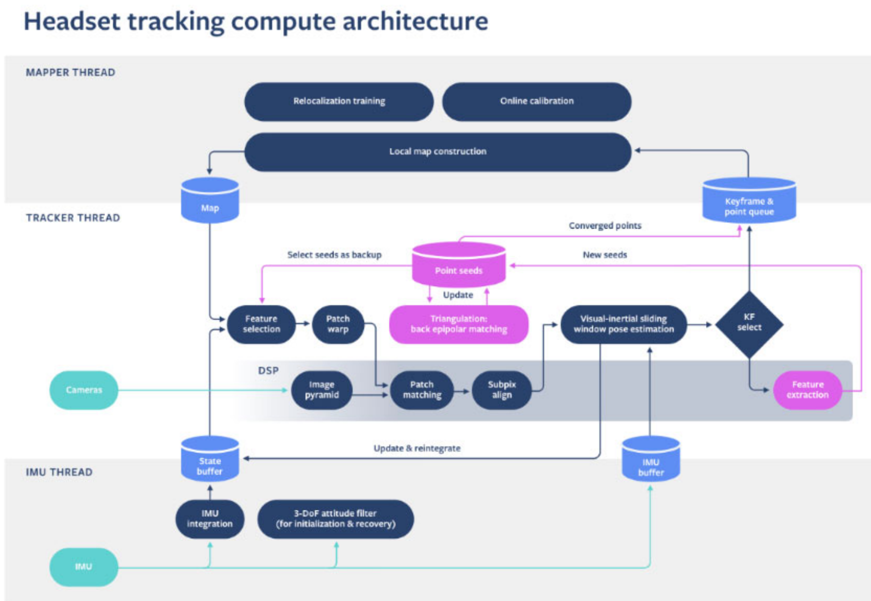 *Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.* *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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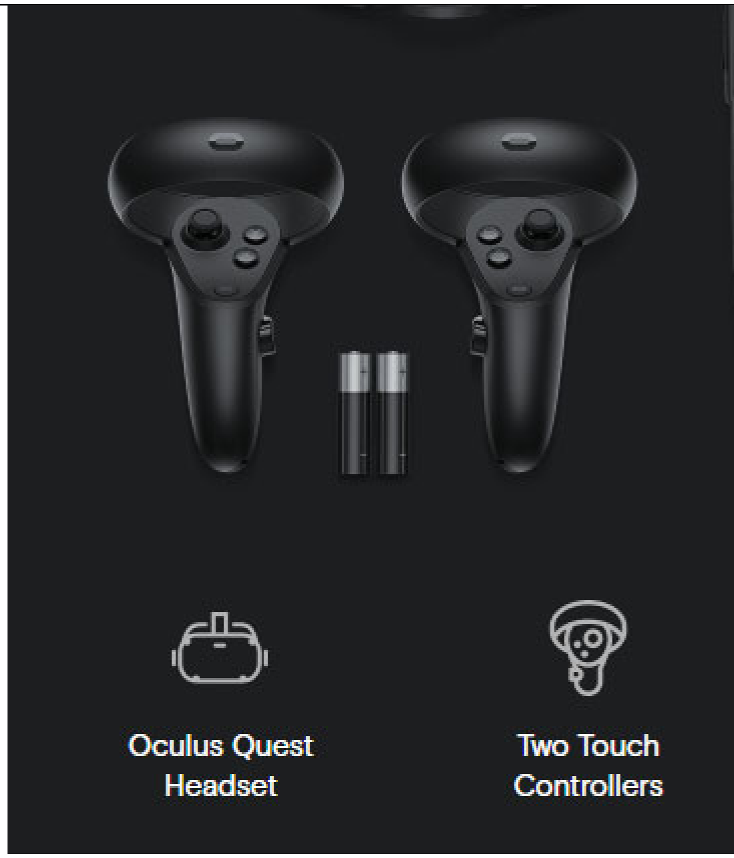
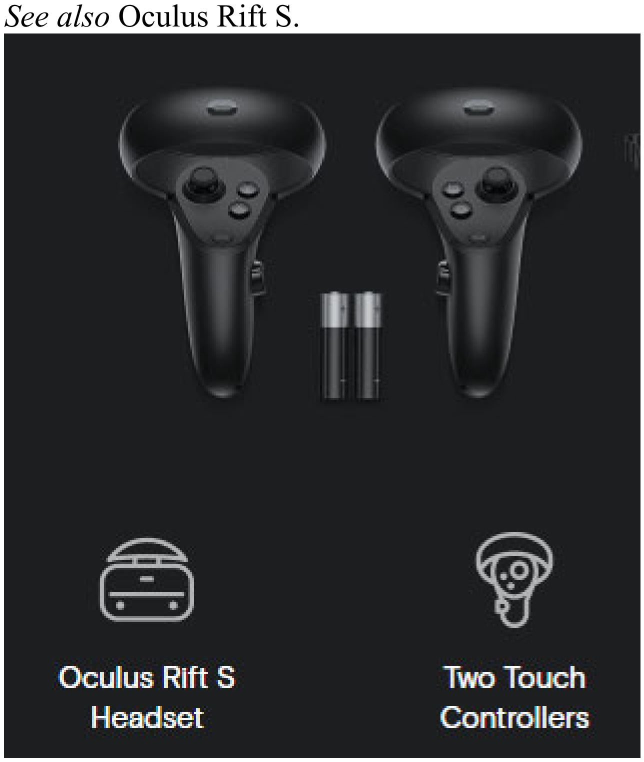
	 *See also* Oculus Rift S.  *See also Powered by AI*.

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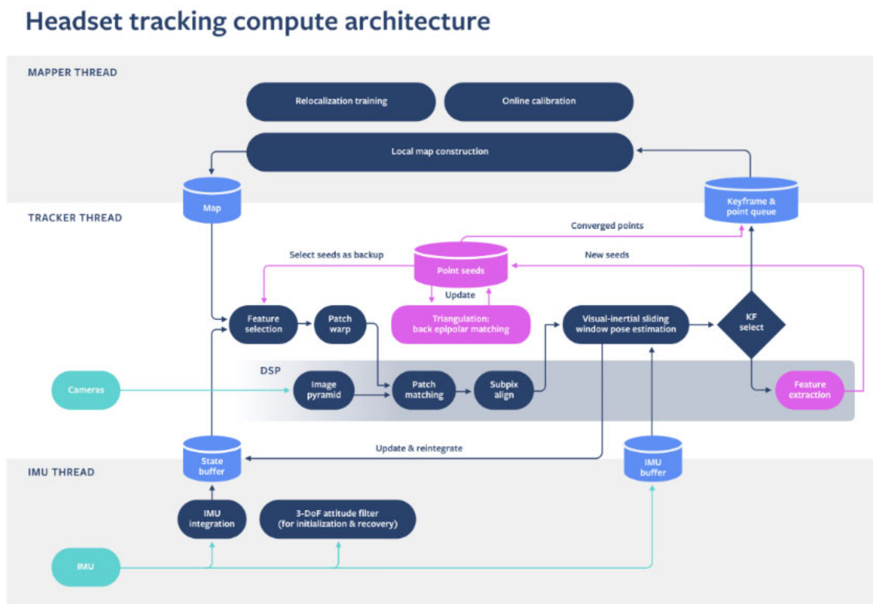

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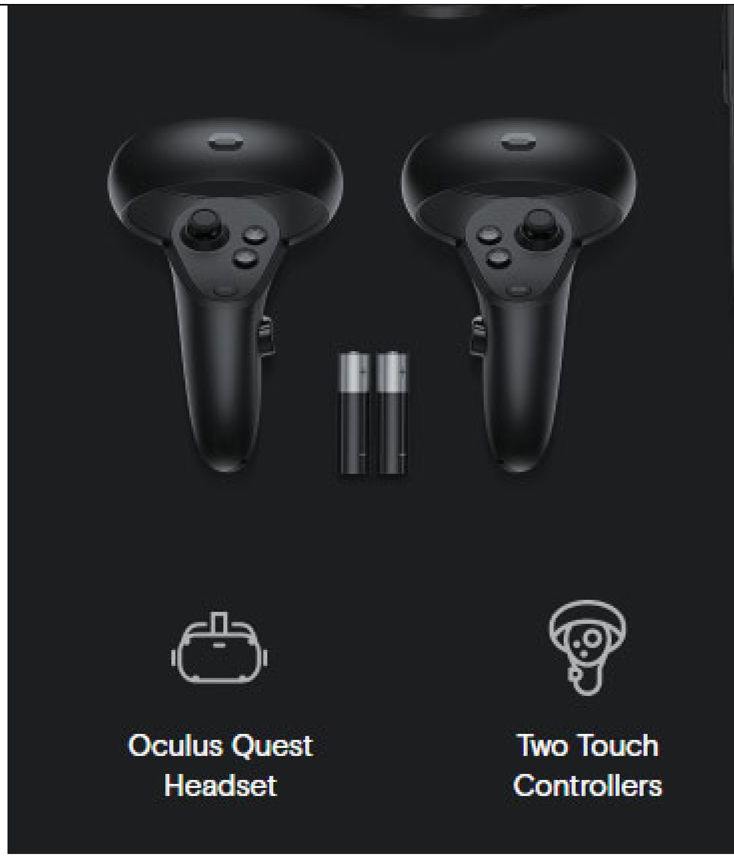
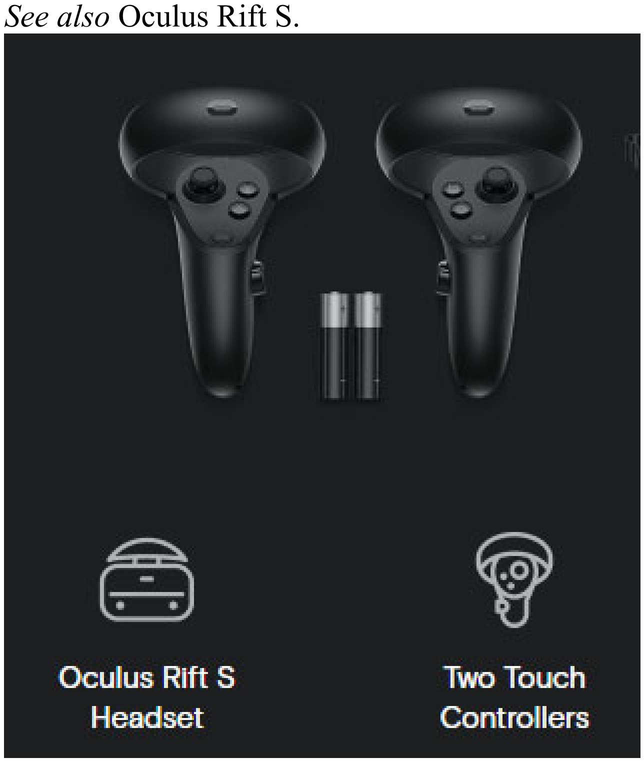
	 *See also* Oculus Rift S.  *See also Powered by AI.*

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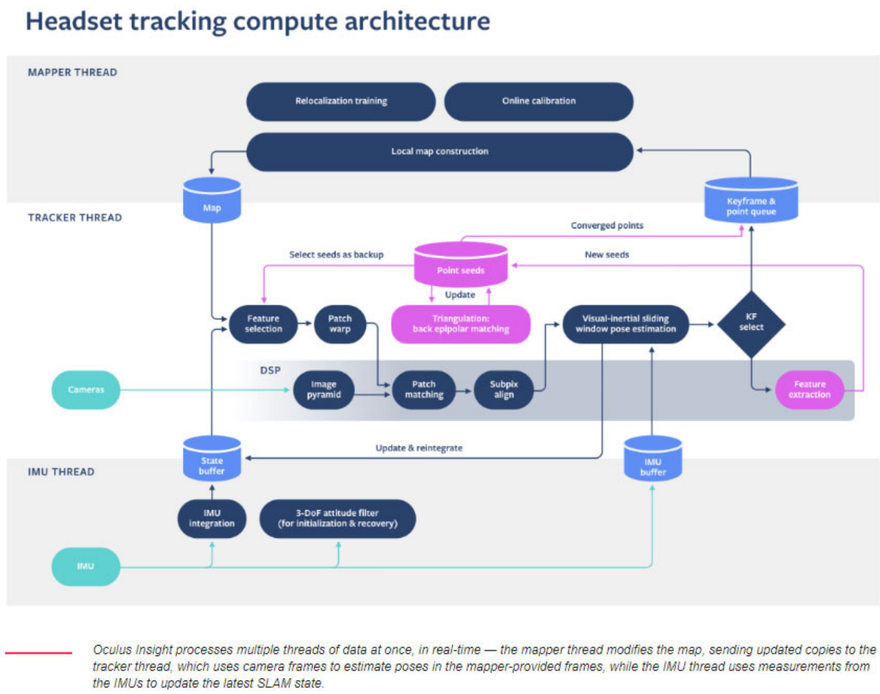

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- RoHS and Green compliant

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

11 Comments Share Save Hide Report 78% Upvoted

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New comments cannot be posted and votes cannot be cast

SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

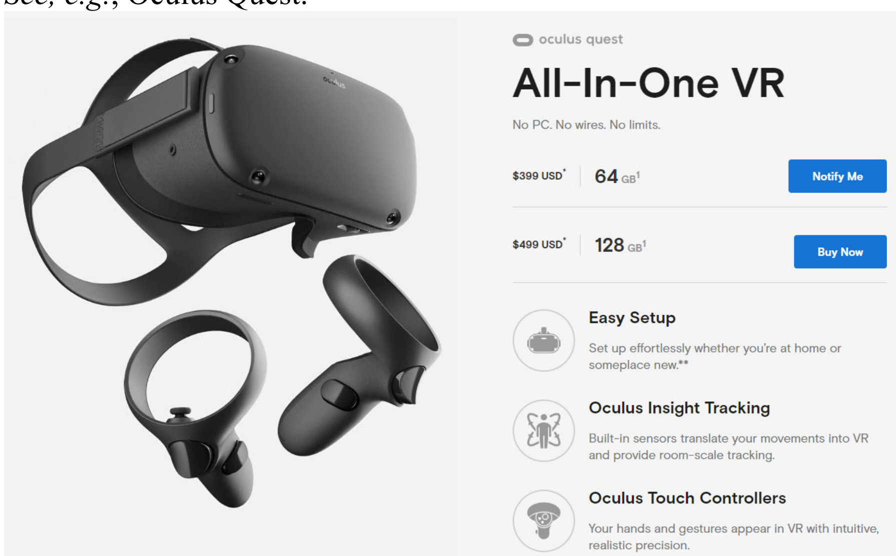
jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

<table>
<tr><th colspan="2">Claim 22</th></tr>
<tr><td>(22) The method of claim 11 wherein repeatedly updating the state further includes: updating the state according to the accepted information related to an actual sensor measurement.</td><td>

See supra claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which repeatedly updating the state further includes updating the state according to the accepted information related to an actual sensor measurement. For example, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives and accepts data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), which enables the Oculus Insight tracking system to update the estimated position and orientation of the user's head, hand(s), and/or the Oculus controller(s) according to the accepted data. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.



See also Oculus Quest Features.

</td></tr>
</table>

See, e.g., Hand Tracking.

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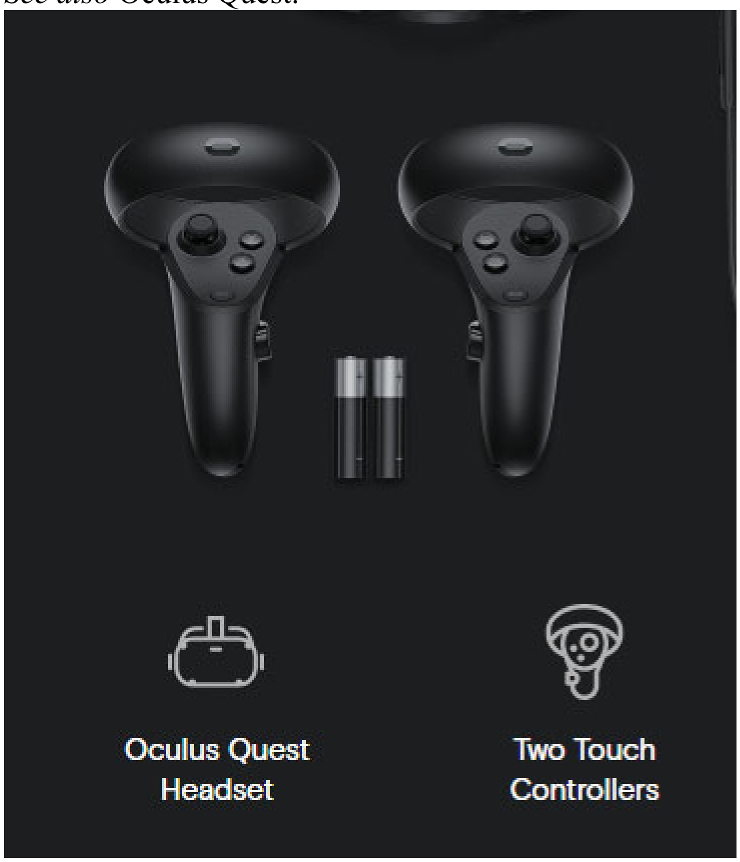
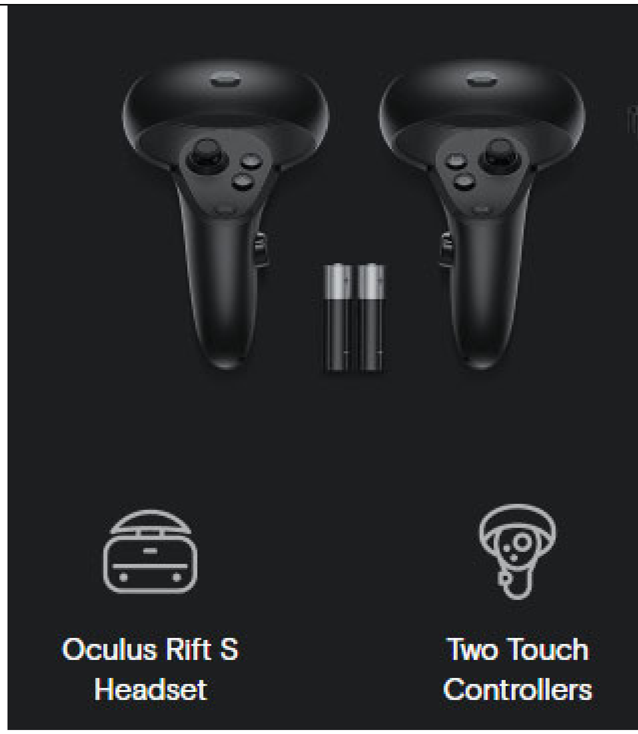
See also Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

	 *See also* Oculus Quest.  *See also* Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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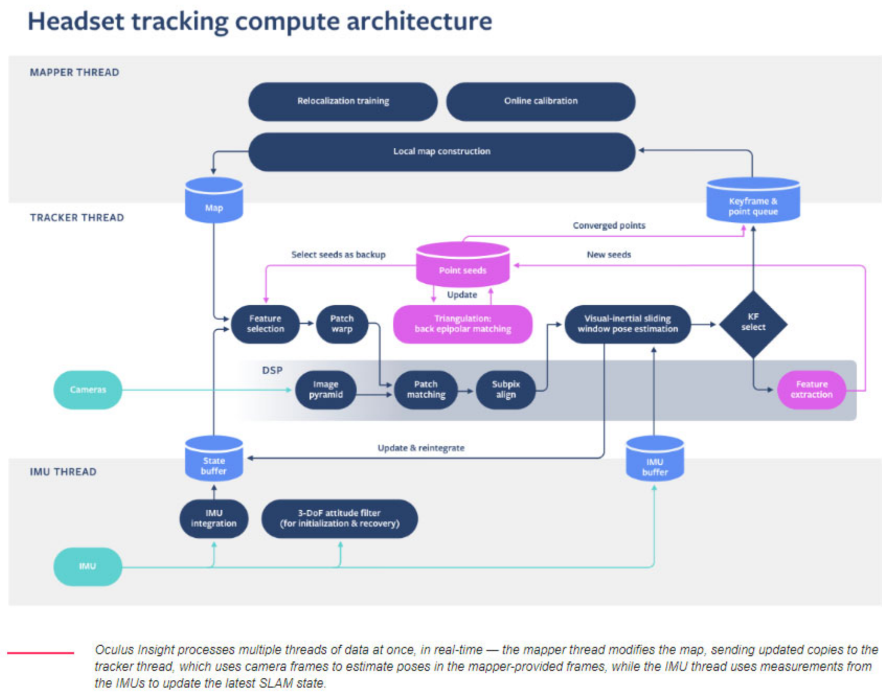

See also From the Lab, Sensor Placement at 0:23.

See also From the Lab, Sensor Placement at 0:30.

See also Heaney.

More Precise Tracking

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Facebook's VR controllers are tracked via infrared LEDs under the plastic

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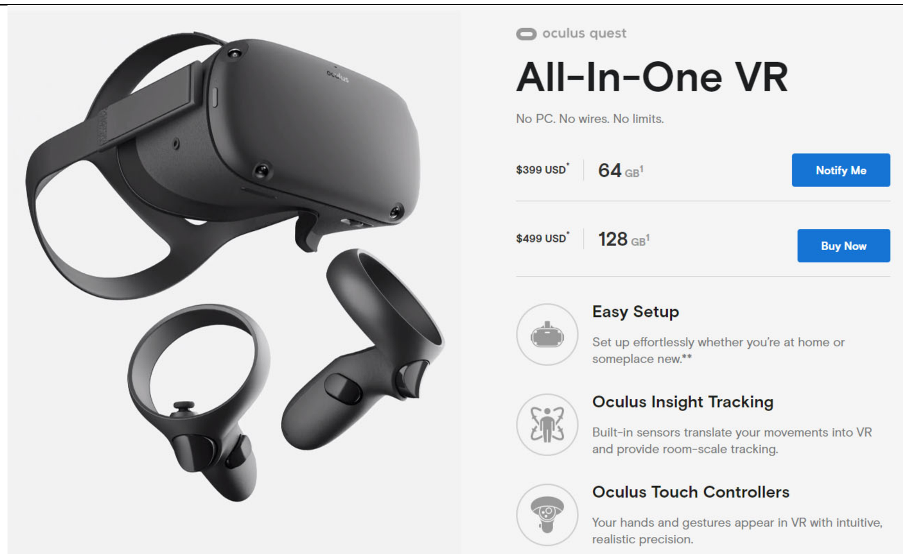
	The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer. Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.  The IMU in the current Touch controllers for Rift S and Quest *See also* ICM-20601 Specification.
Claim 23	
(23) The method of claim 20 wherein repeatedly updating the state further includes: updating the state according to accepted measurements from inertial sensors.	*See supra* claims 1, 20. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 20 in which repeatedly updating the state further includes updating the state according to accepted measurements from inertial sensors. For example, the headset in the Accused Products receives and accepts measurement data from the IMUs within the headset and/or the IMUs within the Oculus controller(s), which are inertial sensors, and updates the estimated position and orientation of the user's head, hand(s), and/or the Oculus controller(s) according to the accepted measurements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.



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See also Designing for Hands.

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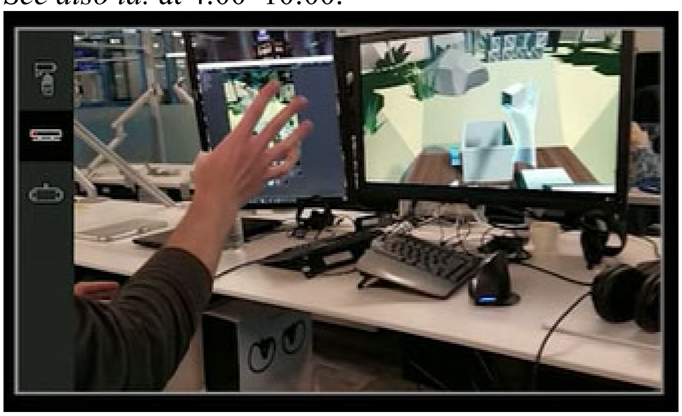

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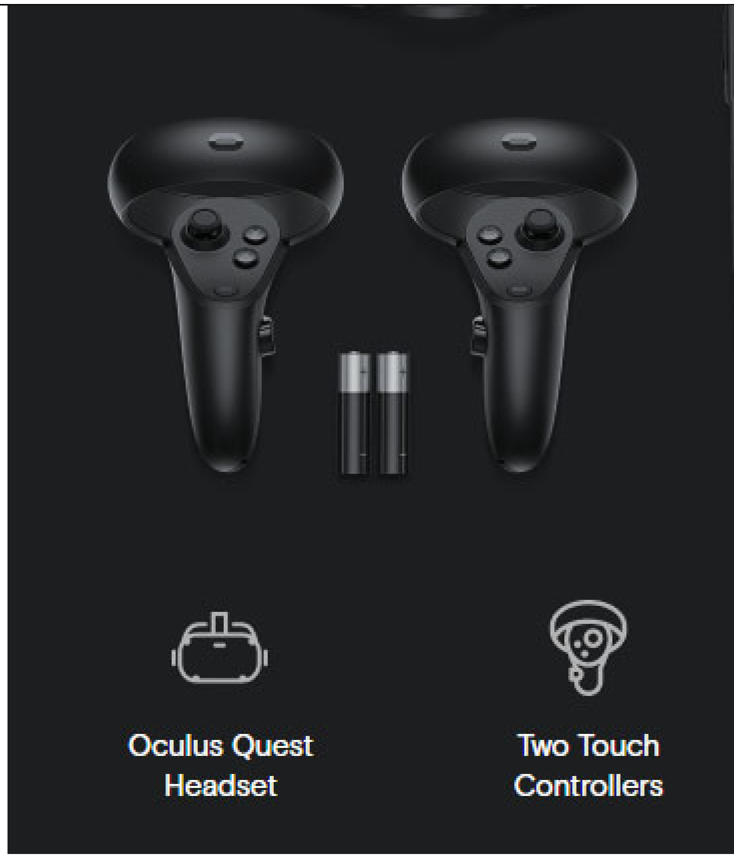
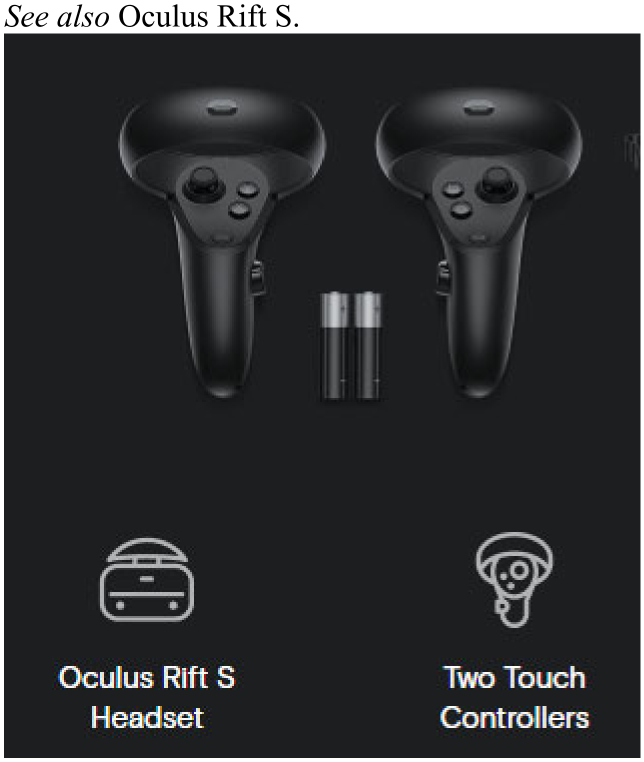


See also Oculus Rift S.



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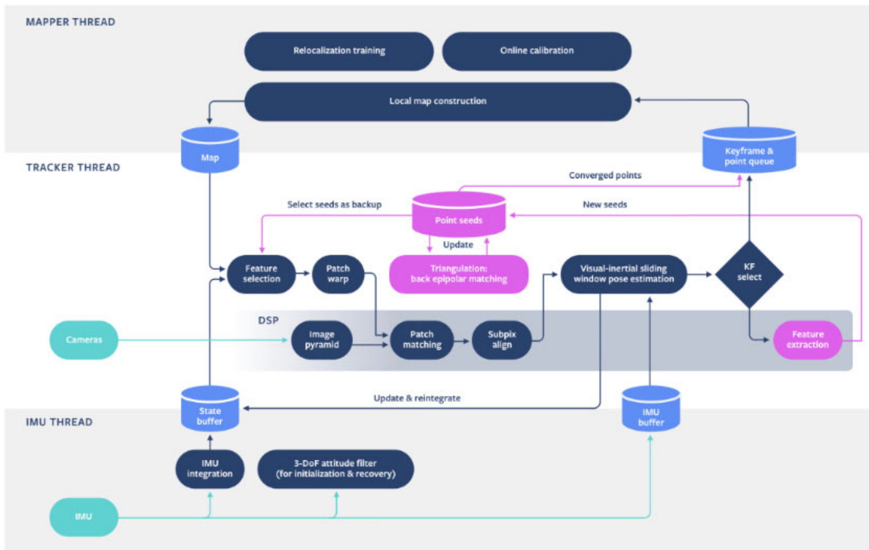
	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.

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A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

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Claim 24	
(24) The method of claim 1 wherein updating the state estimate includes applying a Kalman Filter approach.	*See supra* claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which updating the state estimate includes applying a Kalman Filter approach, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products uses a Kalman filter approach to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial. *See, e.g.*, Hand Tracking.

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Taking SLAM technology ...

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1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
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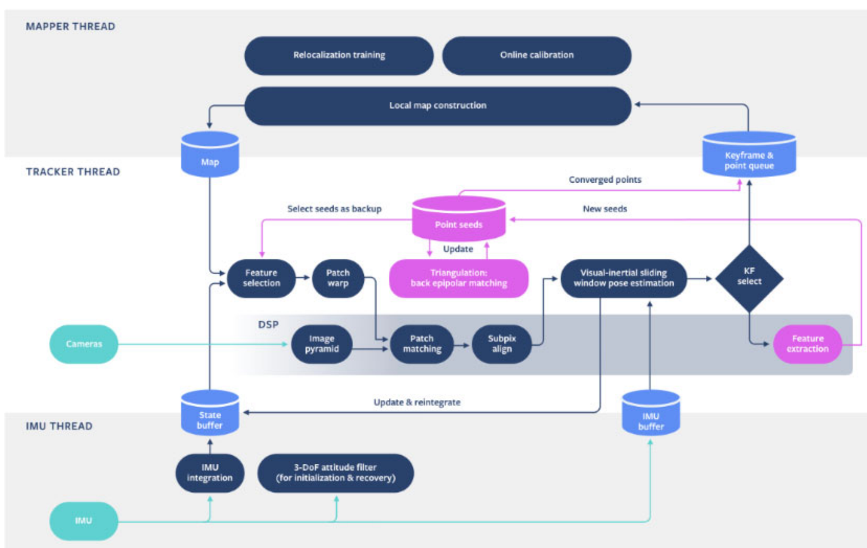

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Claim 25	
(25) The method of claim 1 wherein each of said sensing elements comprises at least one of a sensor and a target.	*See supra* claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which each of said sensing elements comprises at least one of a sensor and a target, and Facebook performs such step itself. For example, the set of sensing elements in the Accused Products comprises at least one sensor (e.g., cameras and/or IMUs within the HMD, and/or the IMUs within the Oculus controllers) and at least one target (e.g., the user's head, the user's hand(s), the Oculus controller(s), and/or objects in the environment). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

See also Hand Tracking.

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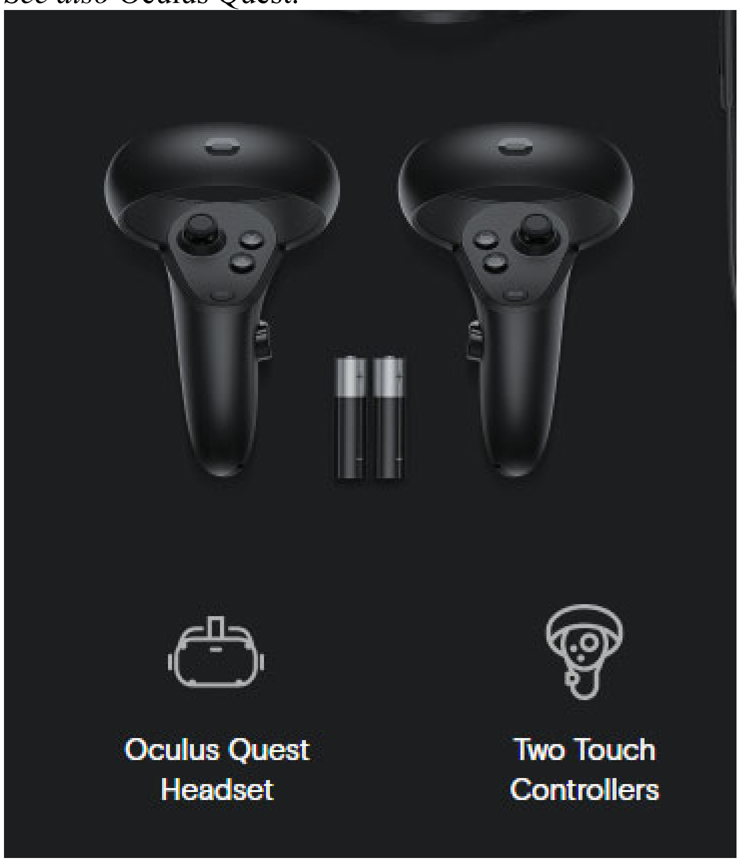
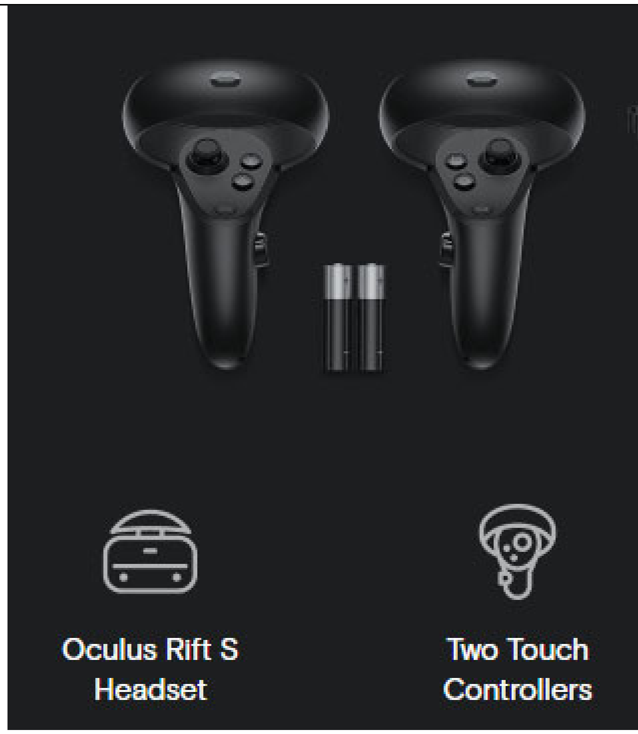
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also id.

At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

See also Powered by AI.

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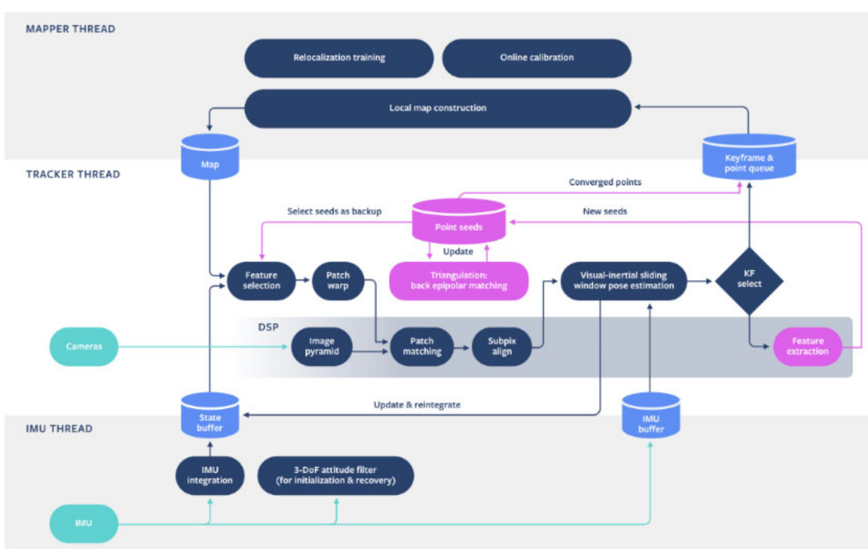
Headset tracking compute architecture



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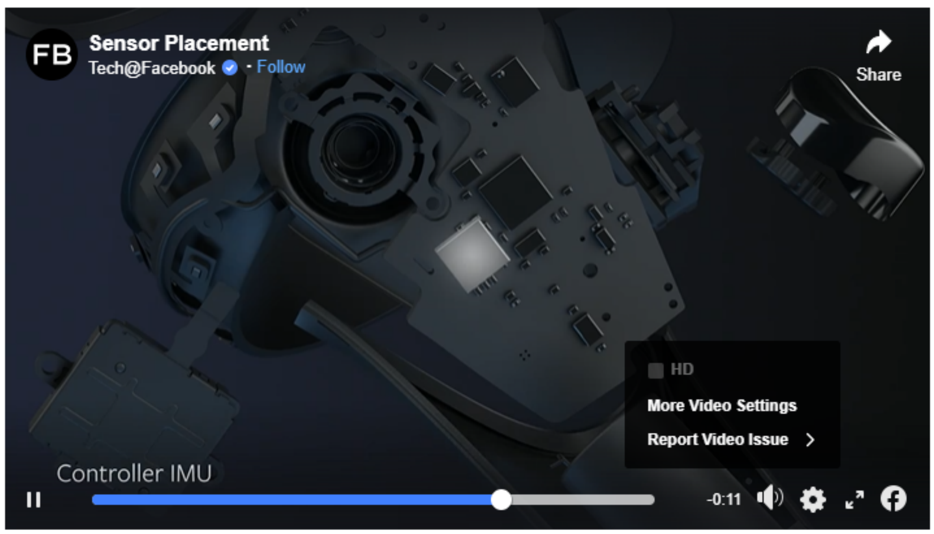
	See also From the Lab, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.  *See also* Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

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Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

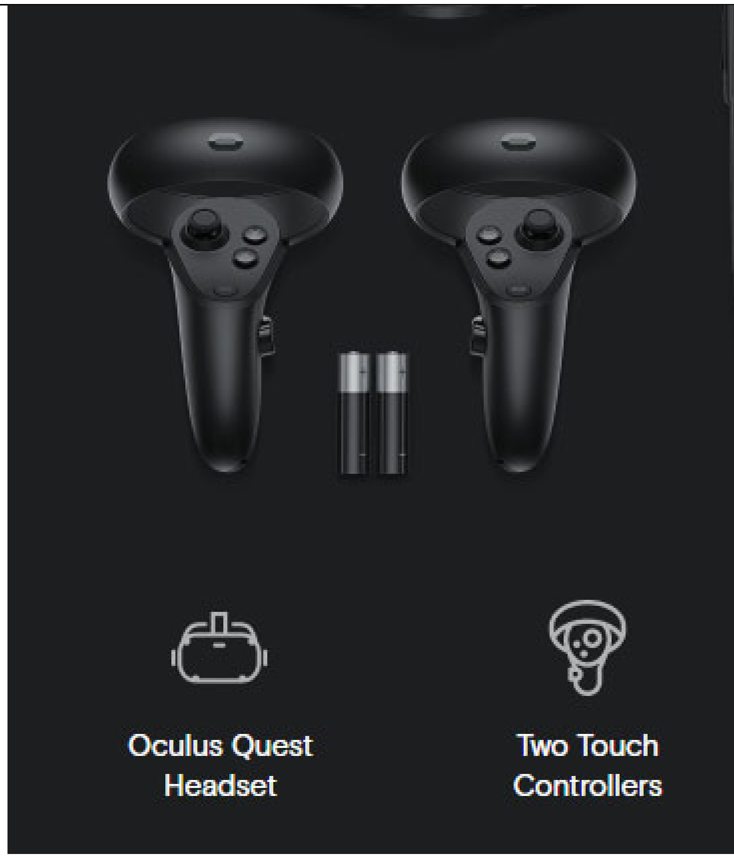
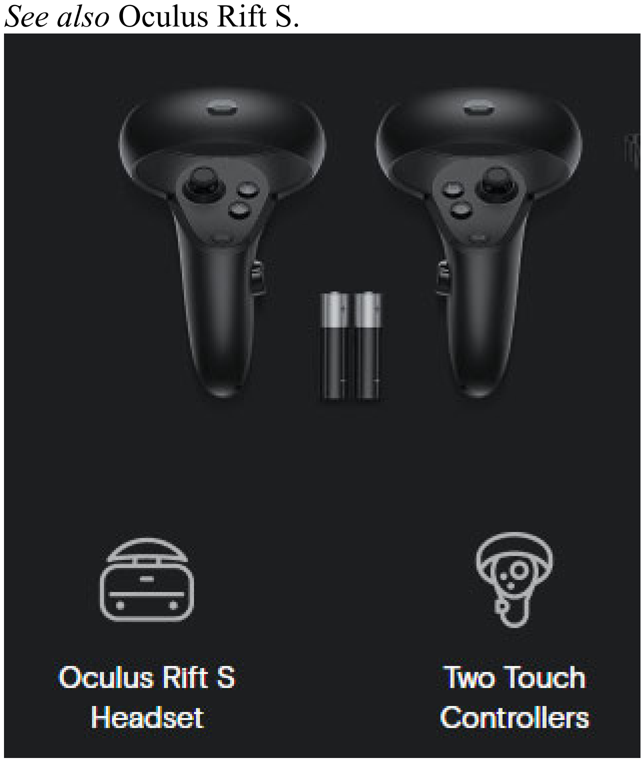
Claim 26	
(26) The method of claim 25 wherein the target comprises an active device that interacts with the sensor.	*See supra* claims 1, 25. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 25 in which the target comprises an active device that interacts with the sensor. For example, the set of sensing elements in the Accused Products comprises a target (e.g., the Oculus controller(s)) that comprises an active device that interacts with the sensor (e.g., the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

See also Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI.*

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also id.

At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

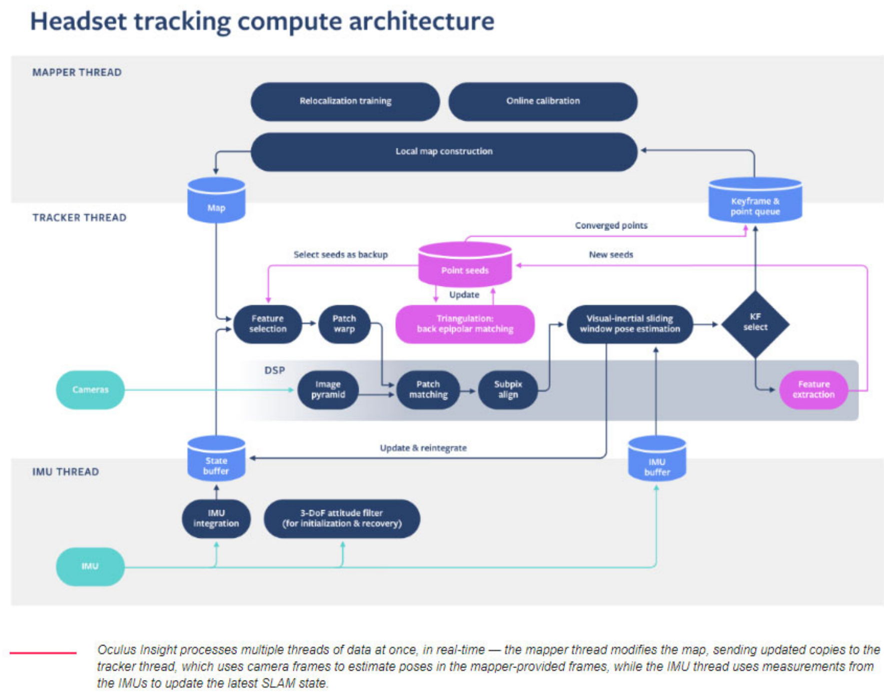
"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.



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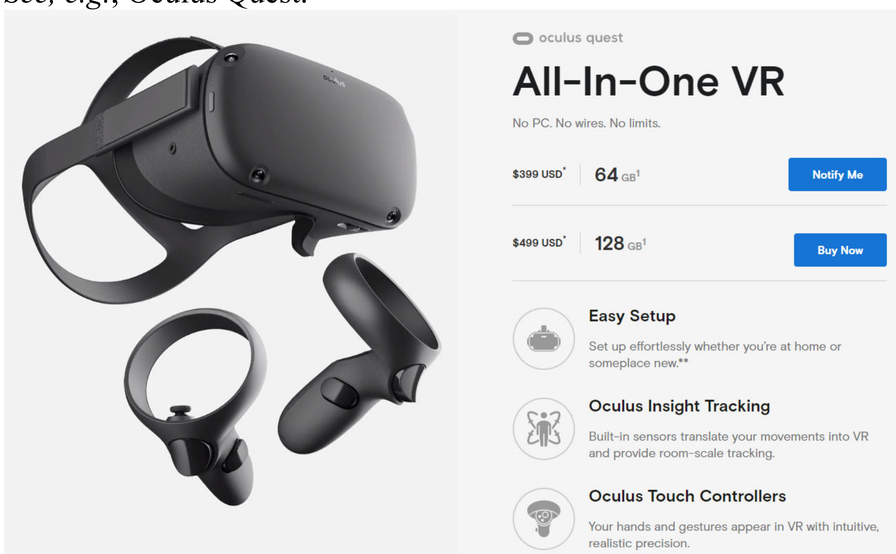
<table>
<tr><th colspan="2">Claim 28</th></tr>
<tr><td>(28) The method of claim 1 wherein the object is selected from a group consisting of a vehicle, a robot, a person, a part of a person, a flying object, a floating object, an underwater moving object, an animal, a camera, a sensing apparatus, a helmet, a tool, a piece of sports equipment, a shoe, a boot, an article of clothing, a personal protective equipment, a rigid object having a dimension between 1 nanometer to 109 meters.</td>
<td>

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the object is a part of a person (e.g., the user's head and/or hand(s) or part of the hand(s)) or a tool or rigid object (e.g., the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.



See also Oculus Quest Features.

See, e.g., Hand Tracking.

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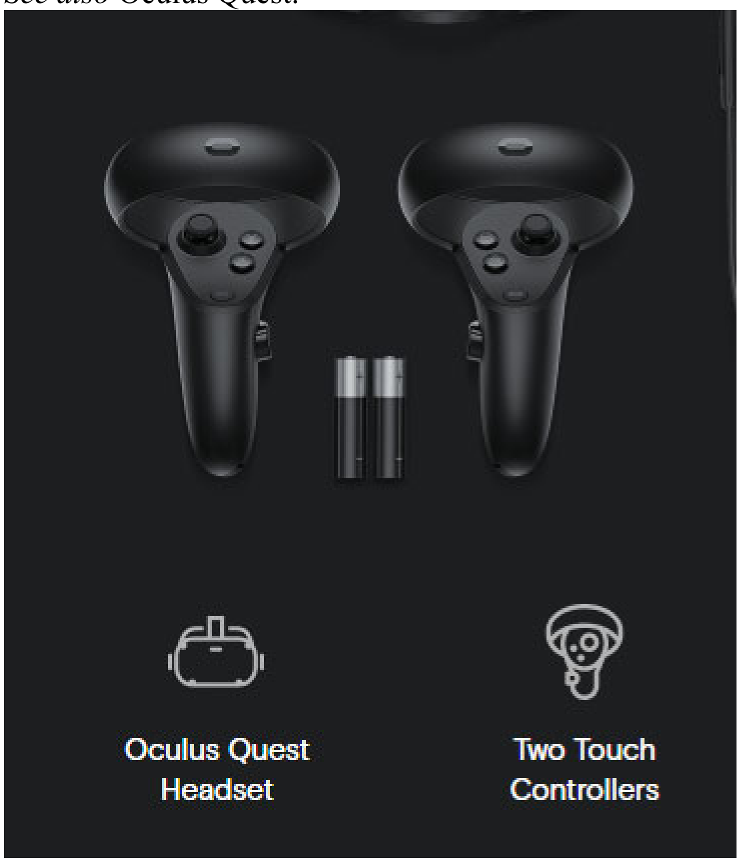
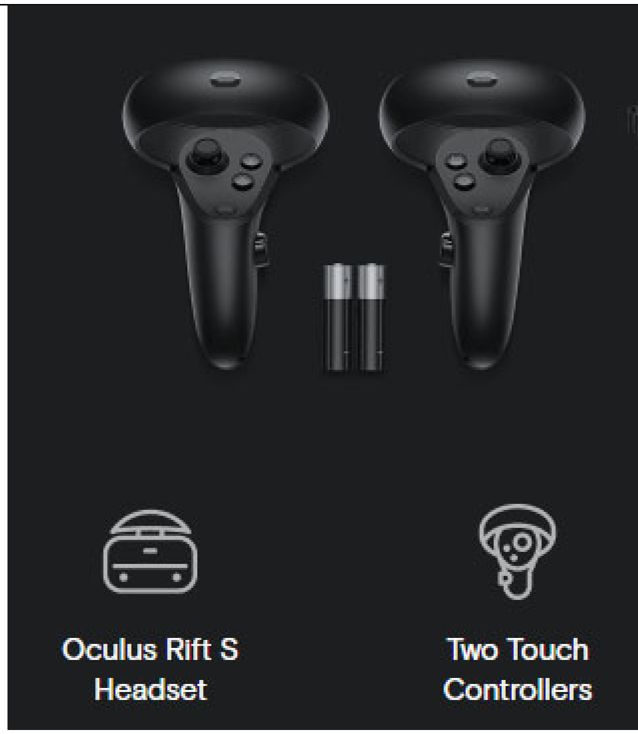
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



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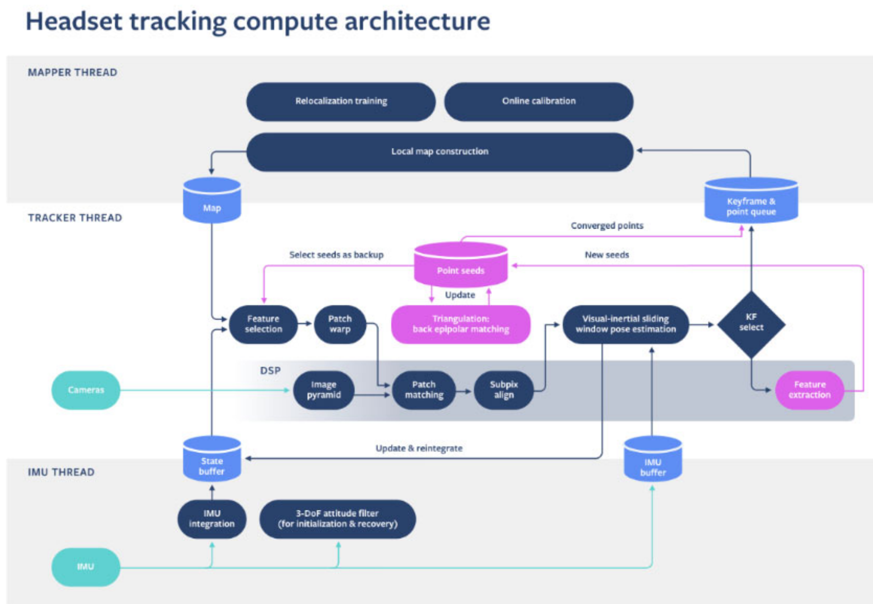

Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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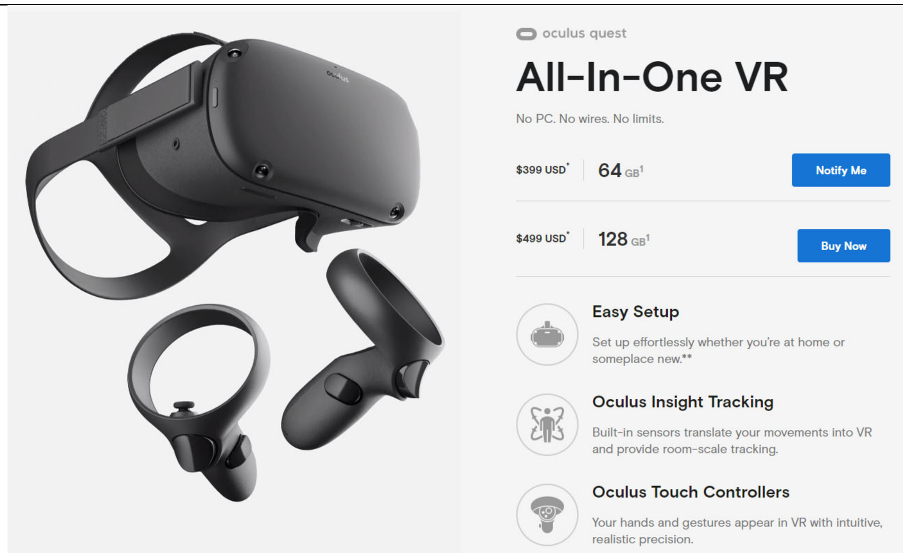
Claim 29	
(29) The method of claim 1 wherein the state estimate comprises information related to a position or an orientation of the object relative to a reference coordinate frame.	*See supra* claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the state estimate comprises information related to a position or an orientation of the object relative to a reference coordinate frame (e.g., the position and orientation of the user's head, the user's hand(s), and/or the Oculus controller(s) relative to a reference coordinate frame). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.



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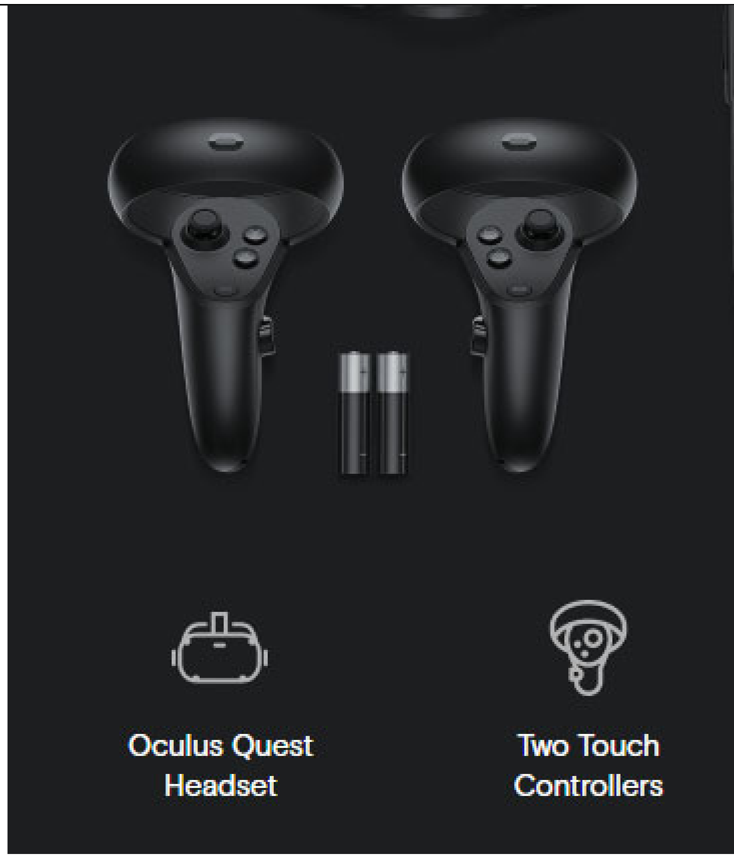

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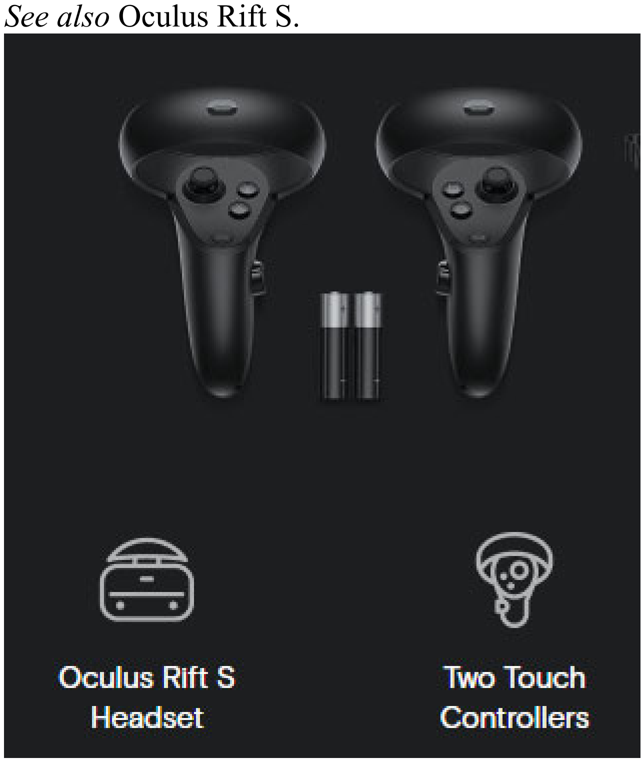

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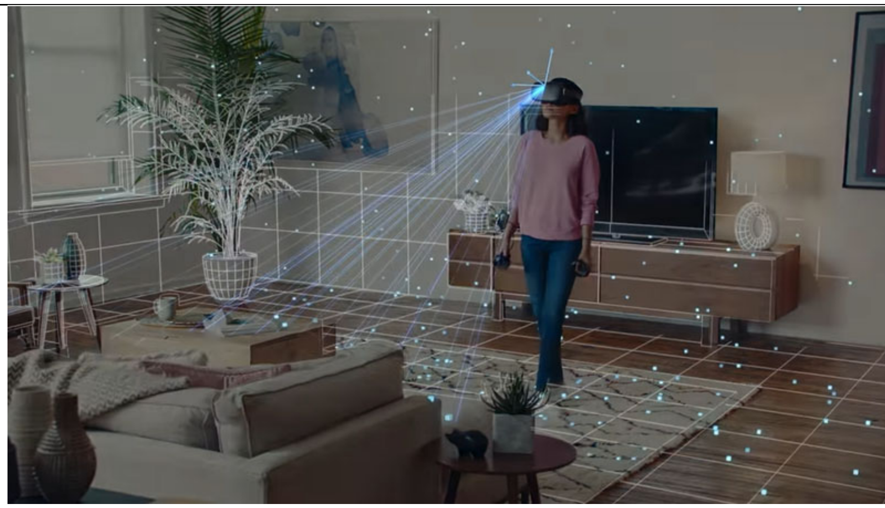
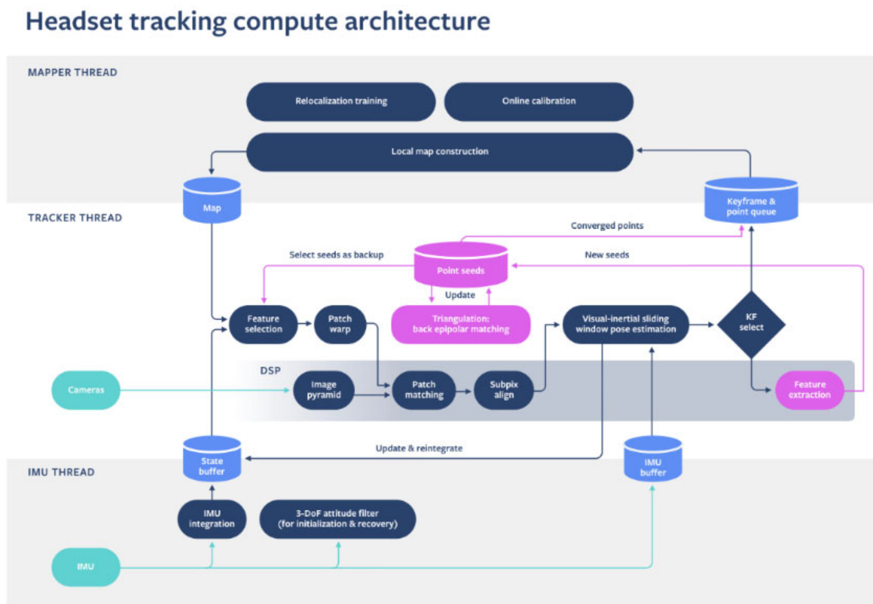
	 *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.* Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR. *See also id.*



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Claim 30	
(30pre) A sensor module comprising:	Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise a sensor module. For example, the Accused Products comprise software and hardware components (e.g., the headset and Oculus controller(s) and their associated software, including the Oculus Insight tracking system, and/or a computer or other external processor for the Oculus Rift S) that interact with a corresponding set of measurement sensors (e.g., cameras and/or IMUs within the headset, and/or the IMUs within the Oculus controllers). Facebook encourages, directs, or promotes users to use the sensor module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the sensor module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses. *See, e.g., From the Lab.*

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

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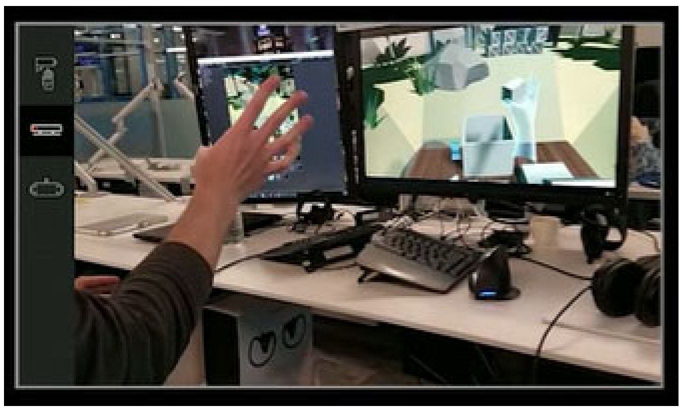
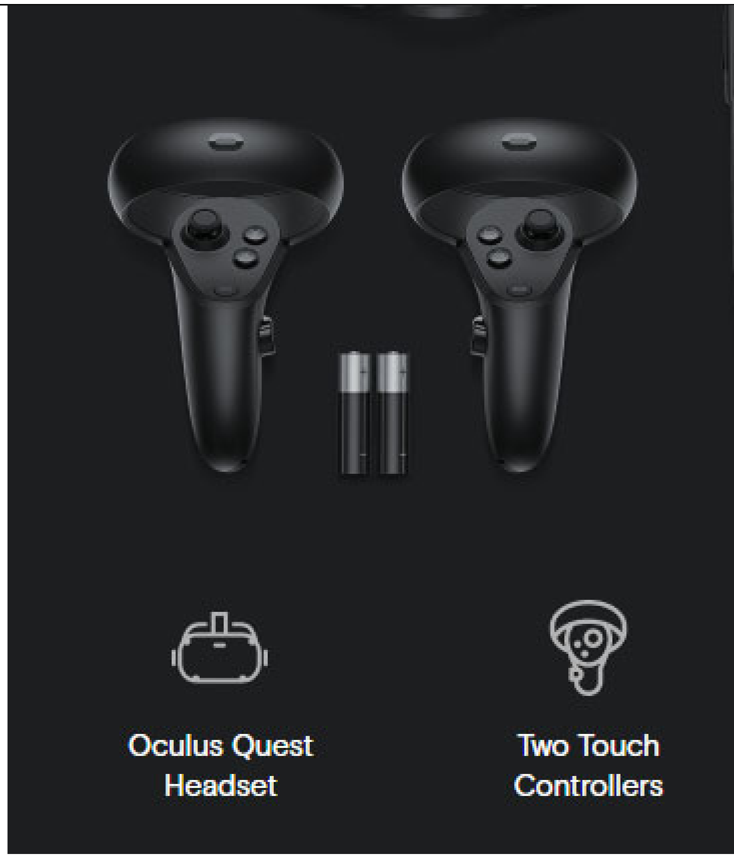
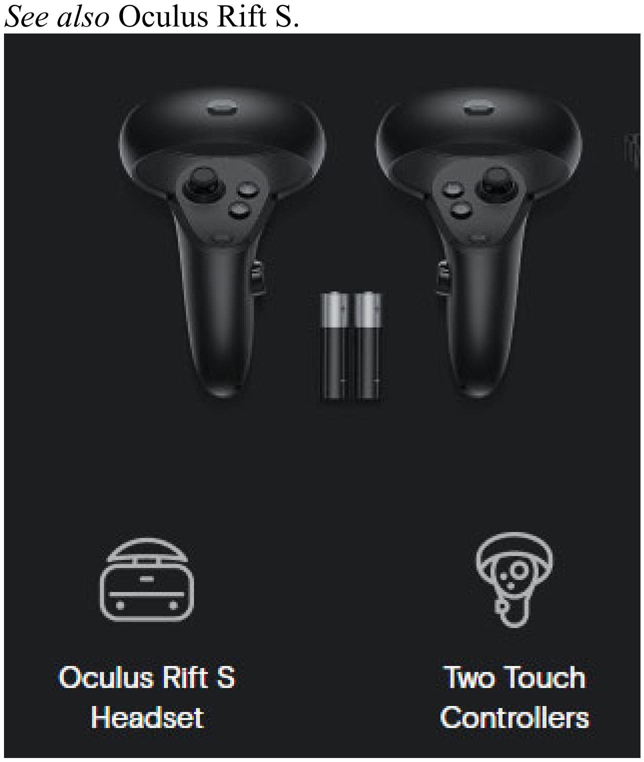
	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI.*

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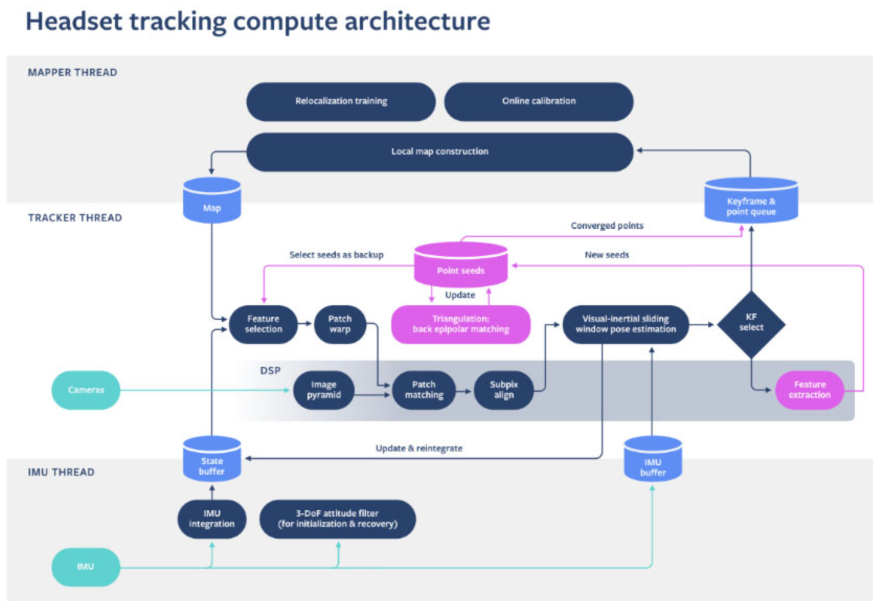

Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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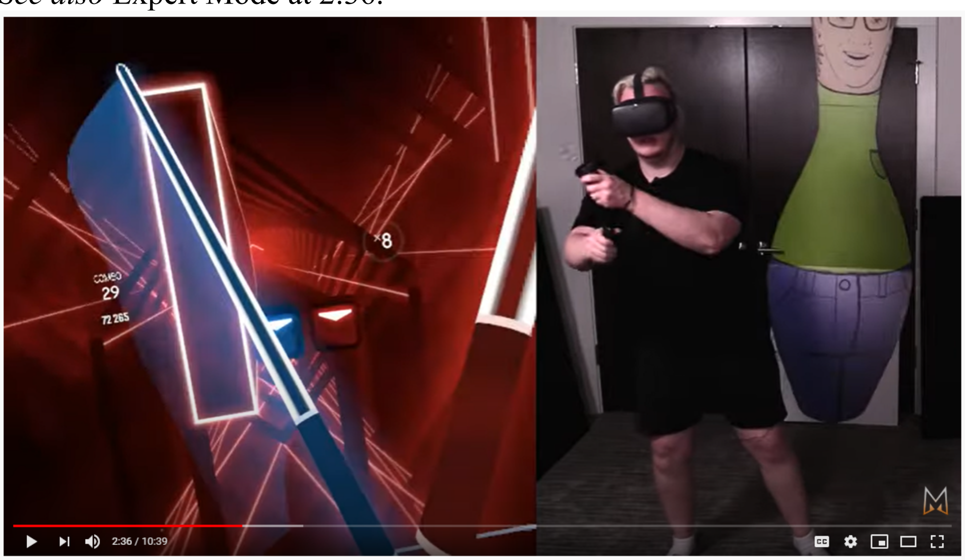

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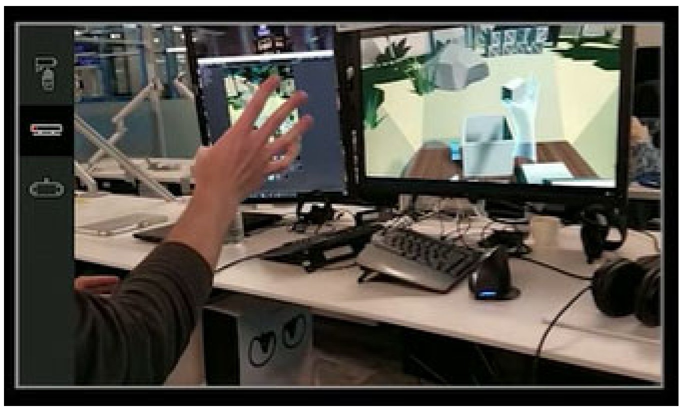
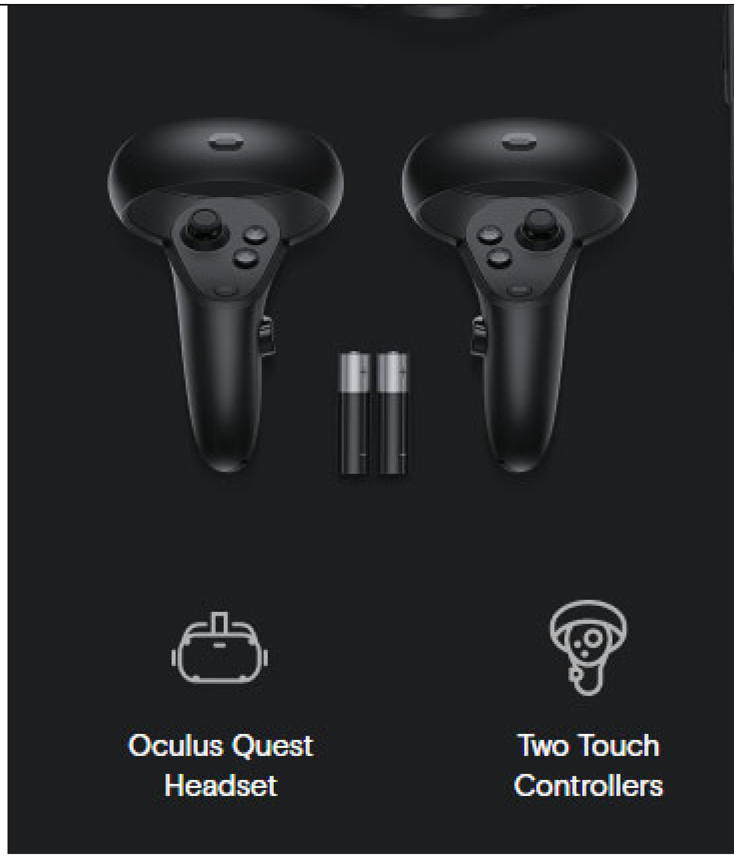
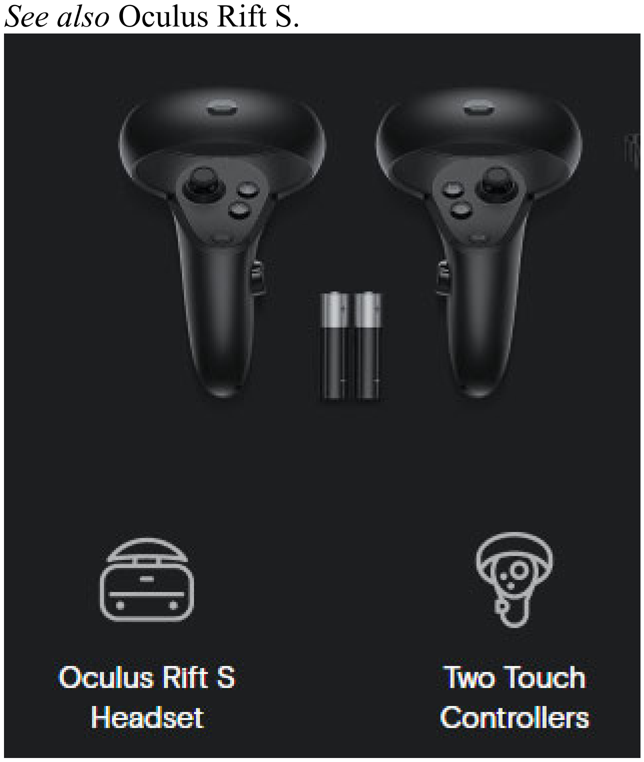
	See also Hand Tracking Deep Dive at 4:00–10:00.  *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

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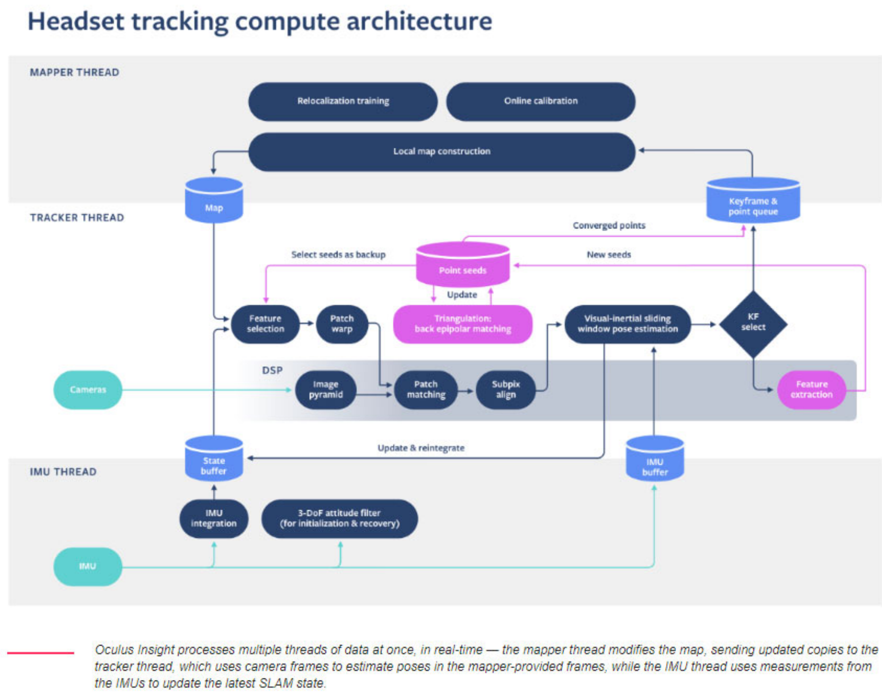

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To unlock the full potential of virtual reality (VR) and augmented reality (AR) experiences, the technology needs to work anywhere, adapting to the spaces where people live and how they move within those real-world environments. When we developed Oculus Quest, the first all-in-one, completely wire-free VR gaming system, we knew we needed positional tracking that was precise, accurate, and available in real time — within the confines of a standalone headset, meaning it had to be compact and energy efficient.

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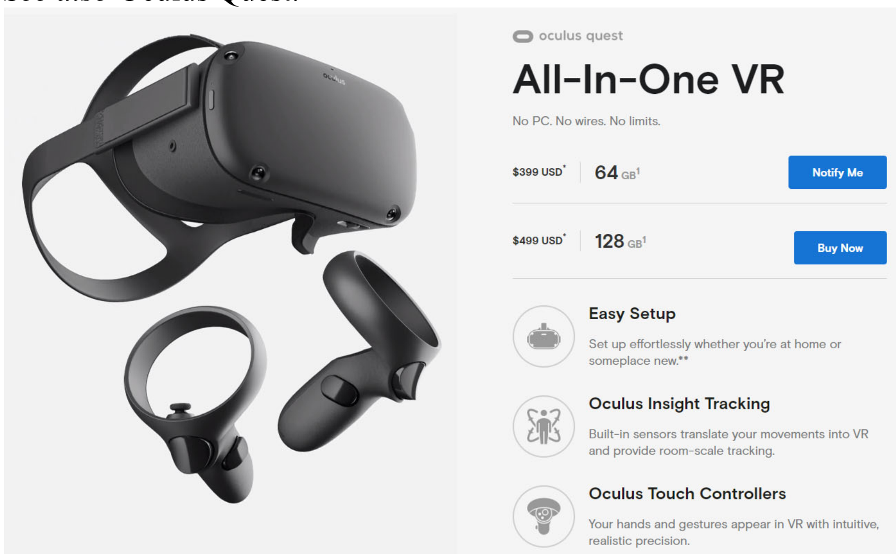

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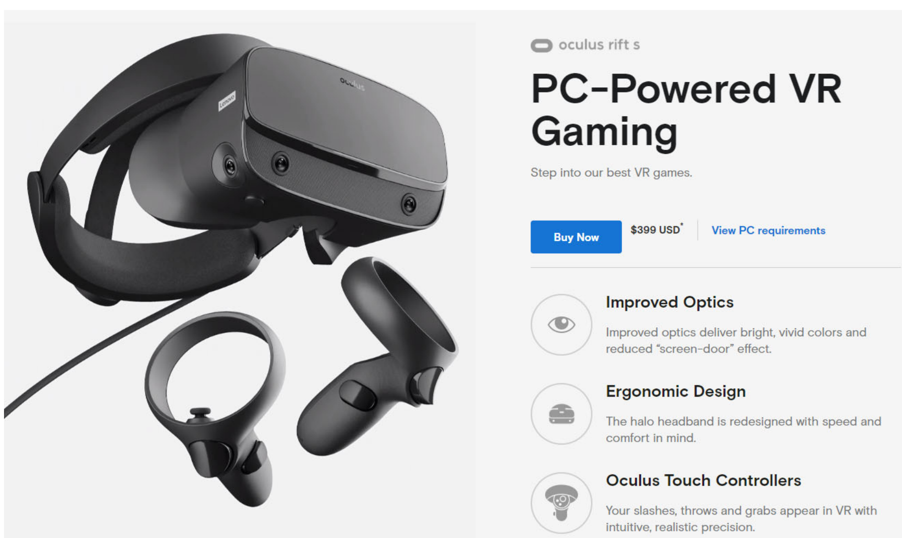


See also Lang.

Image courtesy BadVR, Jad Meouchy

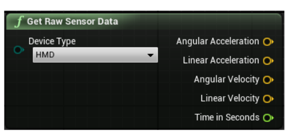
Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

See also Get Raw Sensor Data.

Overview

This blueprint reports raw sensor data from the headset, such as its angular acceleration or linear velocity. If the headset does not support a sensor data reading, then that result will return as zero.

Blueprint



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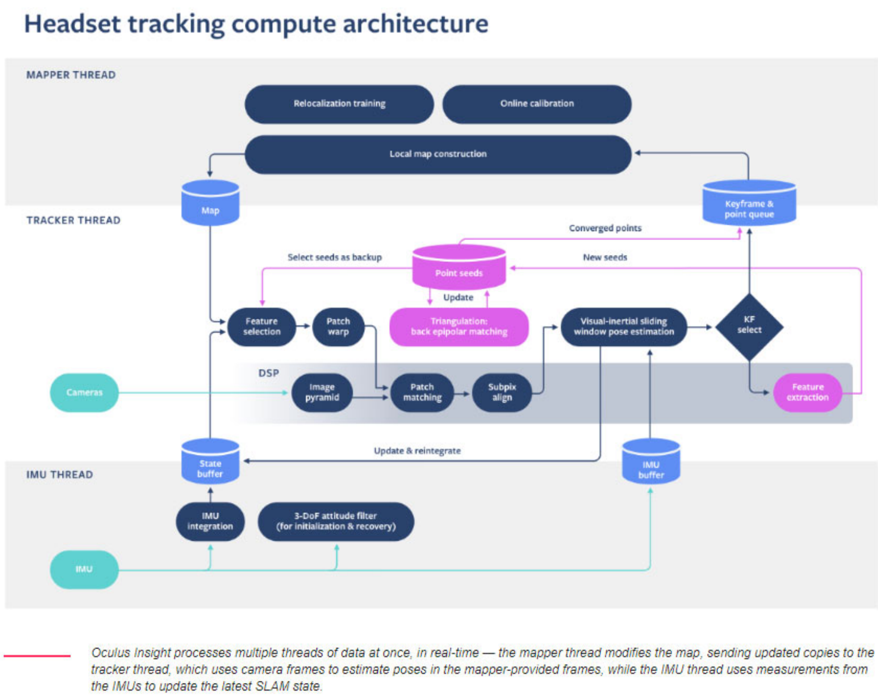

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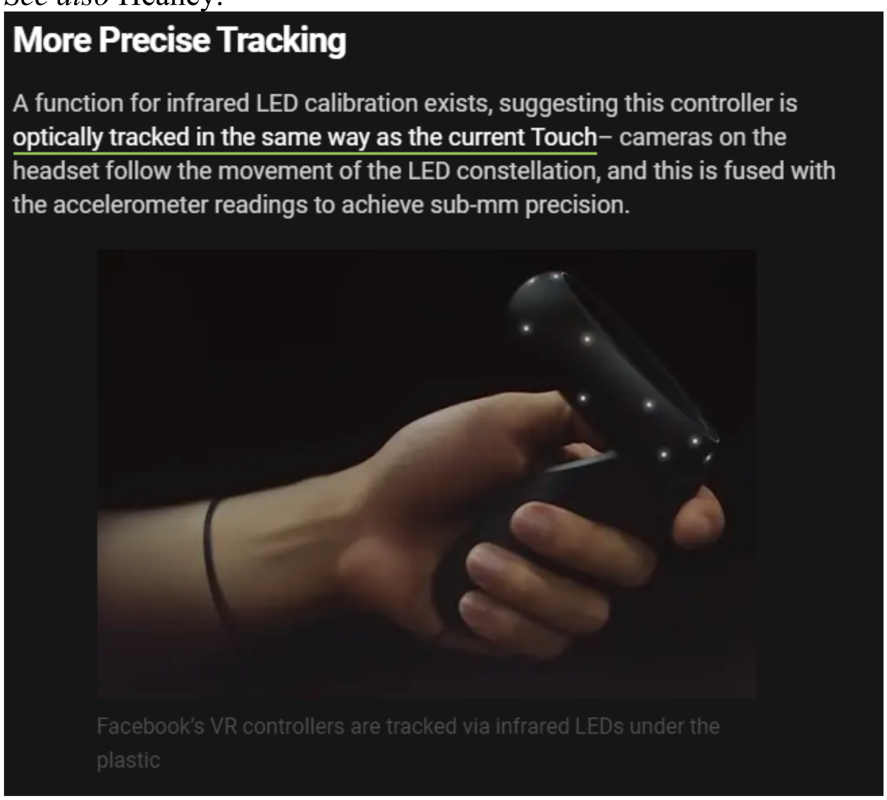

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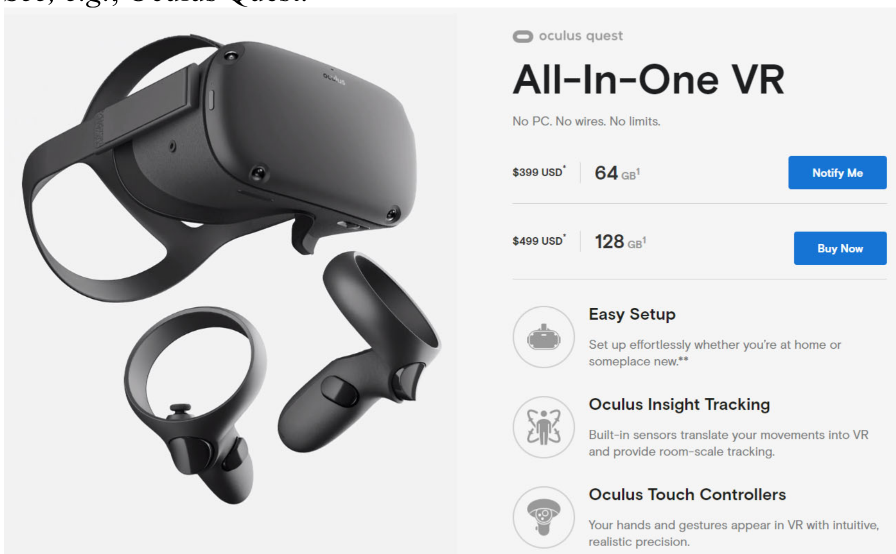

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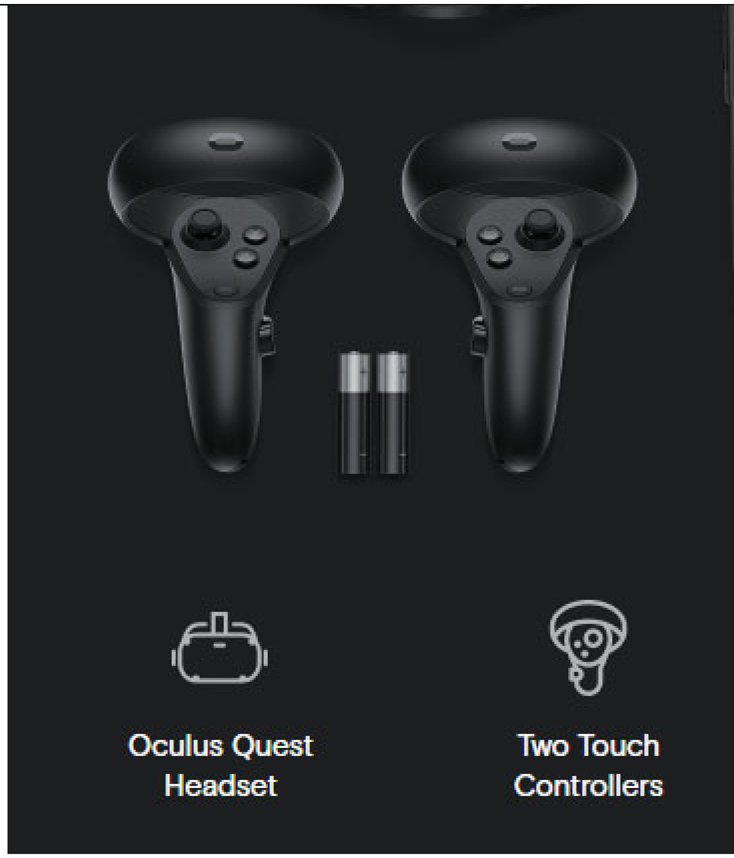
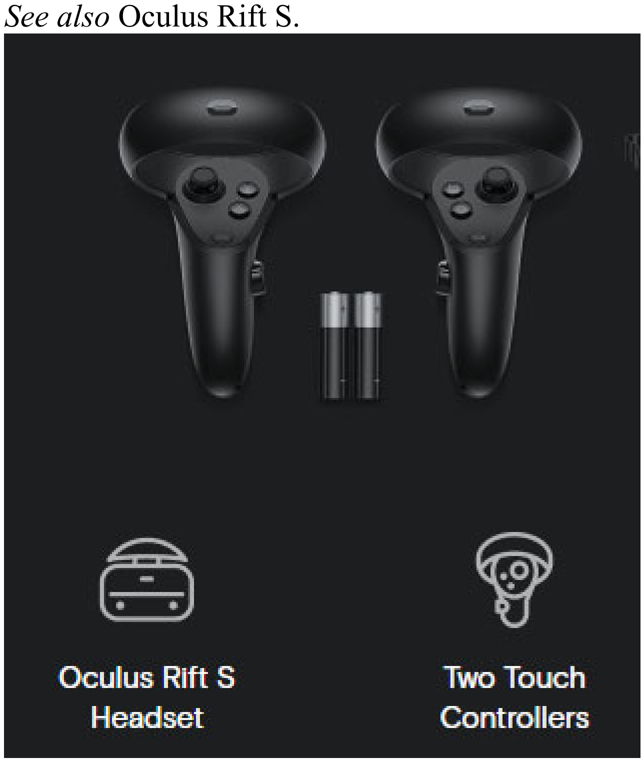
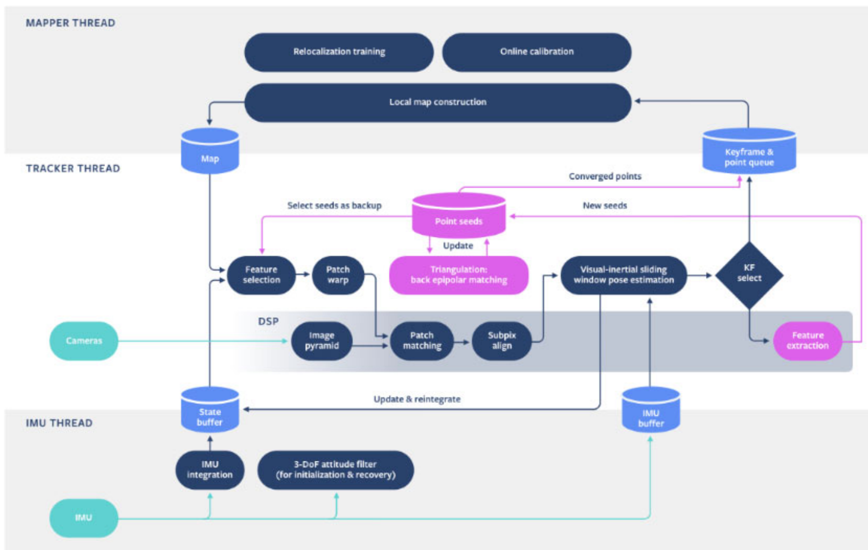
	 *See also* Oculus Rift S.  *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology …** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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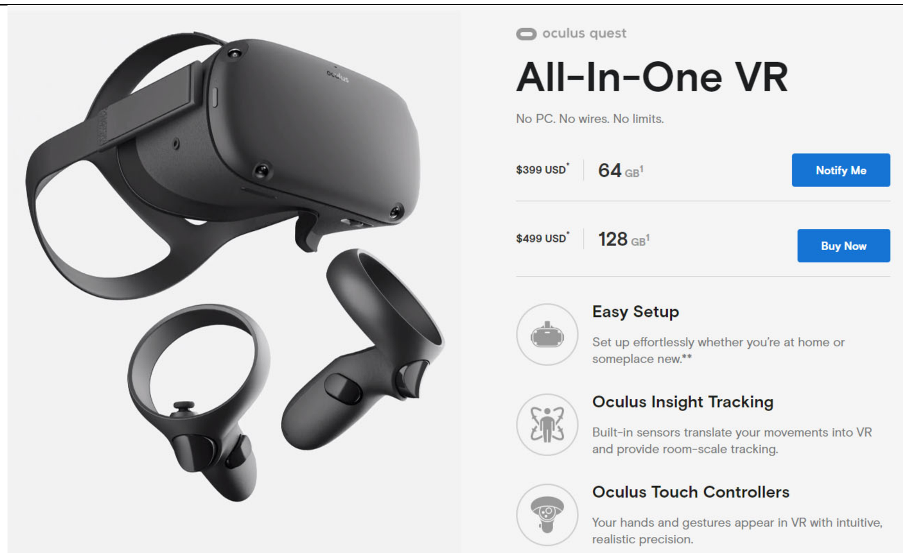
(30d) receive a measurement signal over the sensor interface,	In the Accused Products, the sensor module is configured to receive a measurement signal over the sensor interface. For example, the sensor module in the Accused Products (e.g., the headset and Oculus controller(s) and their associated software, including the Oculus Insight tracking system) is configured to receive a measurement signal (e.g., data from the cameras and IMUs in the headset and/or the IMUs in the Oculus controllers) over the sensor interface. *See, e.g.*, Oculus Quest.



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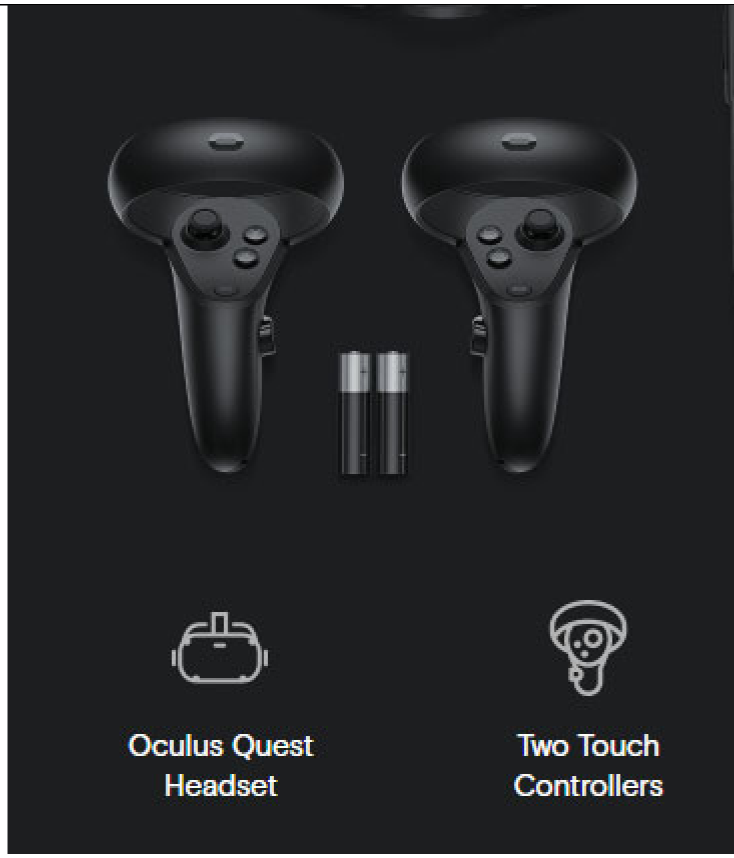
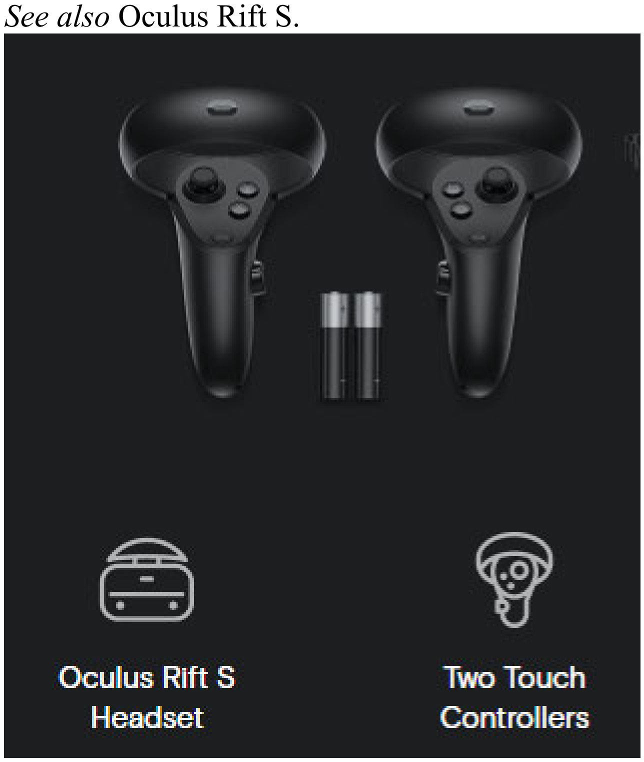
	 *See also* Oculus Rift S.  *See also From the Lab.*

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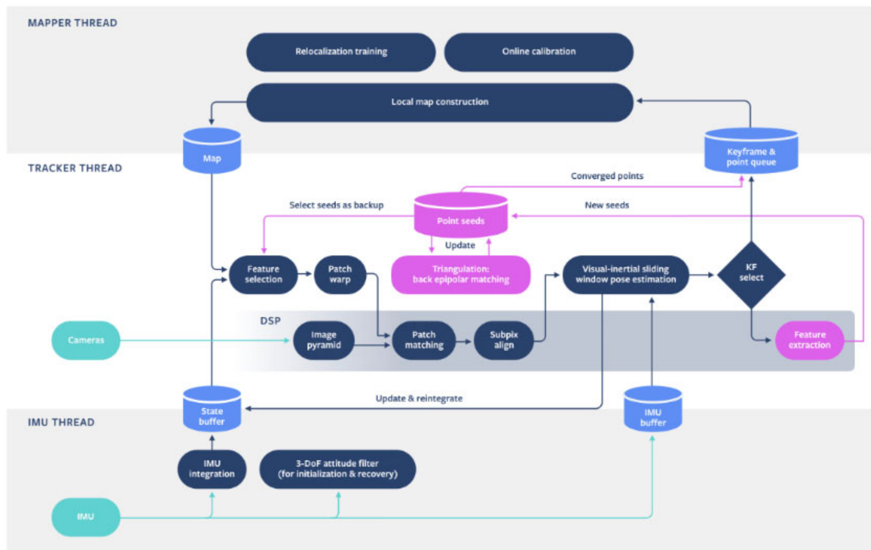

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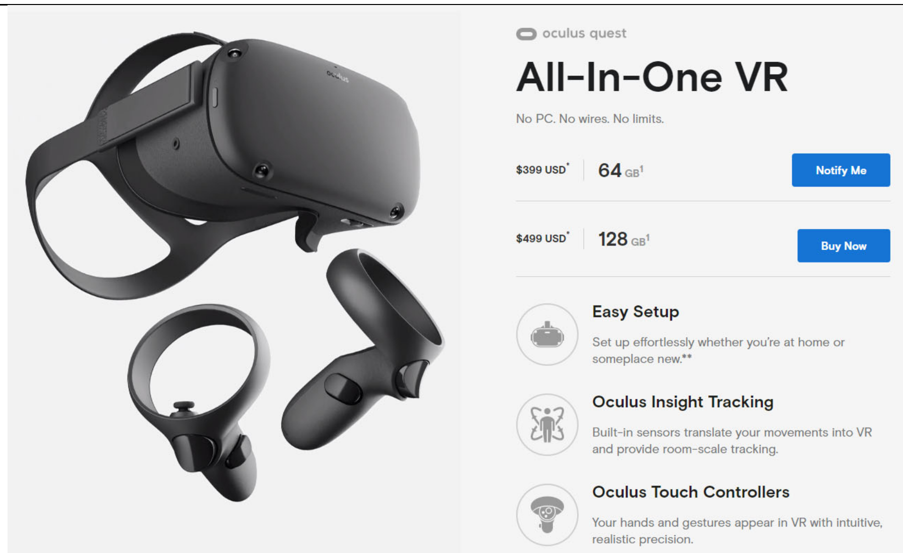

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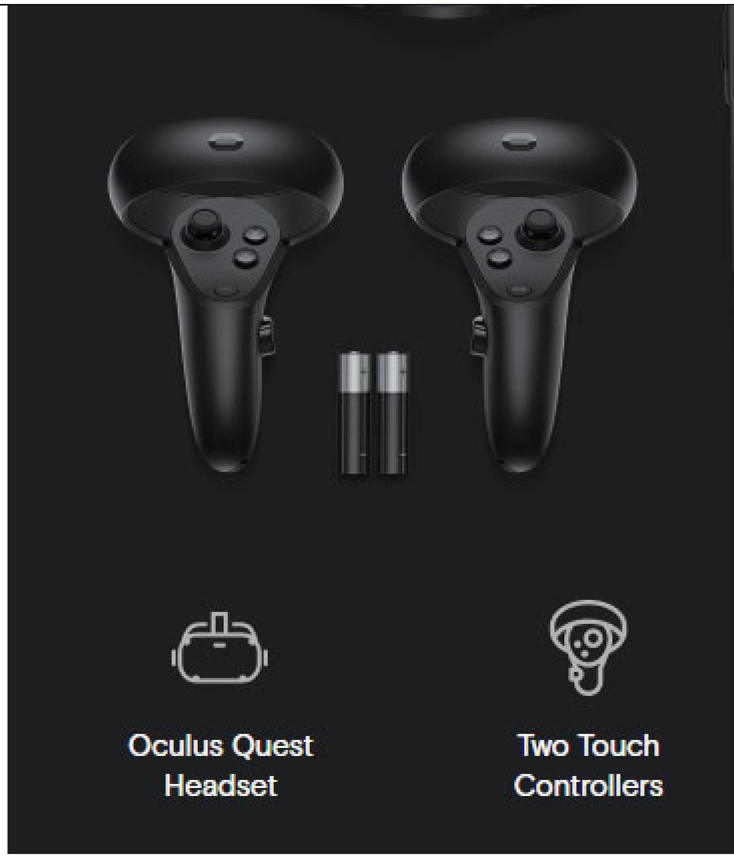
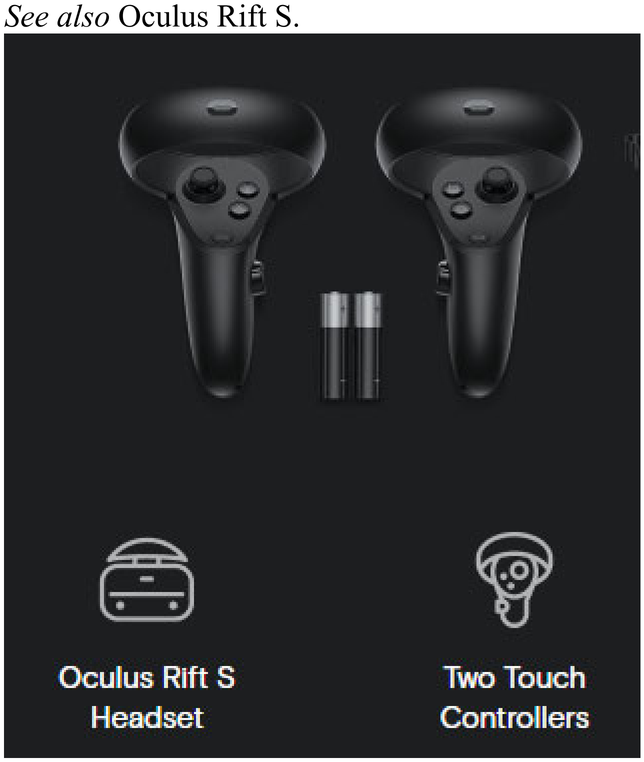
	 *See also* Oculus Rift S.  *See also From the Lab.*

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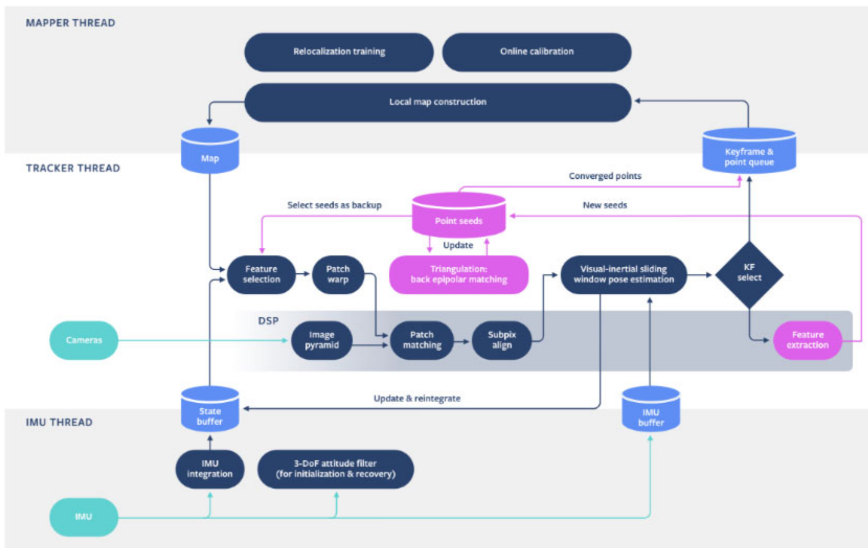

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Claim 31	
(31) The sensor module of claim 30 wherein the sensor module is configured to provide information over the communication interface related to an uncertainty in the measurement information.	*See supra* claim 30. Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, comprising a sensor module that is configured to provide information over the communication interface related to an uncertainty in the measurement information. For example, on information and belief and subject to discovery which has not yet occurred, the sensor module in the Accused Products (e.g., the headset and Oculus controller(s) and their associated software, including the Oculus Insight tracking system, and/or a computer or other external processor for the Oculus Rift S) is configured to provide information over the communication interface that includes data characterizing the uncertainty in the measurement information received from the measurement sensors (e.g., cameras and/or IMUs within the headset, and/or the IMUs within the Oculus controllers). Facebook encourages, directs, or promotes users to use the sensor module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the sensor module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and

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See, e.g., Hand Tracking.

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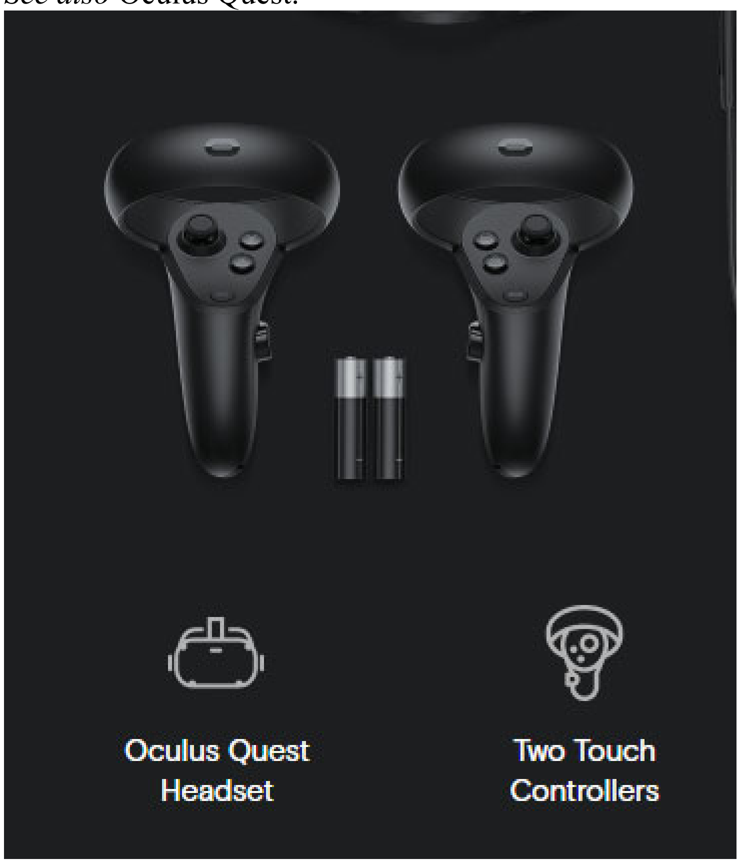
	 *See also* Oculus Quest.  *See also* Oculus Rift S.

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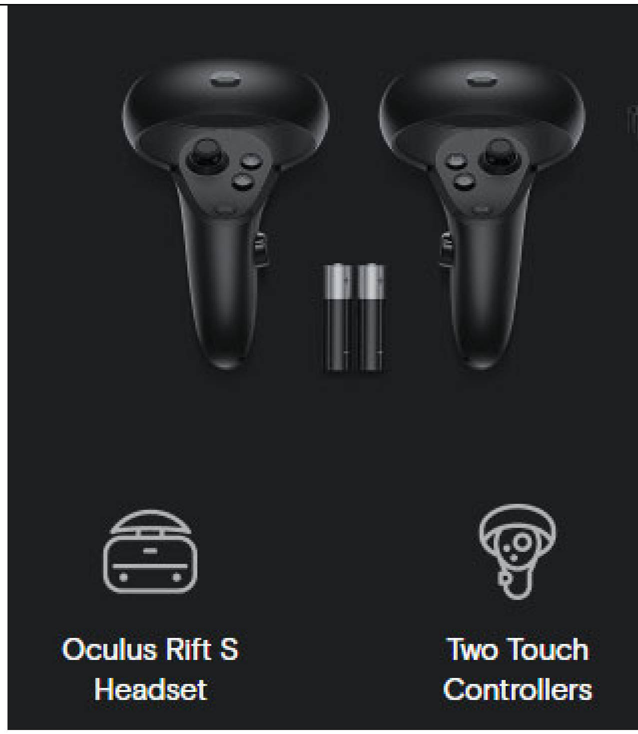

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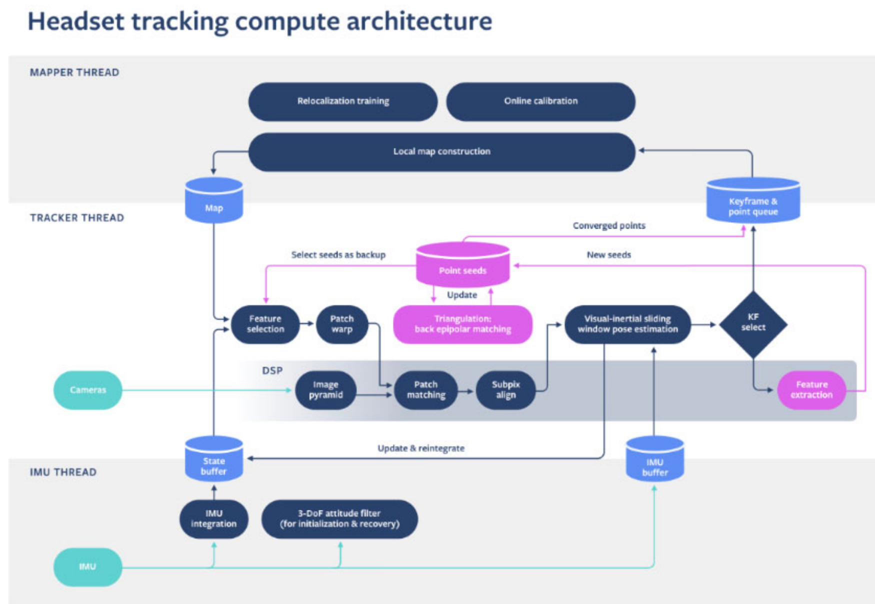
<tr><td></td><td>

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Facebook encourages, directs, or promotes users to use the sensor module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the sensor module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

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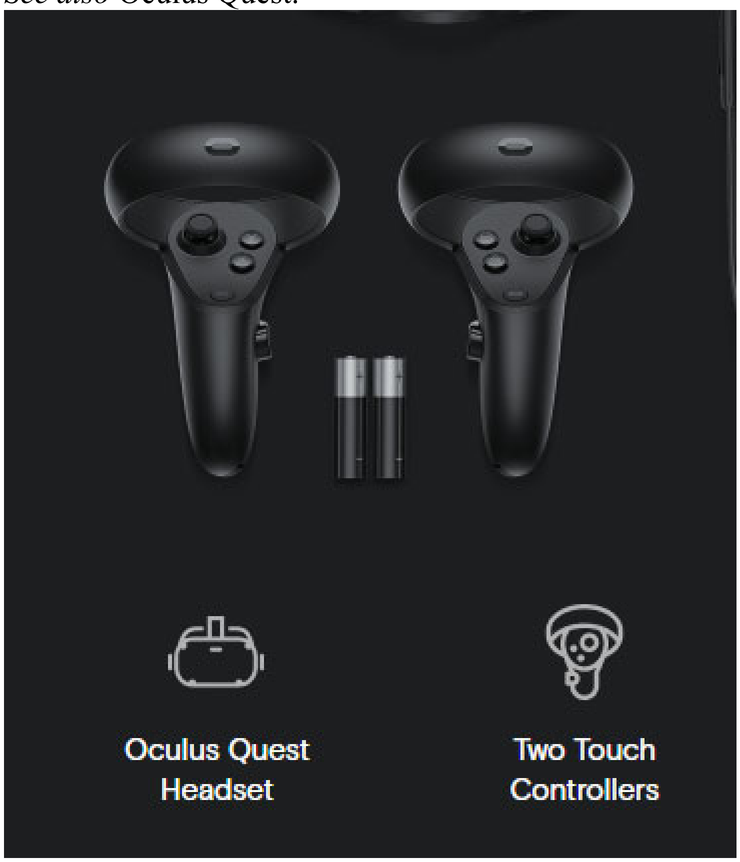
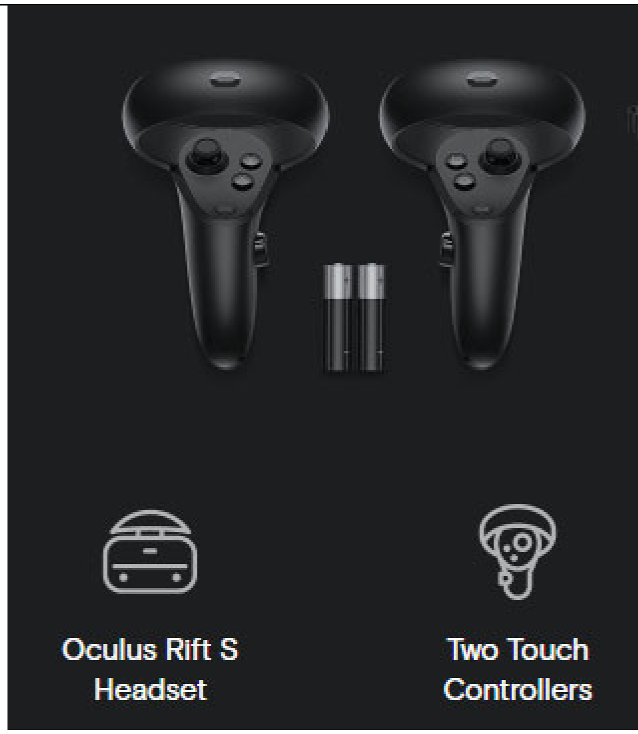
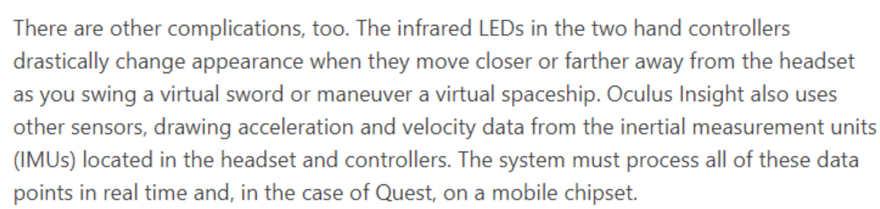
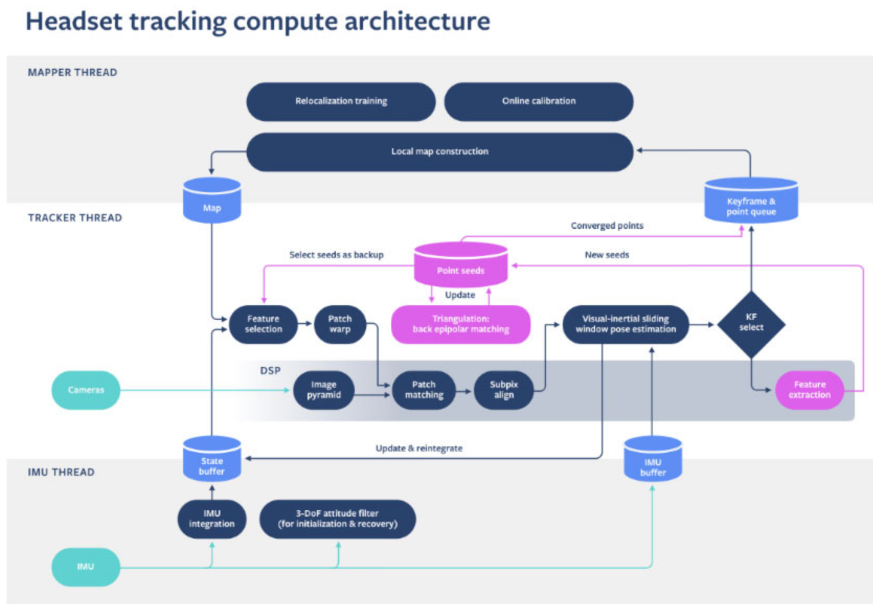
	 *See also* Oculus Quest.  *See also* Oculus Rift S.

	 *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

	Taking SLAM technology ... The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.* SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments. Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR. *See also id.*

	 *Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.*
Claim 33	
(33a) A method comprising: enumerating a set of sensing elements available to a tracking system that includes an estimation subsystem that estimates a position or orientation of an object;	Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. In particular, Facebook encourages, directs, or promotes users to enumerate a set of sensing elements (e.g., cameras and/or IMUs within the HMD, the IMUs within the Oculus controller(s), and/or the Oculus controller(s)) available to a tracking system (e.g., the headset and/or controllers) that includes an estimation subsystem (e.g., the Oculus Insight tracking system) that estimates a position or orientation of an object (e.g., the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. For example, the Accused Products enumerate sensing elements available to the headset and/or controllers, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs). As a further example, when the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation). *See, e.g.*, *From the Lab*.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

See also Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

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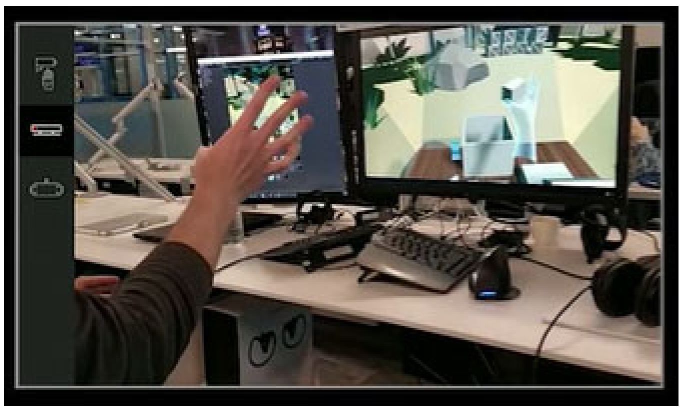
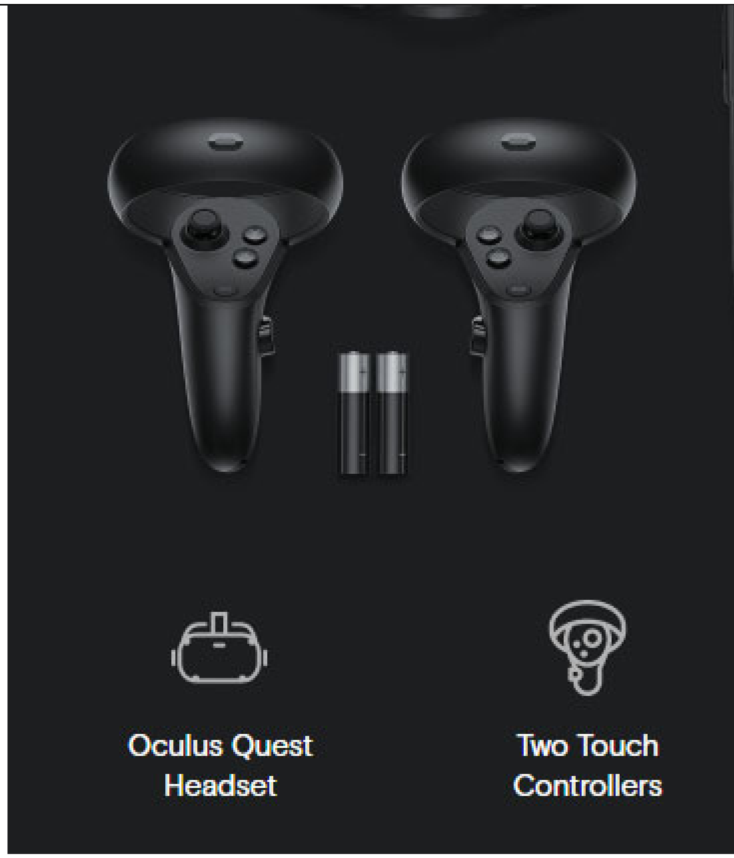
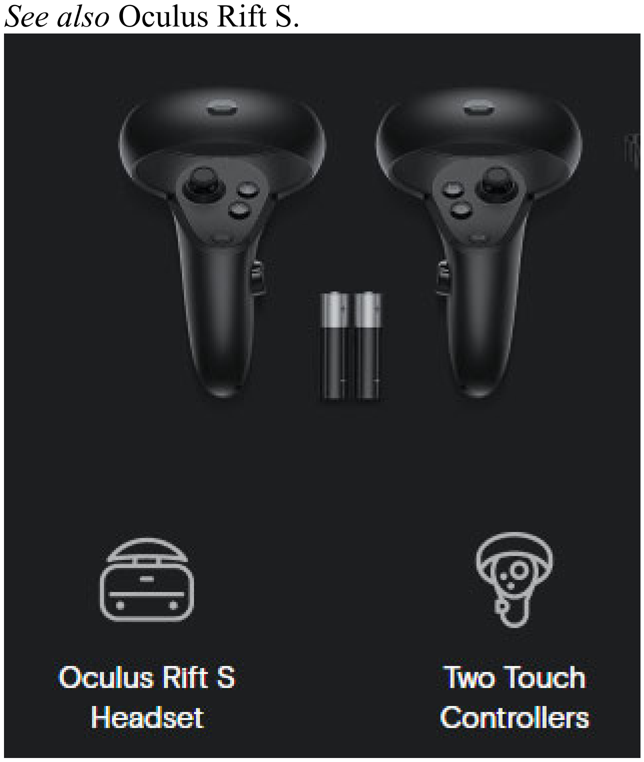
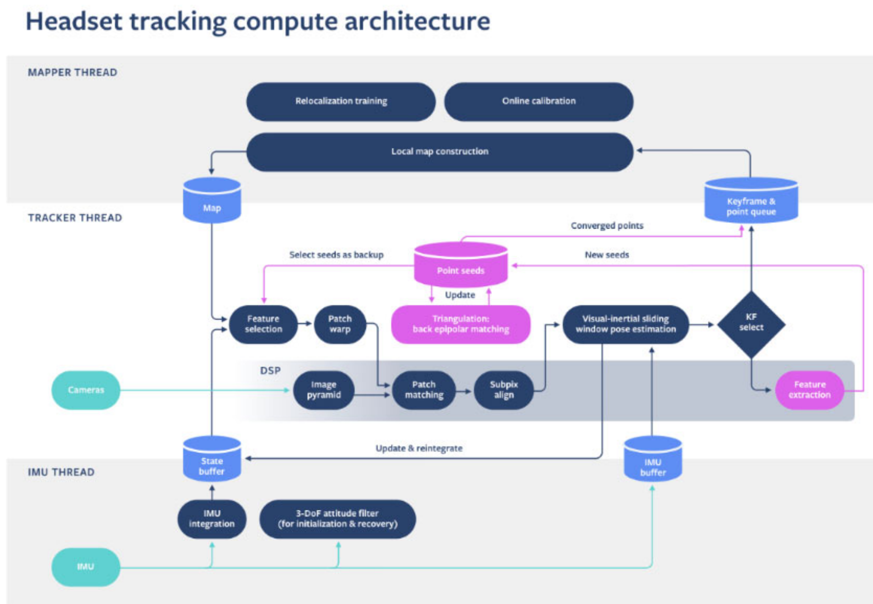
	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

	Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: *See also id.* At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM. *See also From the Lab.* "We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski. Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset. Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up. "With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also id.*

	 *Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.* *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

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- 3-Axis Gyroscope with Programmable FSR of ±500dps, ±100dps, ±2000dps and ±4000dps
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- MEMS structure hermetically sealed and bonded at wafer level
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See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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New comments cannot be posted and votes cannot be cast

SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

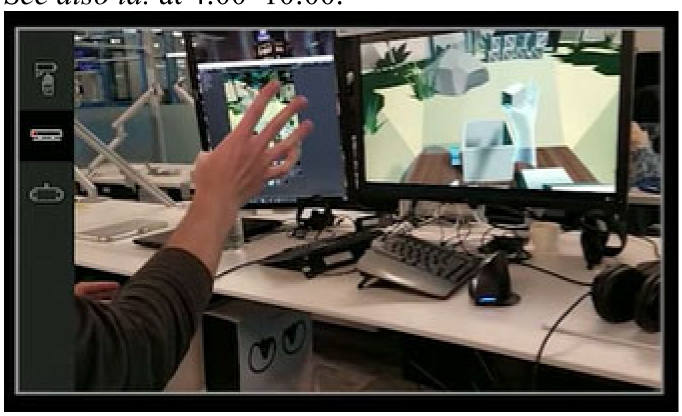
MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

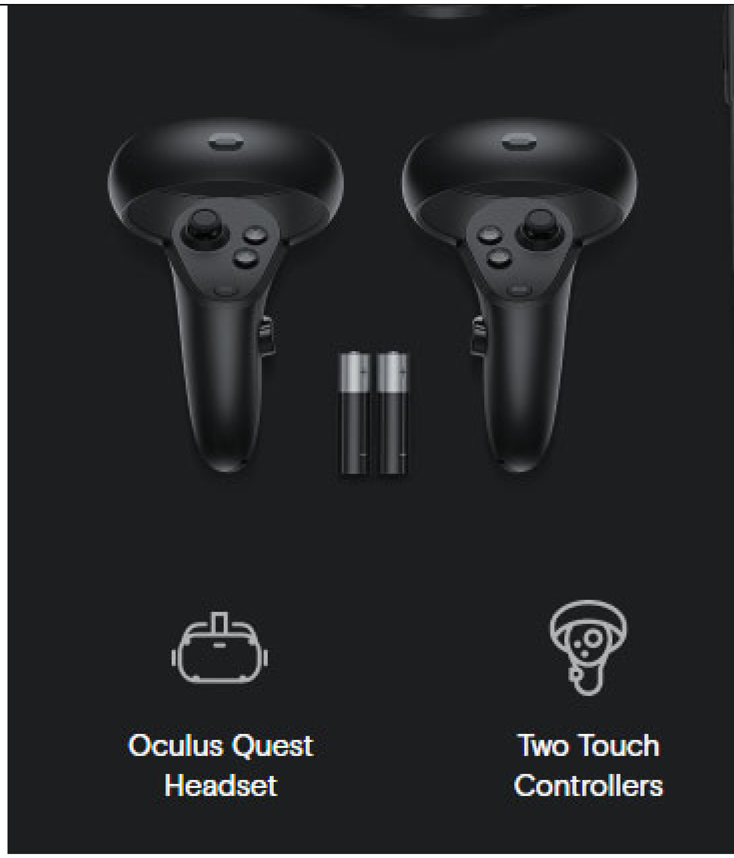
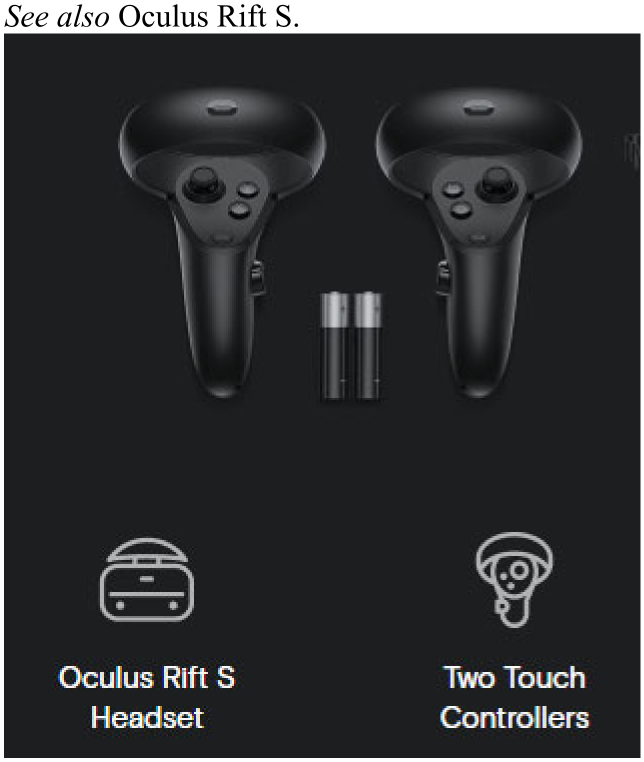
stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

(33b) providing parameters specific to the set of sensing elements to the tracking system to enable the estimation subsystem to be configured based on the parameters specific to the set of sensing elements; and	Facebook encourages, directs, or promotes users to use the Accused Products to provide parameters specific to the enumerated sensing elements (e.g., the characteristics of the sensing elements and/or the number of controllers in use at a particular time) to the tracking system to enable the estimation subsystem (e.g., the Oculus Insight tracking system) to be configured based on the parameters specific to the enumerated sensing elements. For example, in the Accused Products, parameters specific to the sensing elements enumerated, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), are provided to the tracking system so that the Oculus Insight tracking system can be configured based on parameters specific to the sensing elements enumerated. As a further example, when the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s) and/or the Oculus controller(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation). *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands. **Designing for Hands** 

	See also Hand Tracking Deep Dive at 4:00–10:00.  *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

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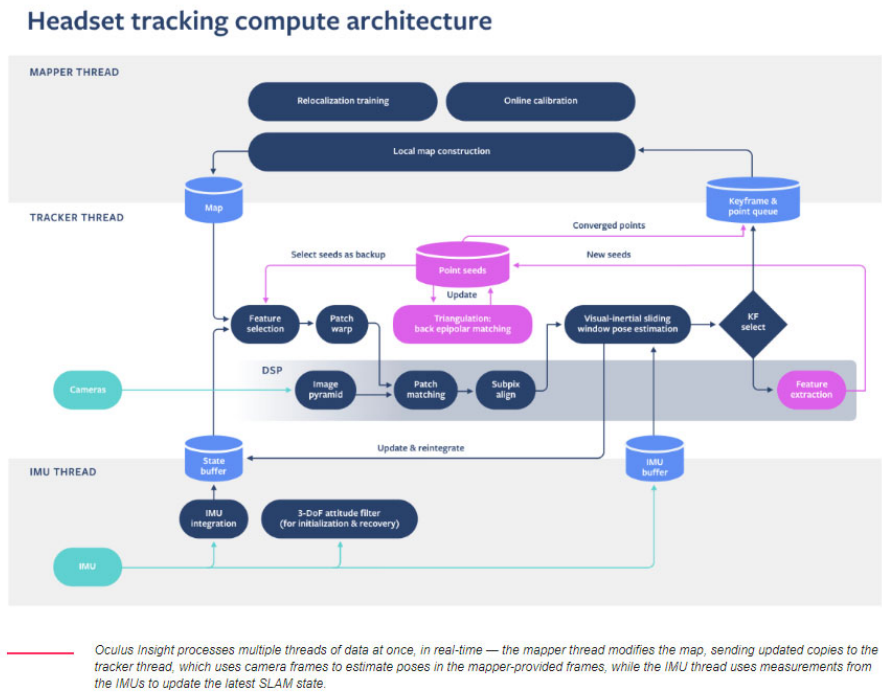

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META 1012
META V. THALES

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	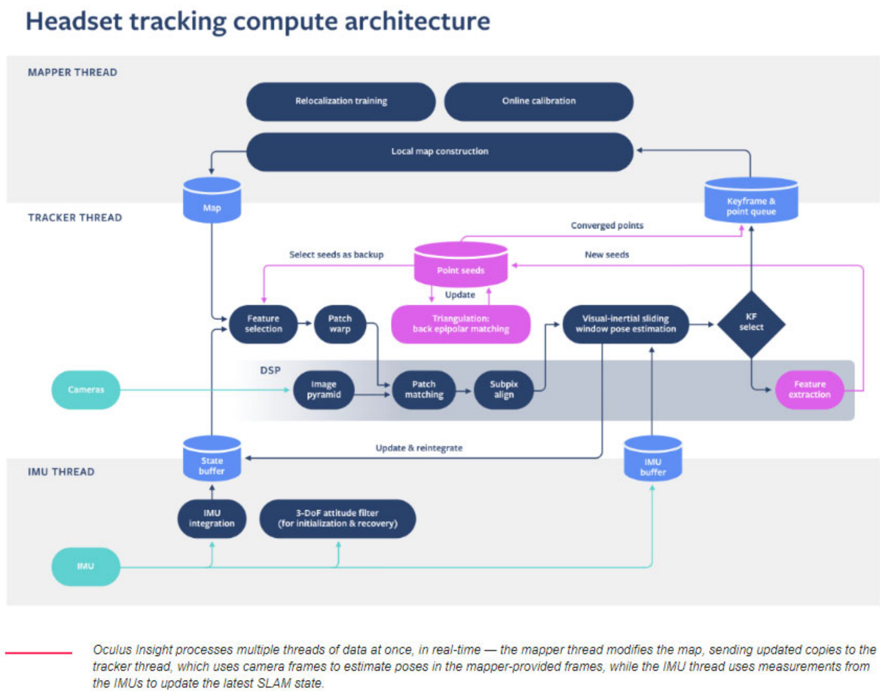 *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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See also Expert Mode at 2:36.

Claim 34	
(34) The method of claim 33, further comprising selecting a pair of sensing elements from the sequence of candidates, the selected pair of sensing elements being ready to make a measurement at the time of selection of the pair or at a predefined time after the time of selection of the pair, the selected pair having highest expected utility of a measurement among the sequence of candidates.	*See supra* claim 33. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 33, further comprising selecting a pair of sensing elements from the sequence of candidates, the selected pair of sensing elements being ready to make a measurement at the time of selection of the pair or at a predefined time after the time of selection of the pair, the selected pair having highest expected utility of a measurement among the sequence of candidates. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products select a pair of sensing elements (e.g., the camera on the headset and an infrared LED, IMUs, and/or other sensors on an Oculus controller) that are ready to make a measurement at the time of selection based on the pair having the highest expected utility of a measurement among a sequence of candidate pairs of sensing elements (e.g., the camera on the headset and a marker on the user's hand). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

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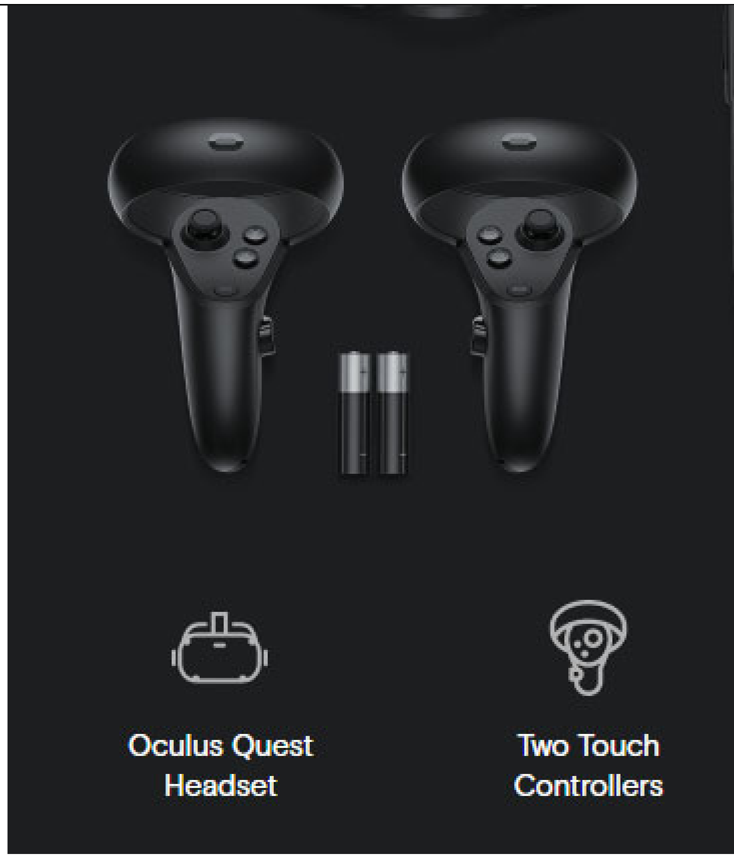
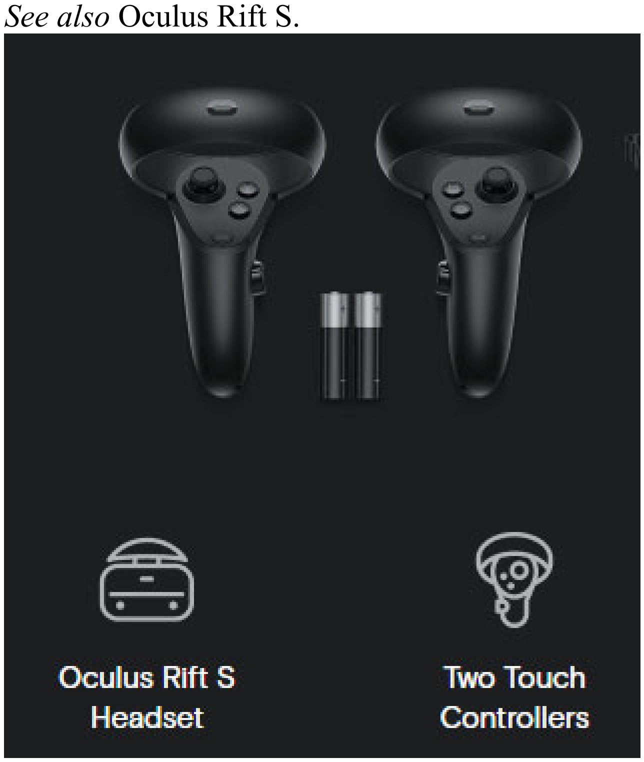
	 *See also* Oculus Rift S.  *See also Powered by AI*.

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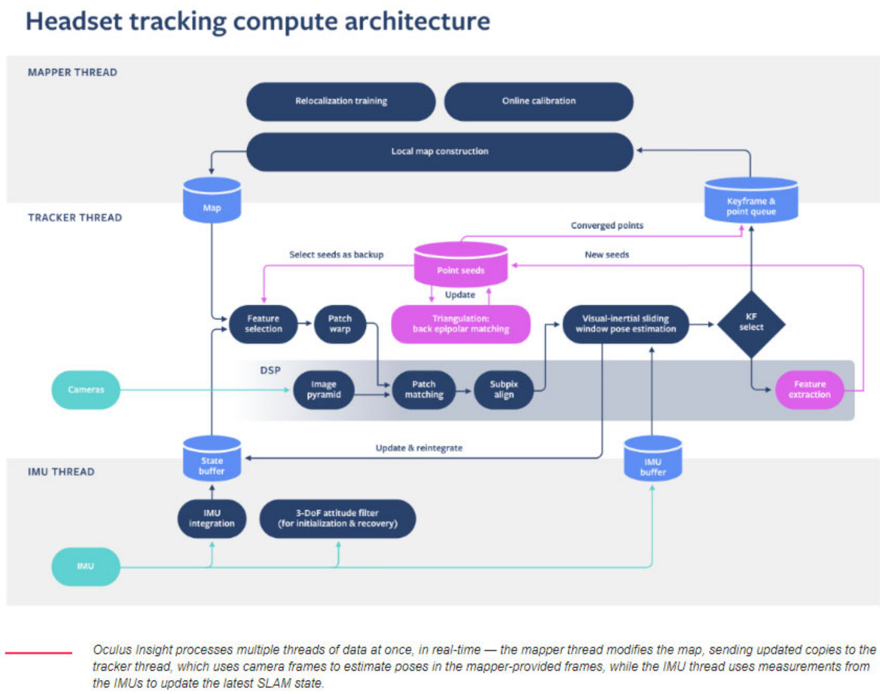

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META 1012
META V. THALES

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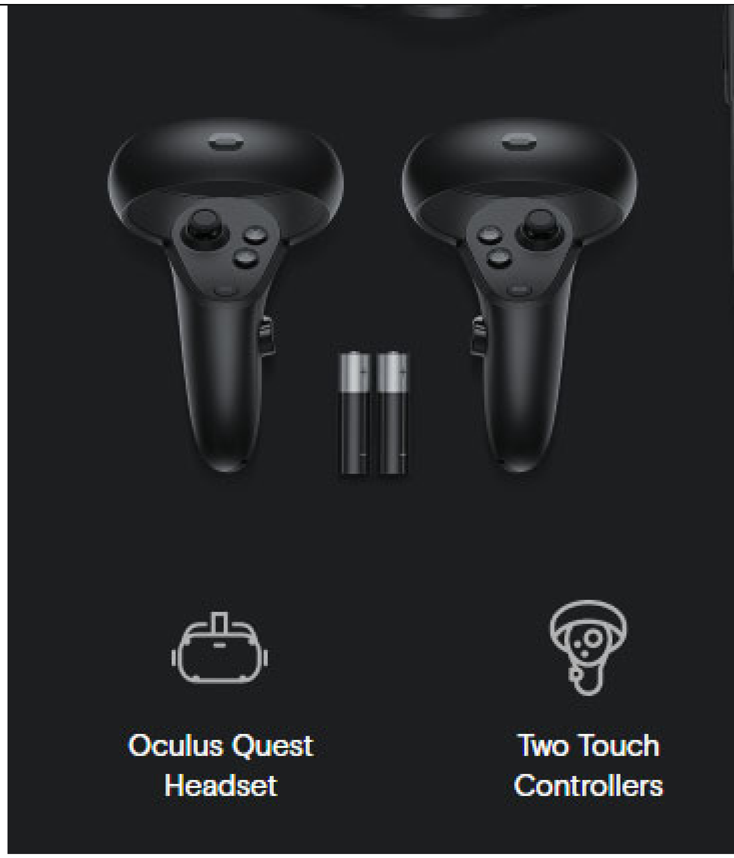
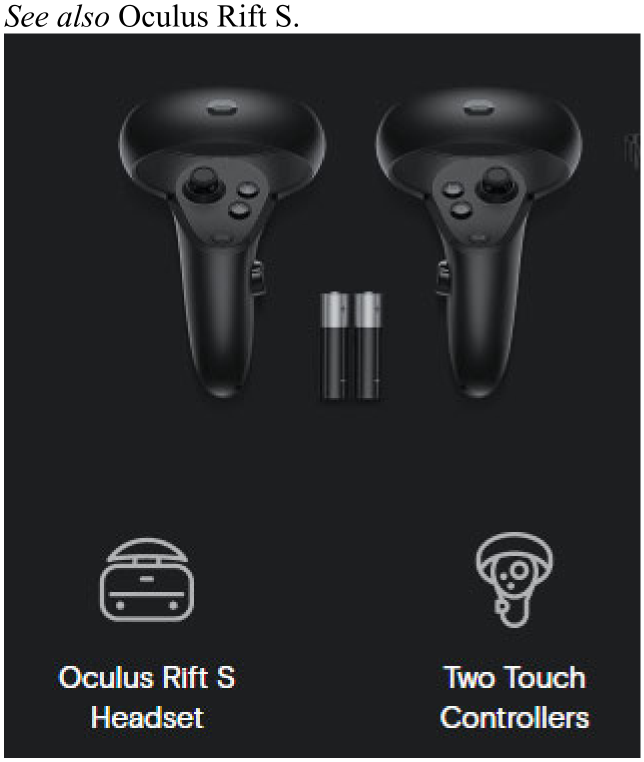
	 *See also* Oculus Rift S.  *See also Powered by AI*.

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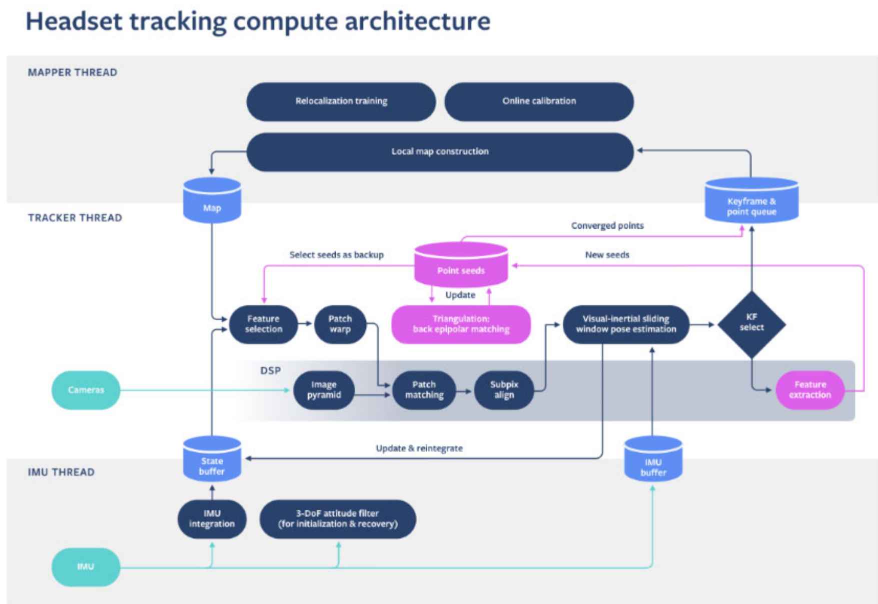

Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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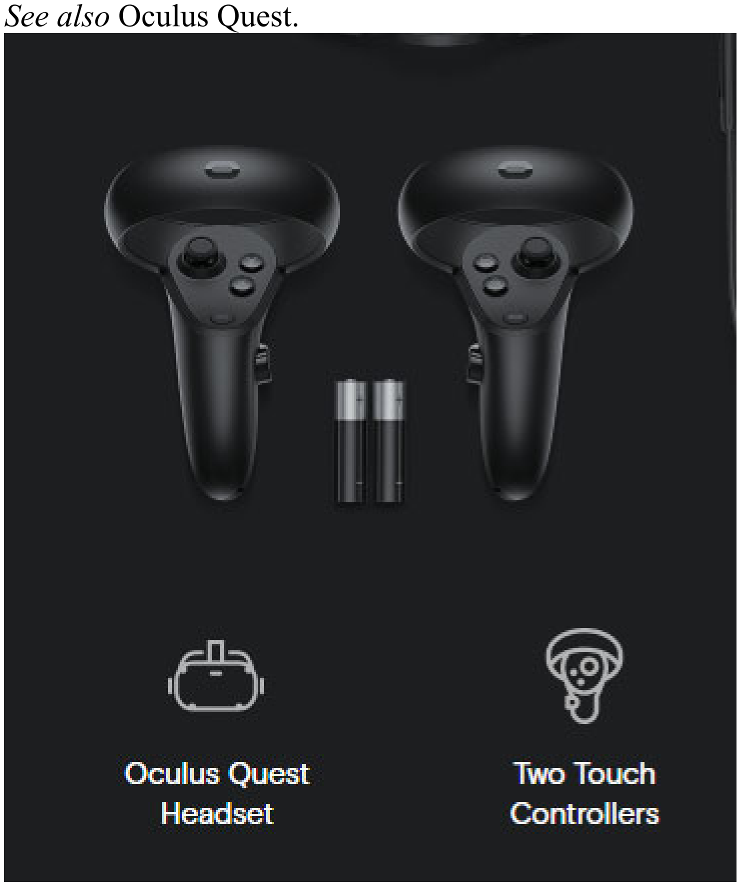
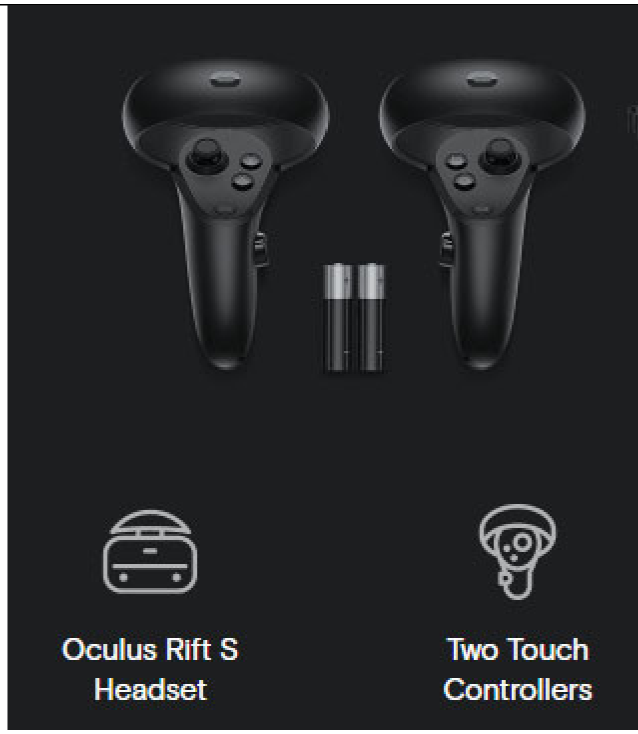
(35) The method of claim 35 wherein the target comprises a natural feature in an environment.	*See supra* claims 33, 35. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 35 in which the target comprises a natural feature in an environment (e.g., landmarks like the corners of furniture or the patterns on the floor). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Quest.  *See also* Oculus Rift S.

META 1012
META V. THALES

	 *See also Powered by AI.* Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: *See also Powered by AI.* At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM. *See also Powered by AI.*

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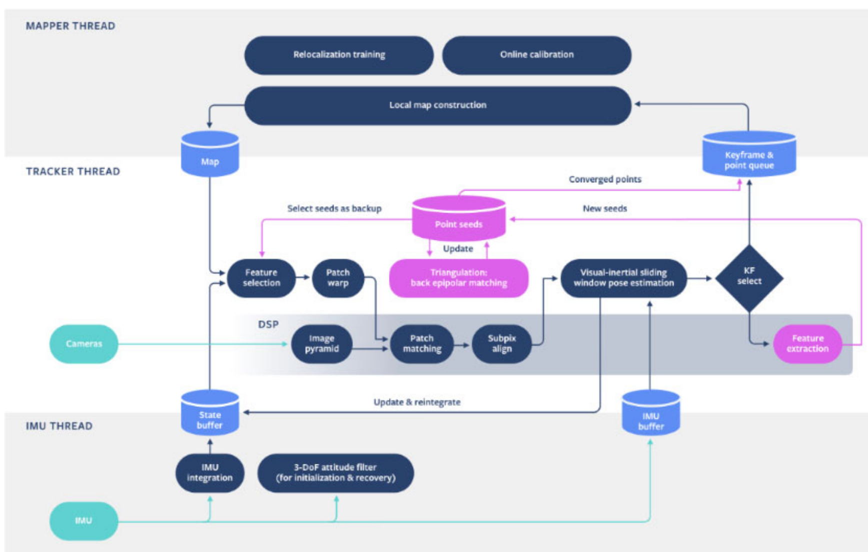
headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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<td colspan="2">Claim 44</td>
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<td>(44a) A method comprising: estimating a calibration parameter of a sensing element that is either a sensor or a target, the sensing element being fixed either to an environment or to an object being tracked;</td>
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Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. For example, the Accused Products take measurements to use for calibration, including with respect to the cameras and/or IMUs in the headset, and/or the IMUs in the Oculus controller(s), which are sensors or targets and which are fixed to the user's head, the user's hand(s), and/or the Oculus controller(s).

The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

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See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

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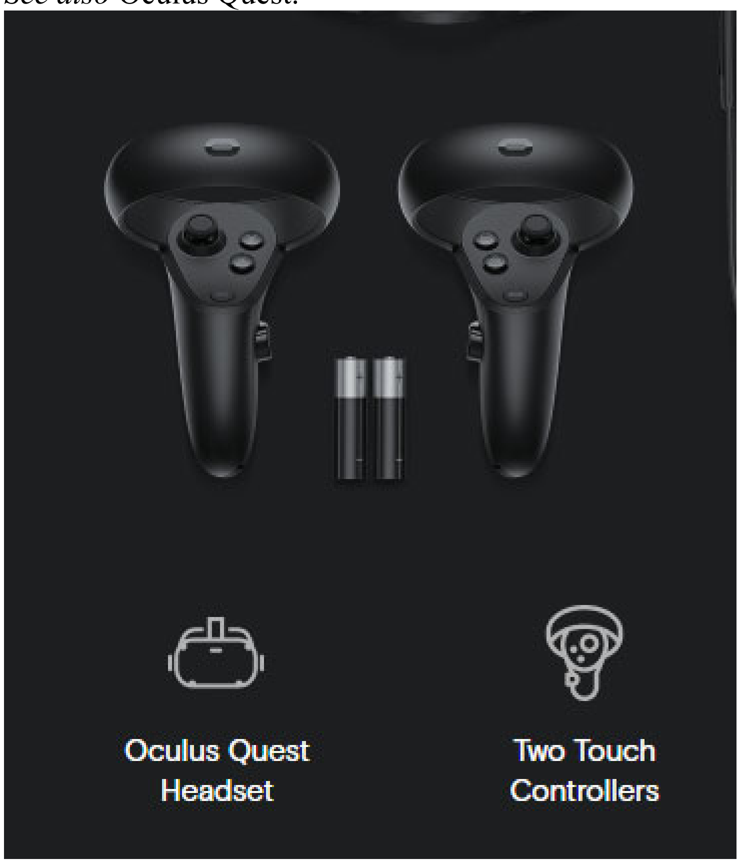
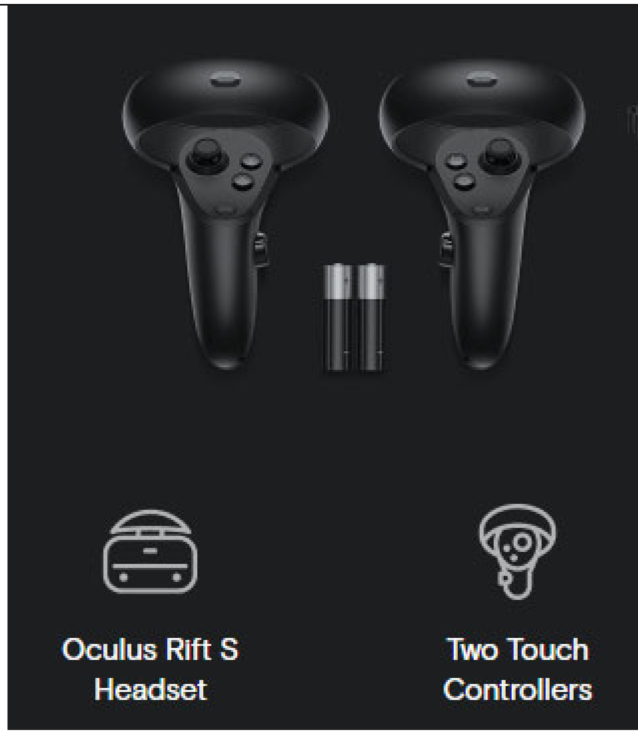
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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	Taking SLAM technology ... The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.* SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments. Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR. *See also id.*

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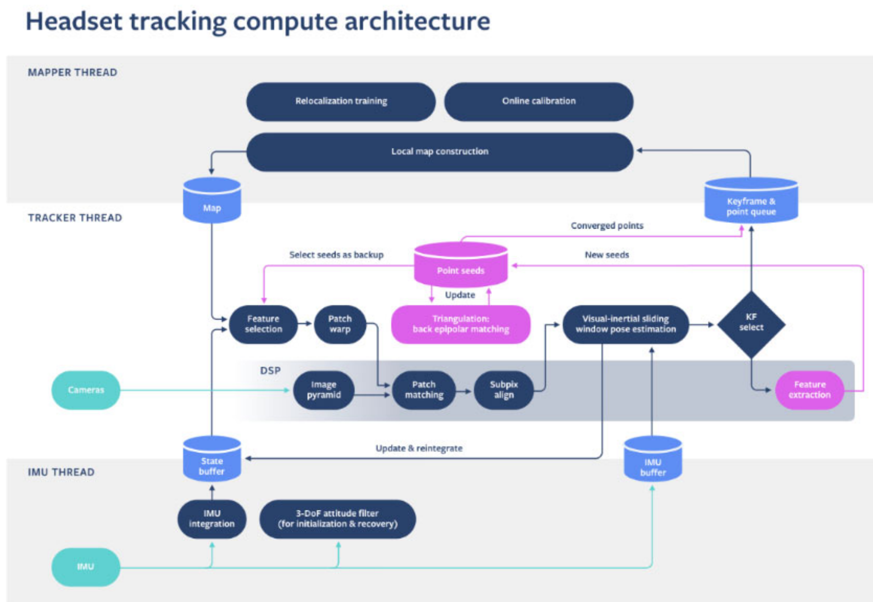

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Facebook encourages, directs, or promotes users to use the Accused Products to determine whether the sensing element is the sensor or the target. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products determine whether the cameras and/or IMUs in the headset, and/or the IMUs in the Oculus controller(s), are the sensor or the target. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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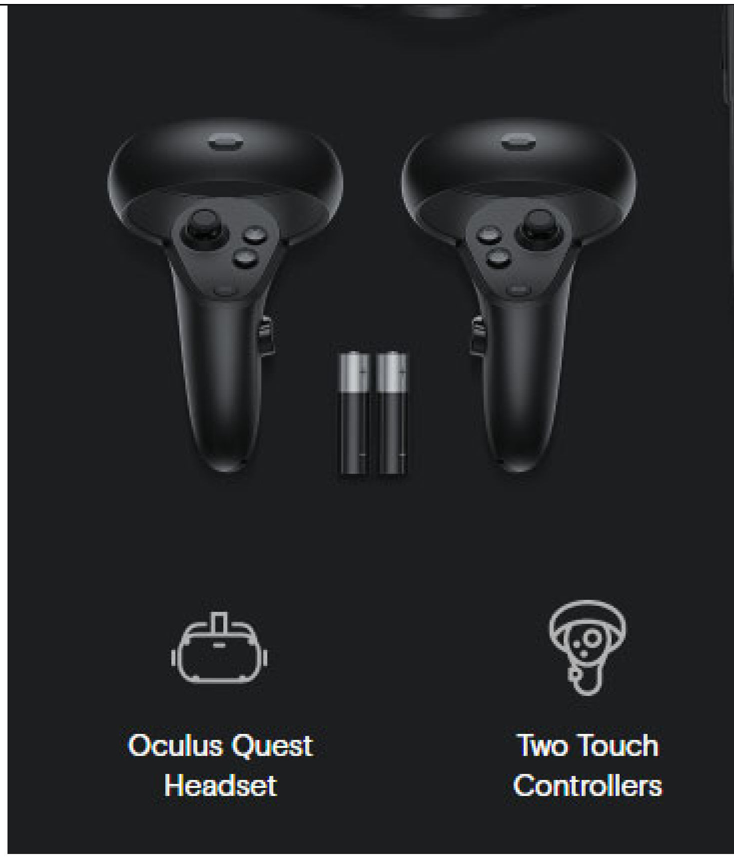

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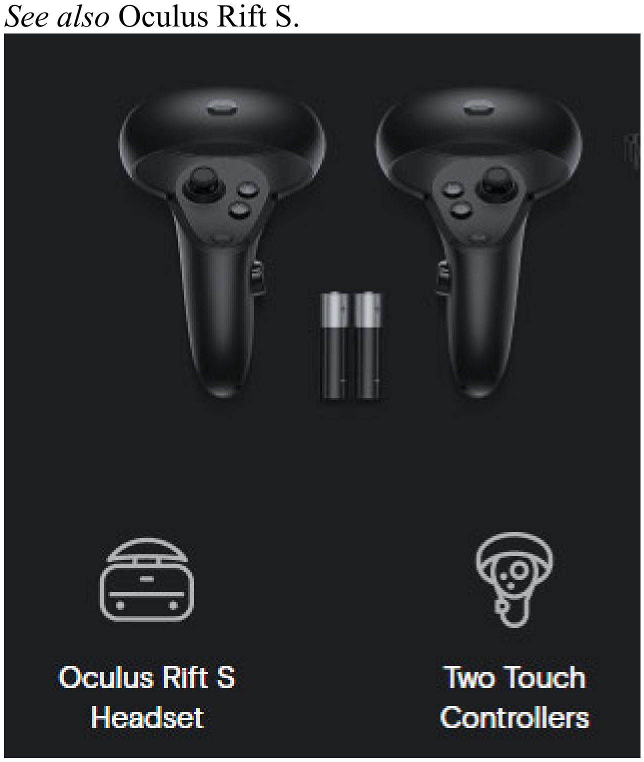

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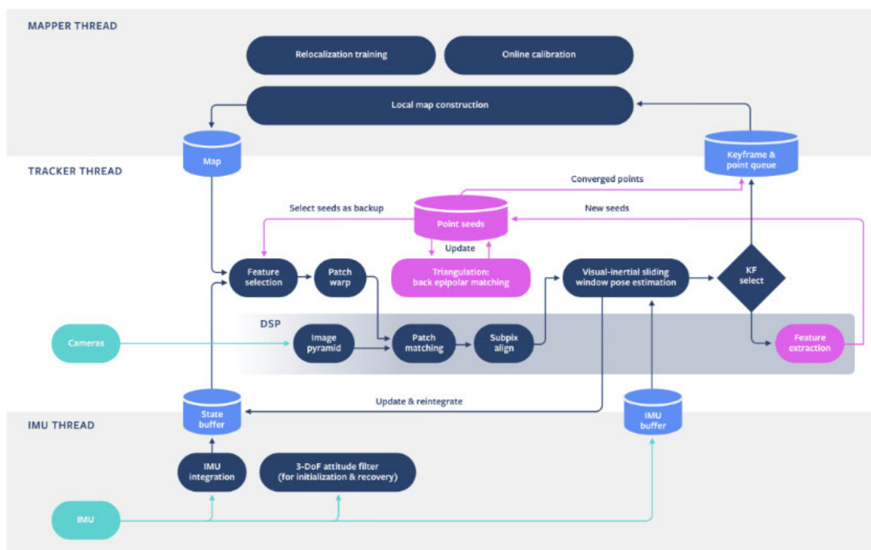
Headset tracking compute architecture



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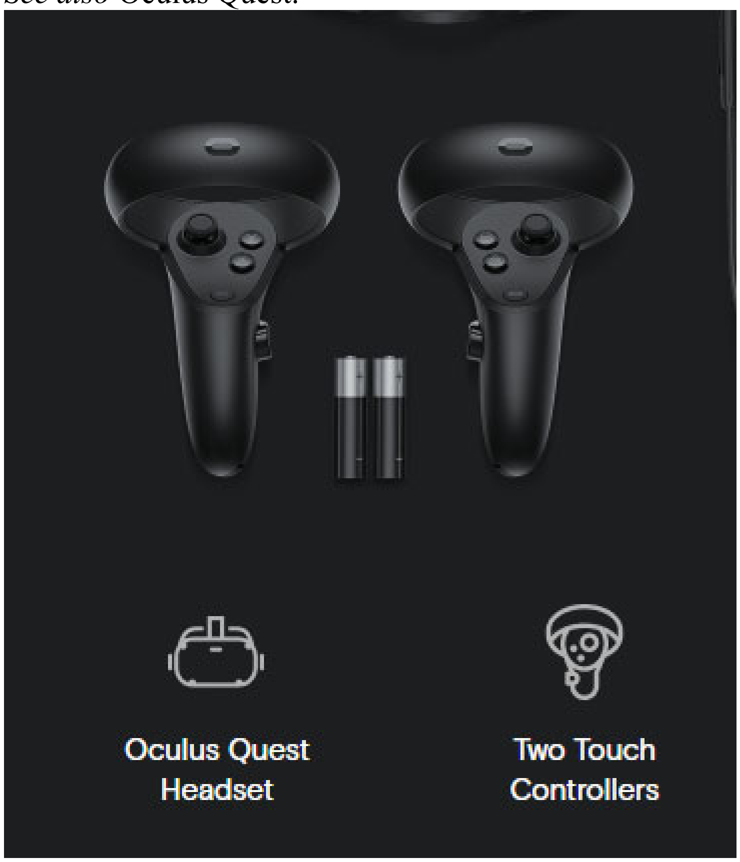
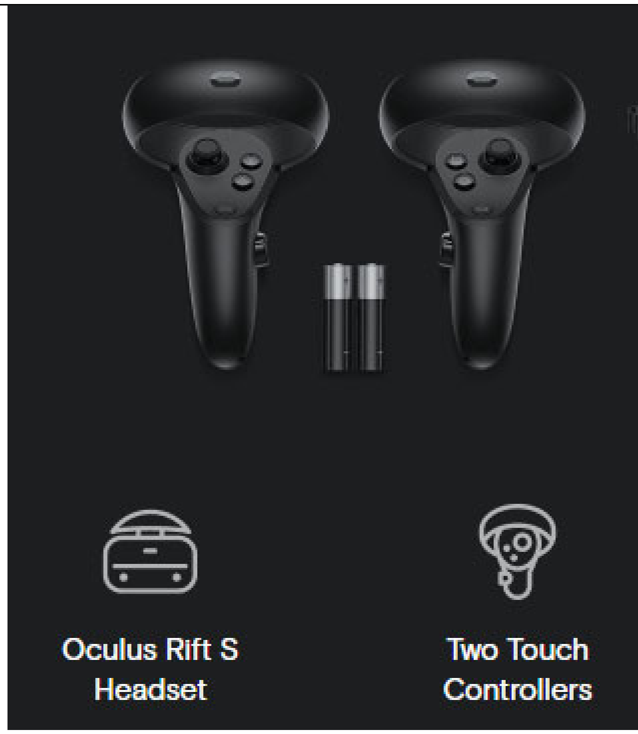
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



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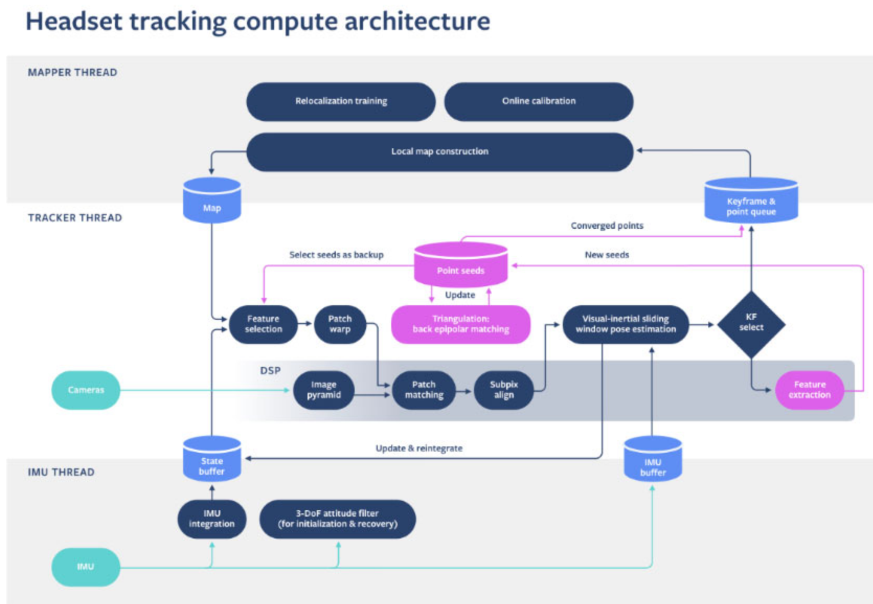
<tr><td></td><td>

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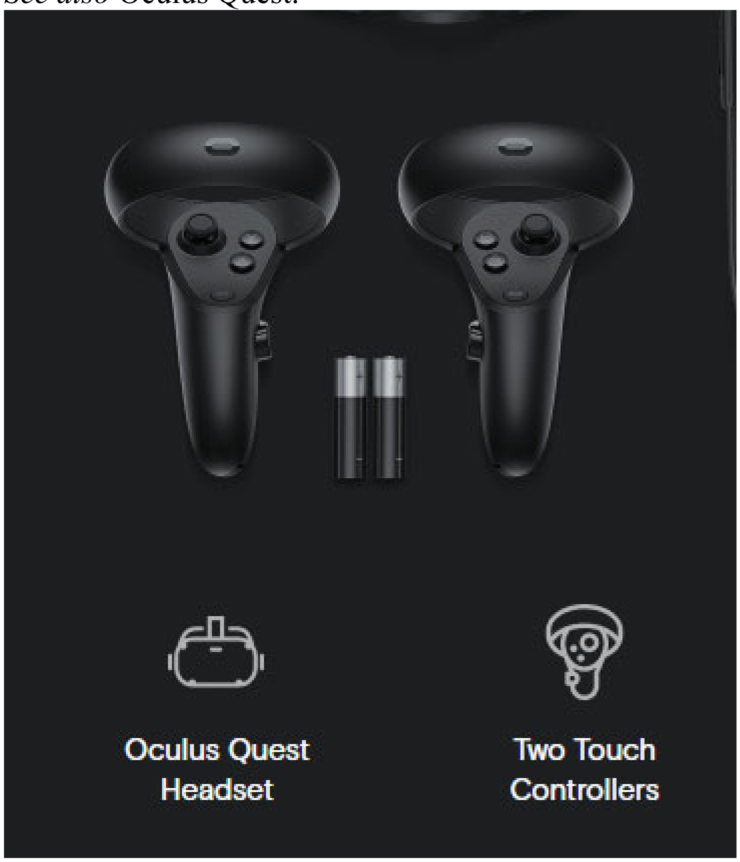
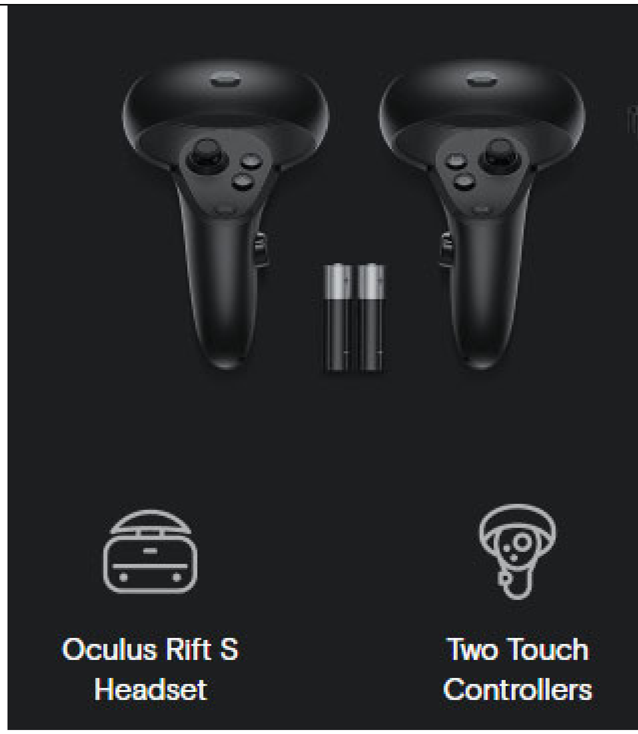
	 *See also* Oculus Quest.  *See also* Oculus Rift S.

	 *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

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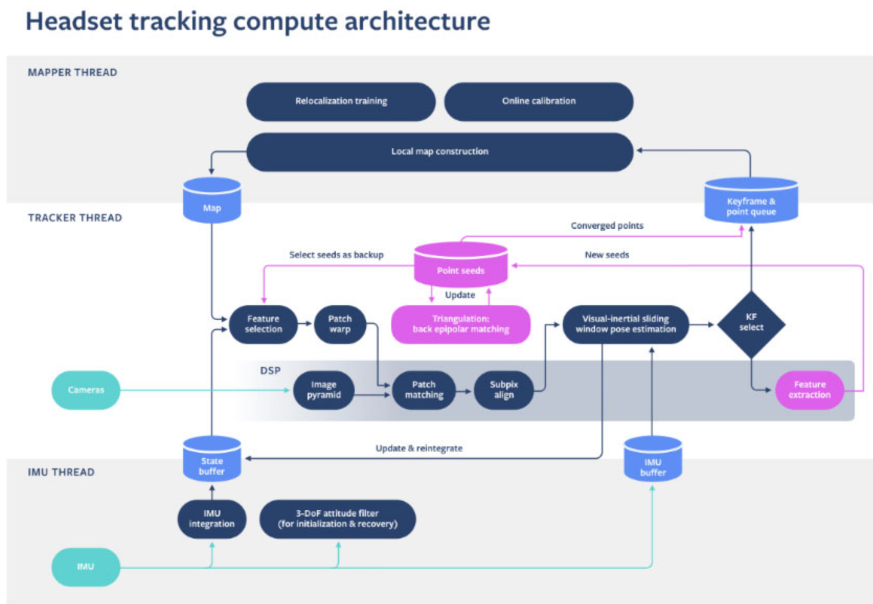

Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.
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<td colspan="2">Claim 47</td>
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<td>(47pre) A method of using multiple sensors in a tracking system comprising:</td>
<td>Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. For example, Facebook uses, and encourages users to use, multiple sensors (e.g., the cameras and/or IMUs within the headset, and/or the IMUs within the Oculus controller(s)) and use a position tracker (e.g., a headset-controller system) to track the position of an object (e.g., the user's hand(s) and/or Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

See, e.g., Compare Headsets.</td>
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	 **Oculus Quest** All-In-One VR Gaming **TRACKING** **Six Degrees of Freedom** With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

Oculus Quest 2
Advanced All-In-One VR Gaming

Starting At **$299 USD***

BUY NOW

TRACKING

Six Degrees of Freedom

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Oculus Rift S
PC-Powered VR Gaming

TRACKING

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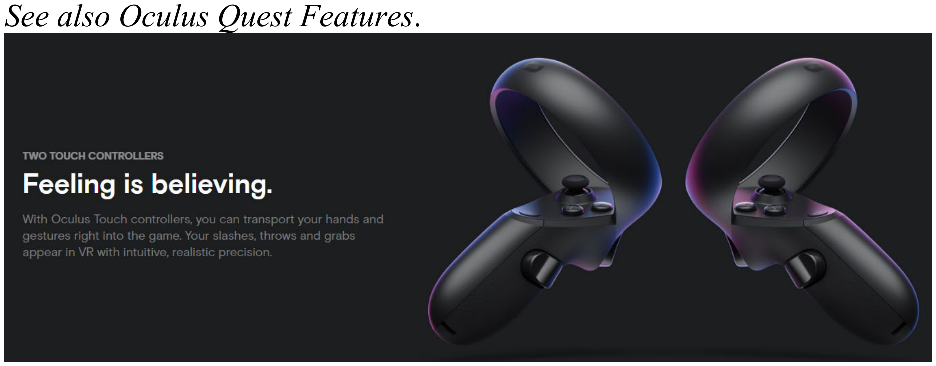

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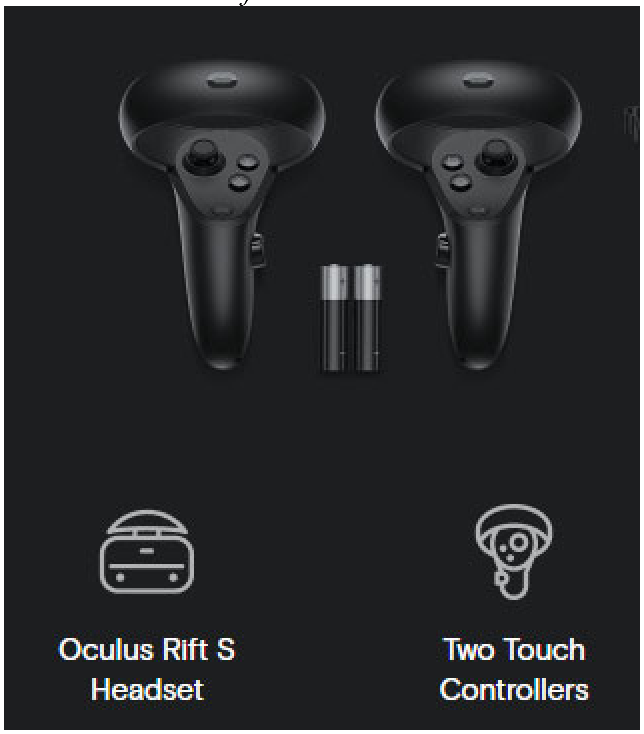
See also Oculus Rift S.



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(47a) providing an estimation module;

</td>
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Facebook encourages, directs, or promotes users to use the Accused Products to provide an estimation module, and Facebook performs such step itself. For example, the Accused Products include an estimation module (e.g., the Oculus Insight tracking system). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest Features.

See also From the Lab.

</td>
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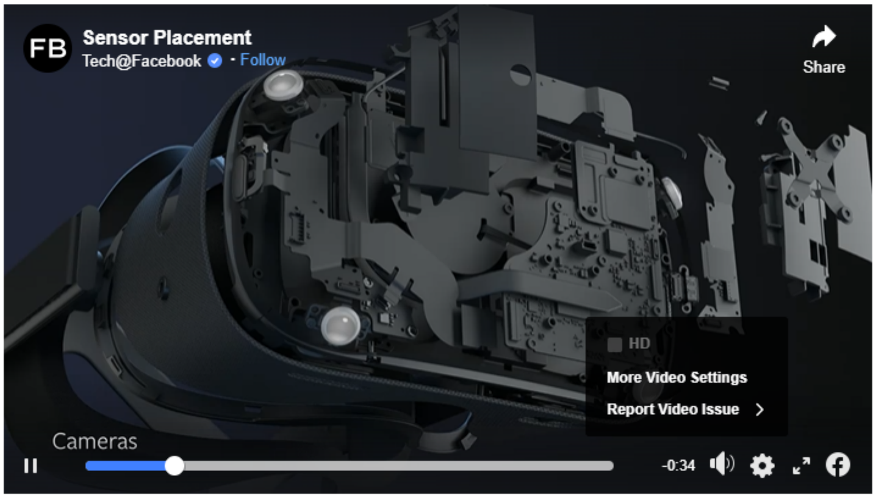
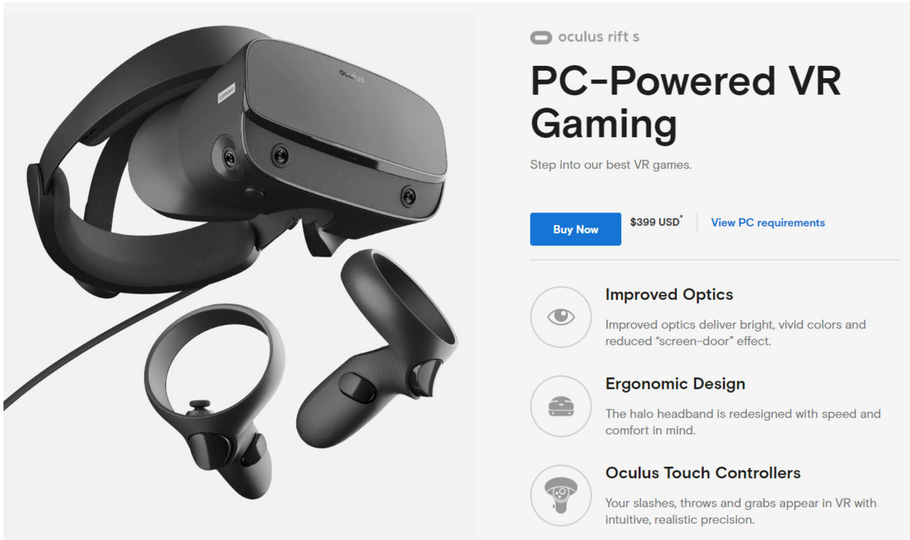
	  *See also* Oculus Rift S. 

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	See also id.
	3DOF vs 6DOF
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	See also Lang.

Image courtesy BadVR, Jad Meouchy

Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

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To unlock the full potential of virtual reality (VR) and augmented reality (AR) experiences, the technology needs to work anywhere, adapting to the spaces where people live and how they move within those real-world environments. When we developed Oculus Quest, the first all-in-one, completely wire-free VR gaming system, we knew we needed positional tracking that was precise, accurate, and available in real time — within the confines of a standalone headset, meaning it had to be compact and energy efficient.

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Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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	"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski. Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset. Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up. "With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski. *See also From the Lab*. **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. *See also From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab*. Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up. *See also* Oculus Quest 2.

See also Compare Headsets.

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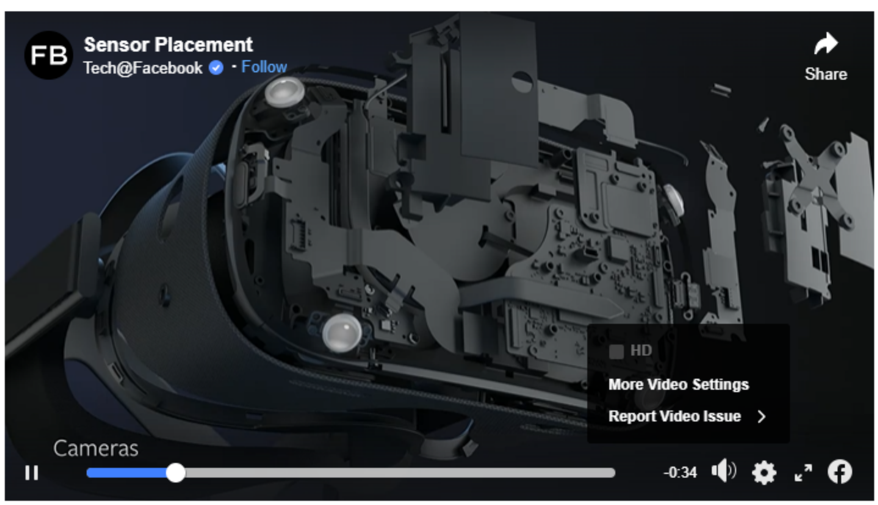

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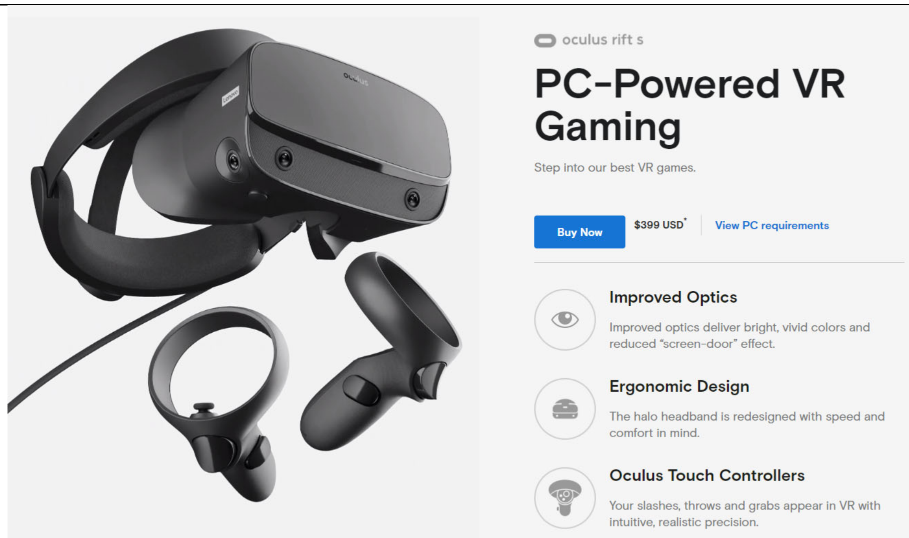

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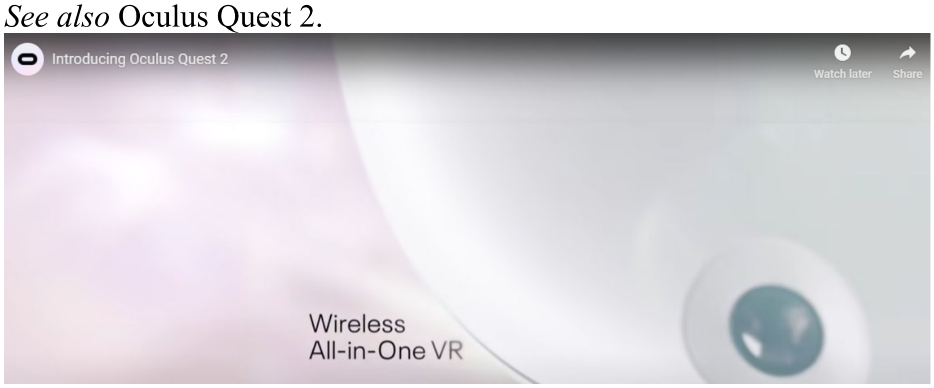

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The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

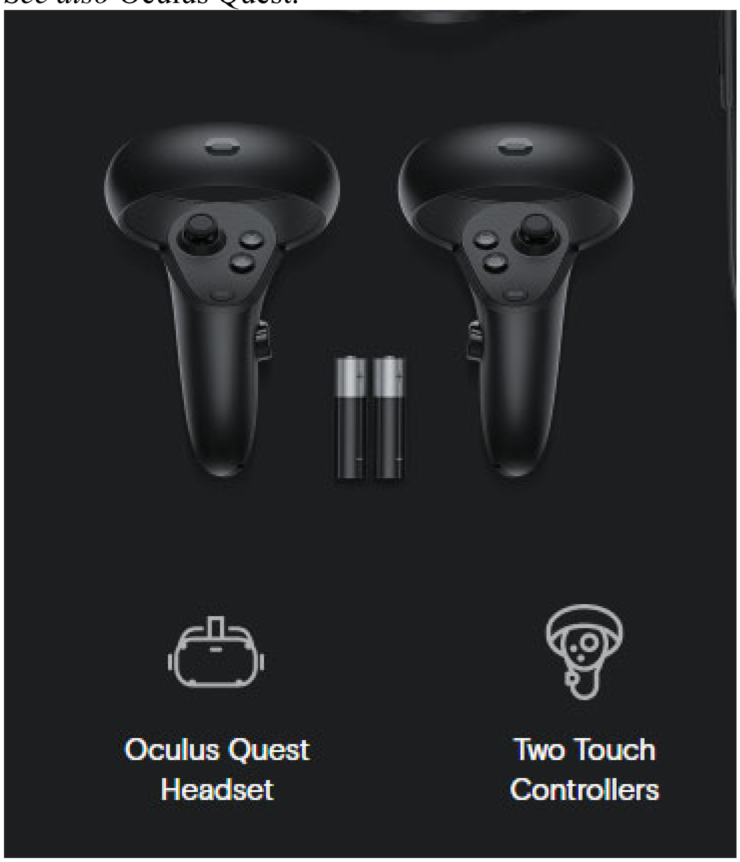
Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

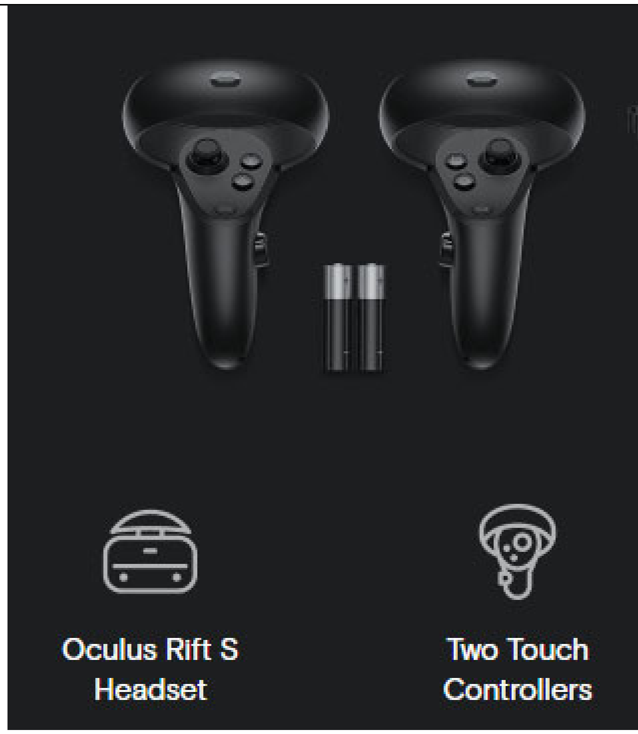
See also Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

	 *See also* Oculus Quest.  *See also* Oculus Rift S.

	 *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

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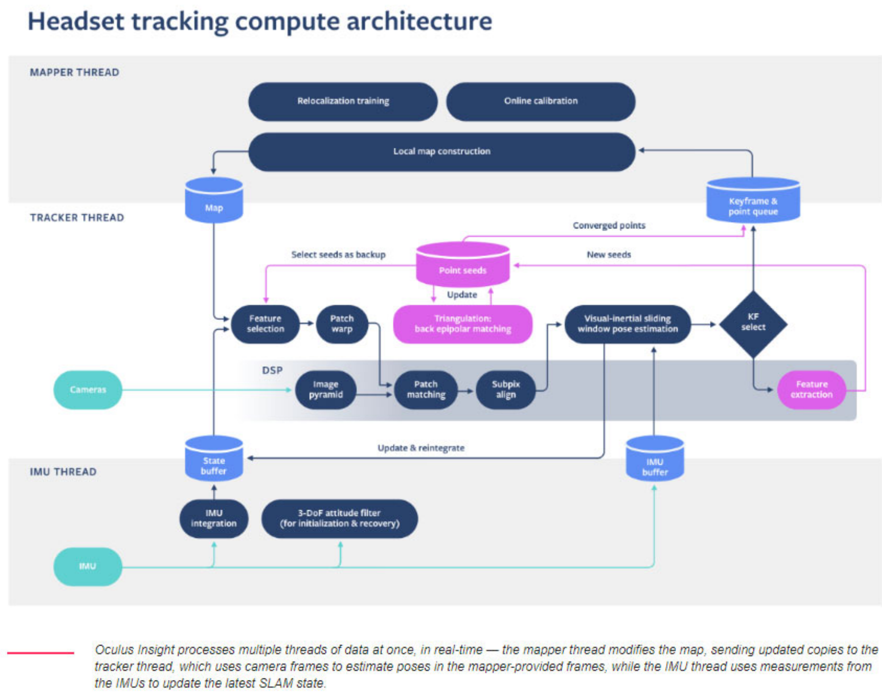

See also From the Lab, Sensor Placement at 0:23.

See also From the Lab, Sensor Placement at 0:30.

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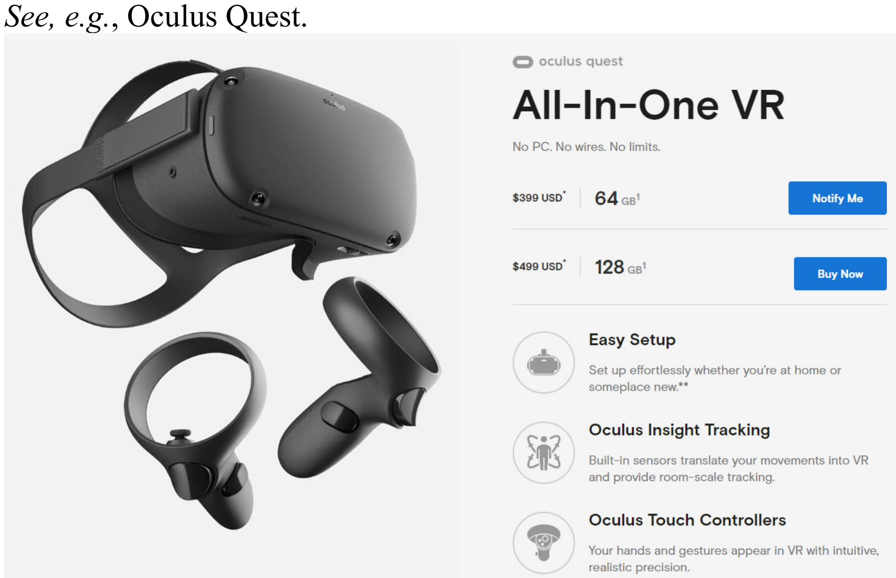
See also Reddit Single Controller Discussion.

	Does the Quest have a single controller mode for any games? https://imgur.com/a/1dLoatG My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help. 11 Comments Share Save Hide Report 78% Upvoted **This thread is archived** New comments cannot be posted and votes cannot be cast SORT BY BEST maltakan0 6 points · 1 year ago Virtual virtual reality can be played with one controller MRHBK 5 points · 1 year ago Quest is a bit heavier too if that is a factor stigzcousin 1 point · 1 year ago This is something I did not think about. Good to know. Thank you jebwillnotdivideus 5 points · 1 year ago Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure. *See also* Expert Mode at 2:36. 

(47d) maintaining estimates of tracking parameters in the estimation module, including repeatedly passing data based on the estimates of the tracking parameters from the estimation module to one or more of the sensor modules, receiving from said one or more sensor modules at the estimation module data based on measurements obtained from the associated sensors, and the data passed to the sensor modules, and combining the data received from said one or more sensor modules and the estimates of the tracking parameters in the estimation module to update the tracking parameters.	Facebook encourages, directs, or promotes users to use the Accused Products to maintain estimates of tracking parameters in the estimation module, including repeatedly passing data based on the estimates of the tracking parameters from the estimation module to one or more of the sensor modules, receiving from said one or more sensor modules at the estimation module data based on measurements obtained from the associated sensors, and the data passed to the sensor modules, and combining the data received from said one or more sensor modules and the estimates of the tracking parameters in the estimation module to update the tracking parameters, and Facebook performs such step itself. For example, the Accused Products maintain estimates of tracking parameters (e.g., the predicted position of the user's hand(s) and/or the Oculus controller(s)) in the estimation module (e.g., the Oculus Insight tracking system). Data based on these estimates are repeatedly passed to one or more of the sensor modules (e.g., the software components associated with the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, and/or a computer or other external processor for the Oculus Rift S). The estimation module also receives from these sensor modules data based on measurements obtained from the associated sensors (e.g., the sensor data received from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)). The Accused Products update the positional and orientation tracking parameters using the data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.  *See also* Oculus Quest Features.

See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

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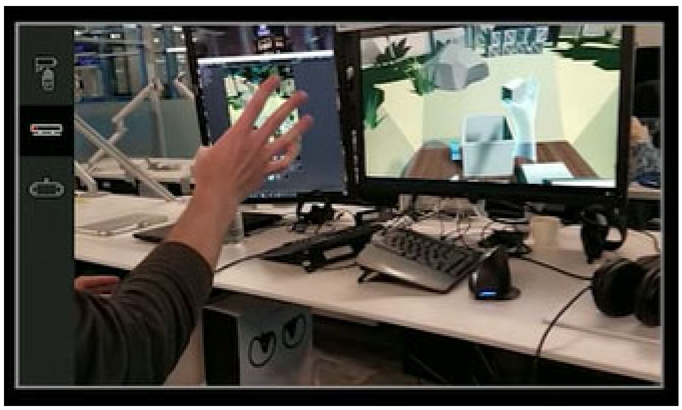
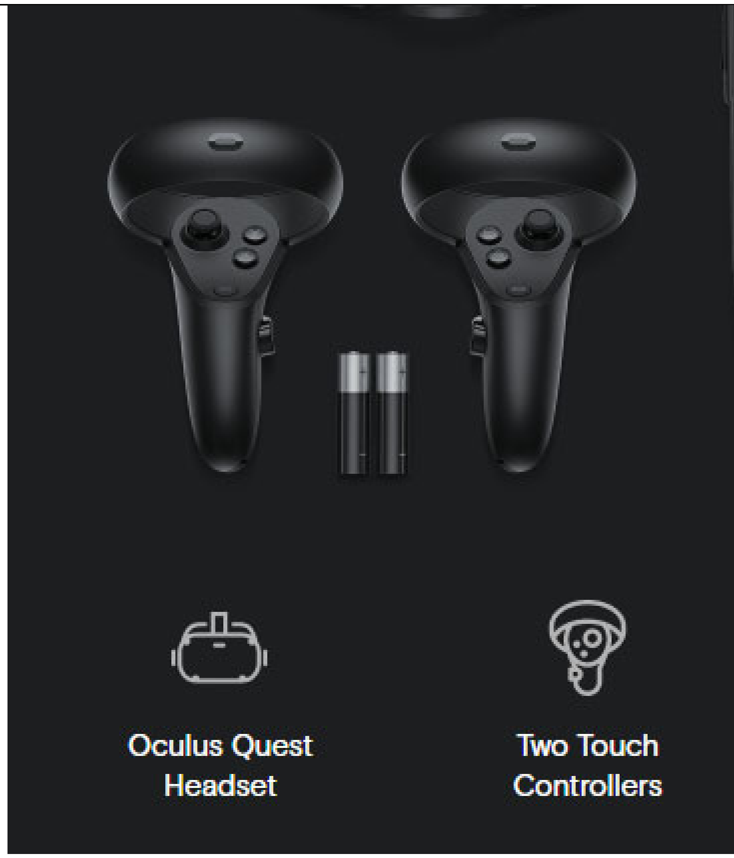
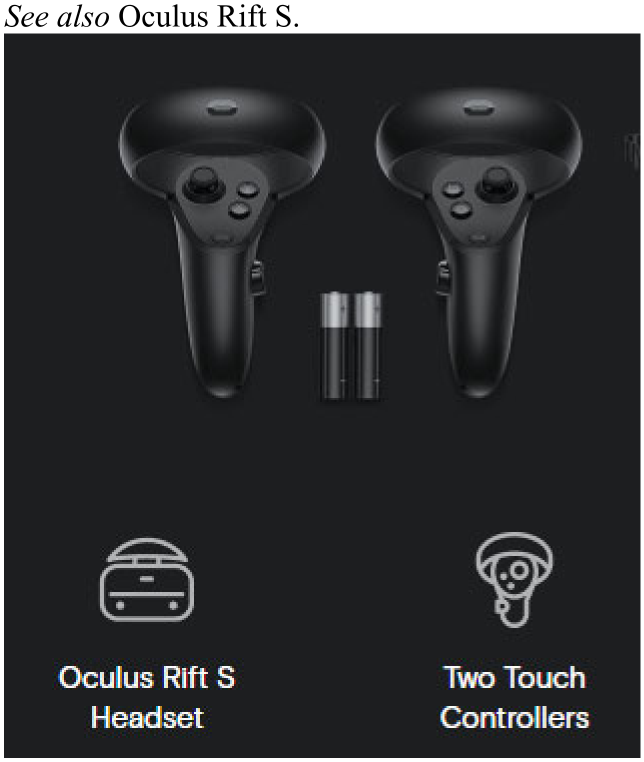
See also Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

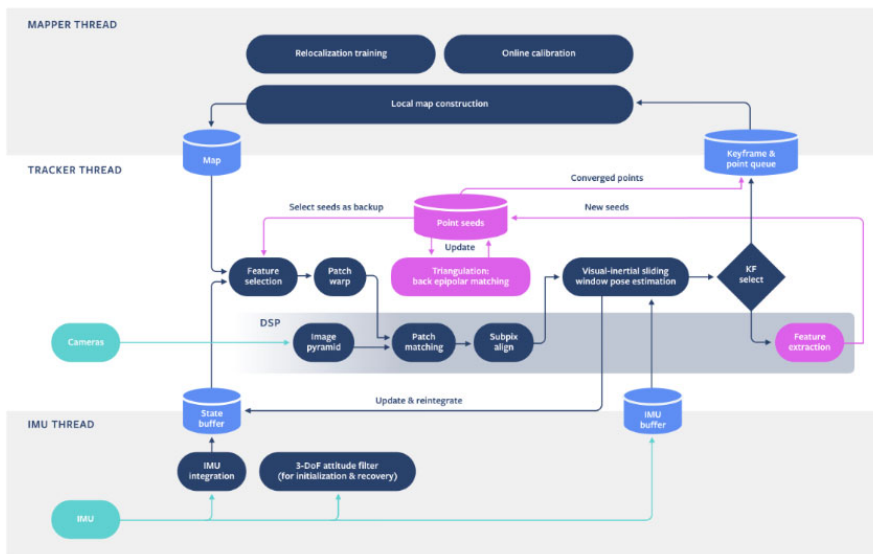
	 *See also* Oculus Rift S.  *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.

See also From the Lab, Sensor Placement at 0:30.

See also Heaney.

More Precise Tracking

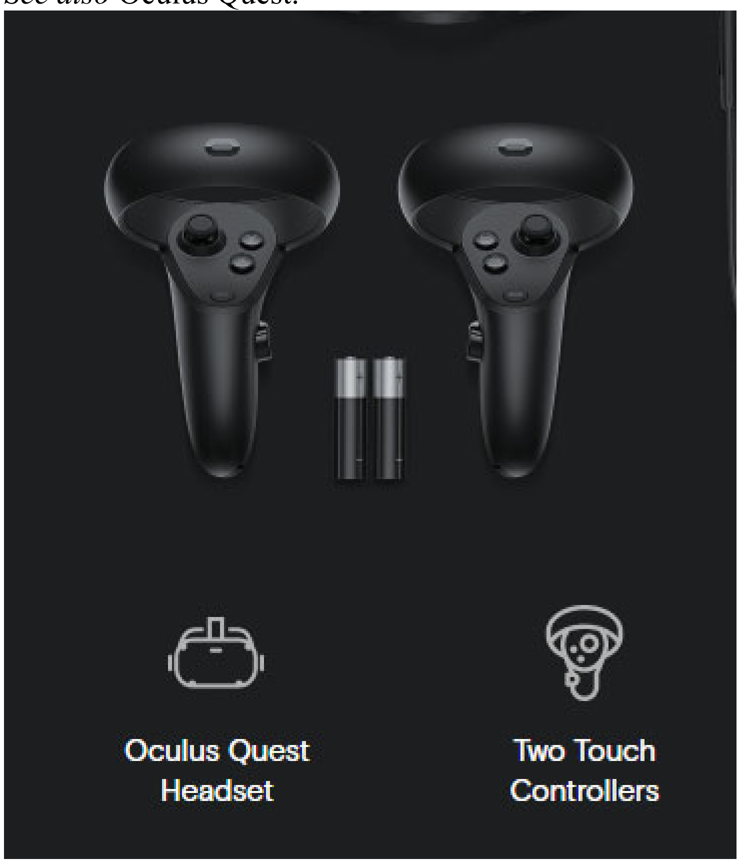
A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

	The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer. Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.  The IMU in the current Touch controllers for Rift S and Quest *See also* ICM-20601 Specification.
Claim 48	
(48) The method of claim 47 wherein the data passed from the estimation module to one or more of the sensor modules includes an estimate of the pose of a target relative to a sensor that was calculated by the estimation module using an estimate of the pose of a tracked object relative to a frame of reference fixed to an environment.	*See supra* claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which the data passed from the estimation module to one or more of the sensor modules includes an estimate of the pose of a target relative to a sensor that was calculated by the estimation module using an estimate of the pose of a tracked object relative to a frame of reference fixed to an environment, and Facebook performs such step itself. For example, in the Accused Products, the estimation module (e.g., the Oculus Insight tracking system) passes data to one or more of the sensor modules (e.g., the software components associated with the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, and/or a computer or other external processor for the Oculus Rift S) that includes an estimate of the pose of a target relative to a sensor (e.g., the predicted position of the user's hand(s) and/or the Oculus controller(s) relative to the cameras in the headset). To calculate these estimates, the Oculus Insight tracking system uses an estimate of the pose of a tracked object (e.g., the user's hand(s) and/or the Oculus controller(s)) relative to a frame of reference fixed to an environment (e.g., landmarks like the corners of furniture or the patterns on the floor). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

	See, e.g., Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands. **Designing for Hands**  *See also* Hand Tracking Deep Dive at 4:00–10:00.  *See also id.* at 4:00–10:00.

	 *See also* Oculus Quest.  *See also* Oculus Rift S.

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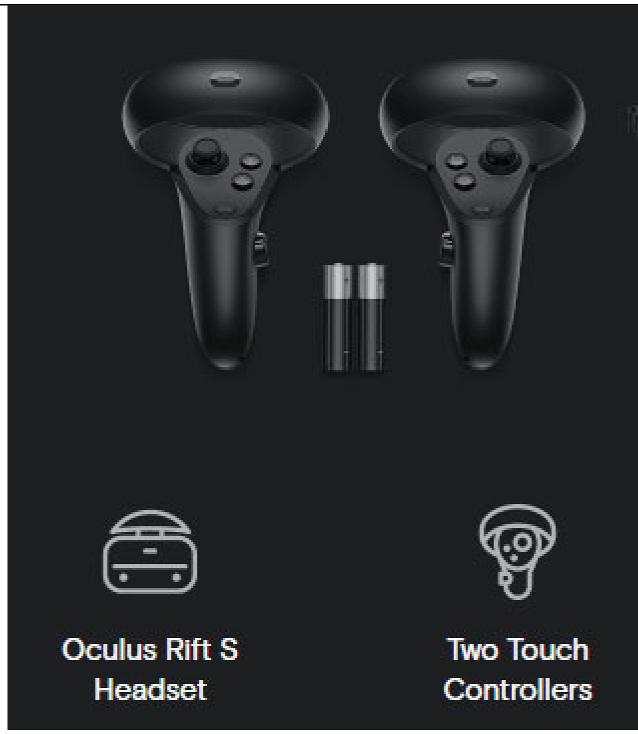

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.
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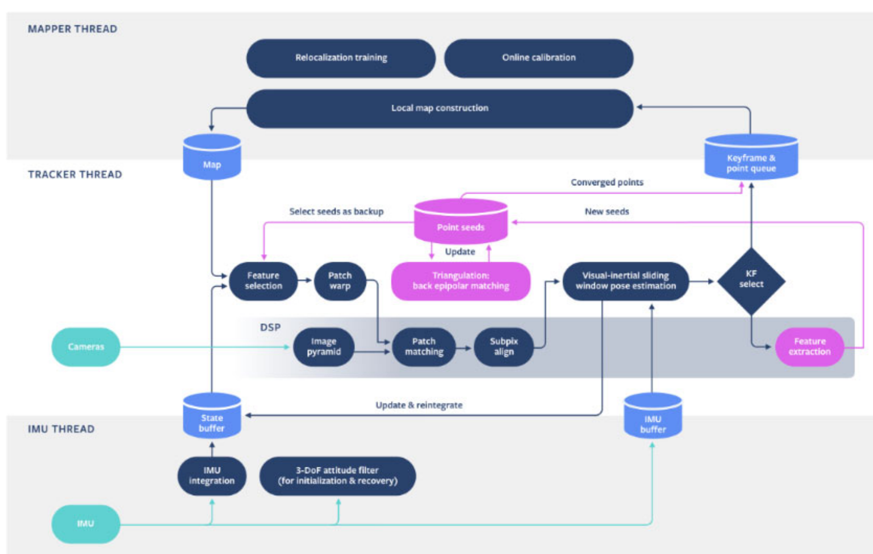
	Taking SLAM technology ... The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

	SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments. Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR. *See also id.* **Headset tracking compute architecture**  *Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.*
Claim 49	
(49) The method of claim 48 wherein the data passed from the estimation module to one or more of the sensor modules does not include the estimate of the pose of the tracked object relative to the frame	*See supra* claims 47, 48. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 48 in which the data passed from the estimation module to one or more of the sensor modules does not include the estimate of the pose of the tracked object relative to the frame of reference fixed to the environment, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, in the Accused Products, the estimation module (e.g., the Oculus Insight tracking system) passes data to one or more of the sensor modules (e.g., the software components associated with the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, and/or a computer or other external processor for the Oculus Rift S) that does not include the estimate of the pose of a tracked object (e.g., the user's hand(s) and/or the Oculus controller(s)) relative to a

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See, e.g., Hand Tracking.
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See also Designing for Hands.
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See also id. at 4:00–10:00.</td>
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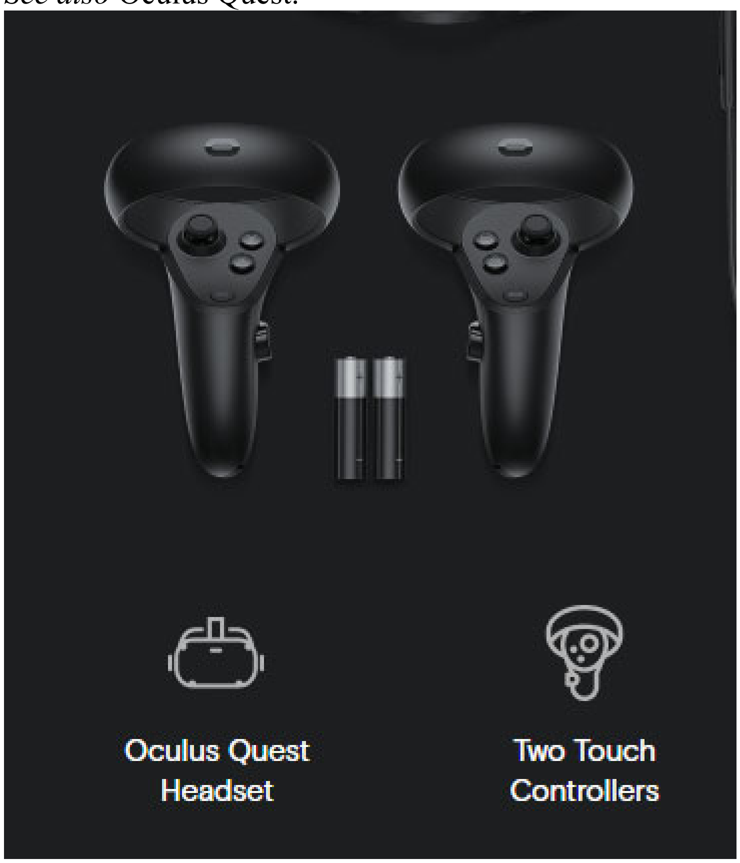
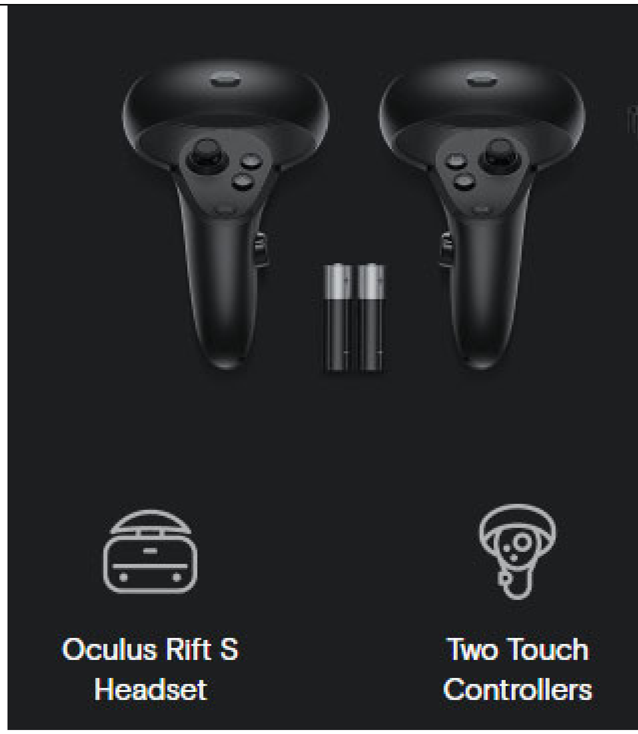
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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	Taking SLAM technology ... The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

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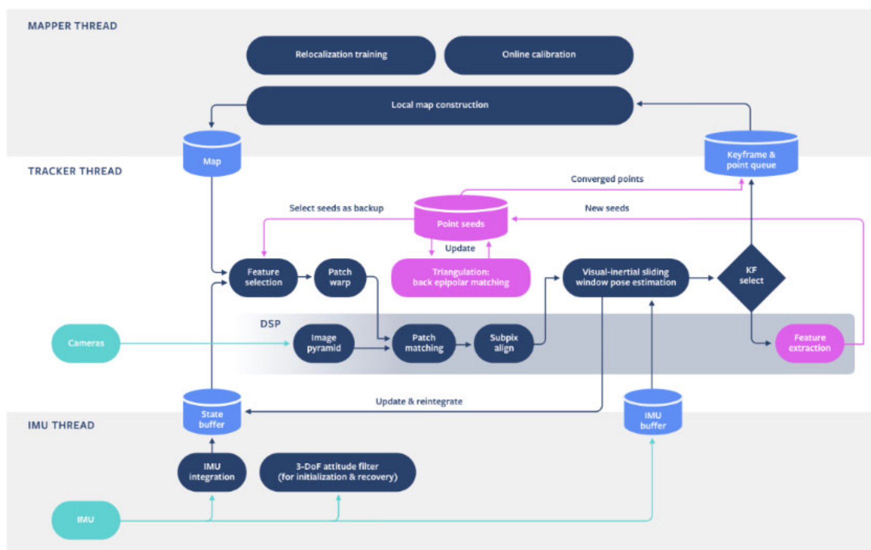
SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



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</td></tr>
<tr><td colspan="2">Claim 50</td></tr>
<tr><td>(50) The method of claim 47 wherein providing the estimation module includes providing a module that is configurable to use different sets of sensor modules coupled to it.</td><td>See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which providing the estimation module includes providing a module that is configurable to use different sets of sensor modules coupled to it, and Facebook performs such step itself. For example, in the Accused Products, the Oculus Insight tracking system is configurable to use different sets of sensor modules corresponding to different sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), coupled to it at a given time. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Oculus Insight tracking system in the Accused</td></tr>
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Products is then configured to use different sets of sensor modules depending on the sensors available at a given time. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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See also Designing for Hands.

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See also Hand Tracking Deep Dive.

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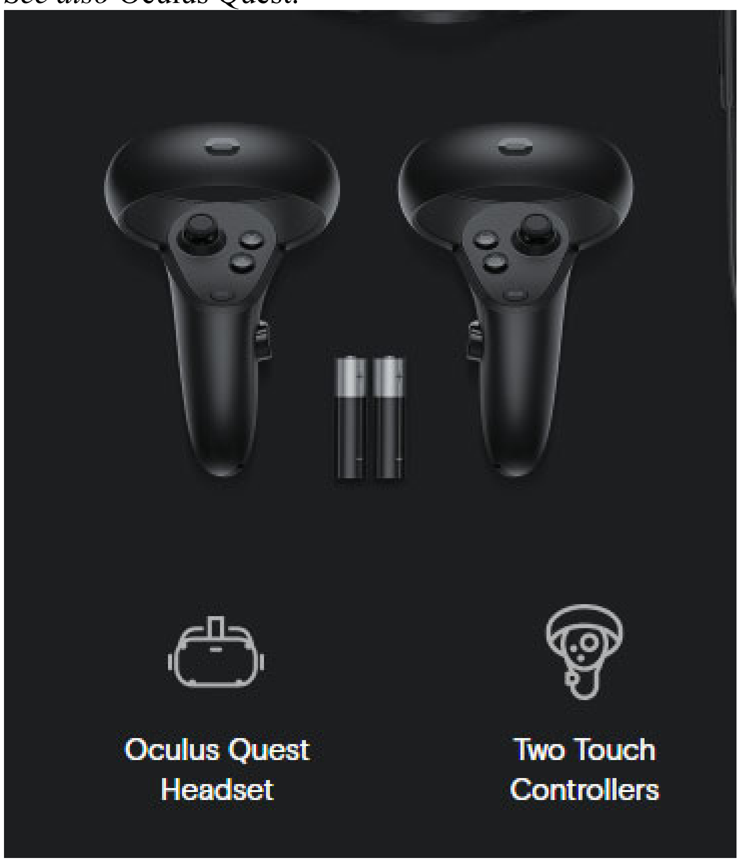
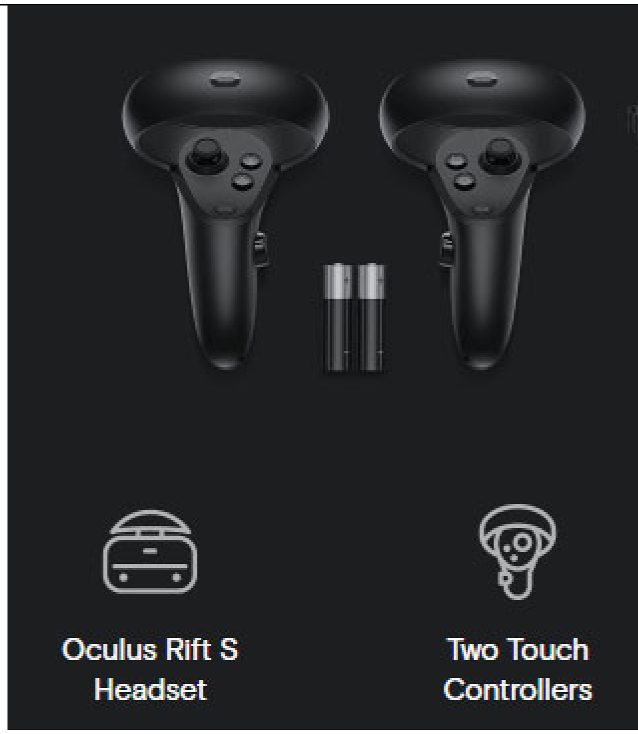
	 *See also* Oculus Quest.  *See also* Oculus Rift S.

	 *See also From the Lab.* There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.*

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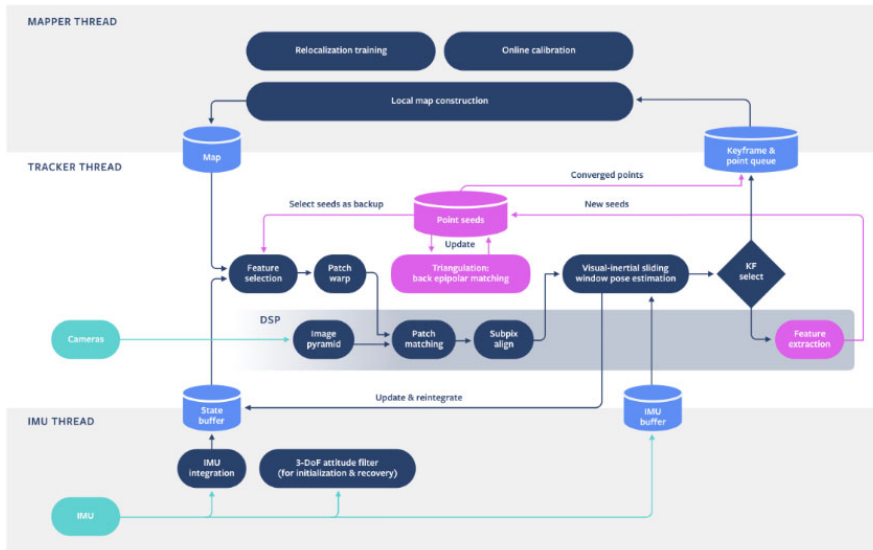
Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

11 Comments Share Save Hide Report 78% Upvoted

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New comments cannot be posted and votes cannot be cast

SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

<table>
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<tr><td>(51) The method of claim 47 wherein maintaining estimates of the tracking parameters in the estimation module includes using a stochastic model in the estimation module.</td><td>See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which maintaining estimates of the tracking parameters in the estimation module includes using a stochastic model in the estimation module, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products predicts the position of the user's hand(s) and/or the Oculus controller(s) using a stochastic model. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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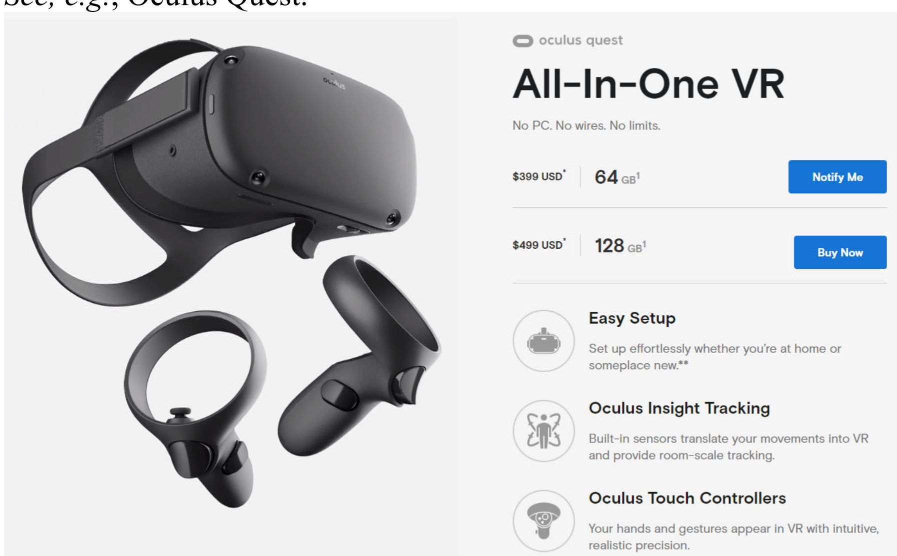

See also Oculus Quest Features.</td></tr>
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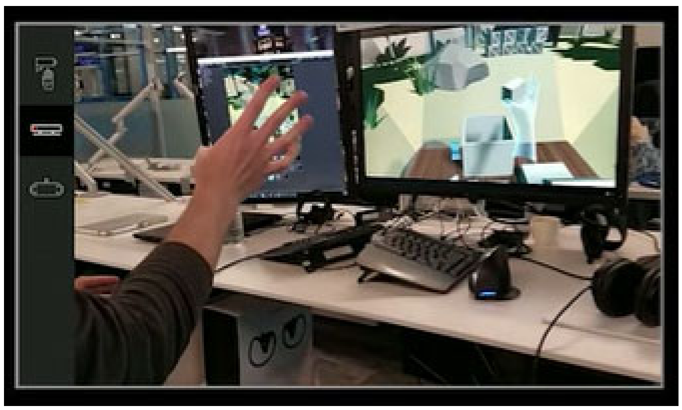
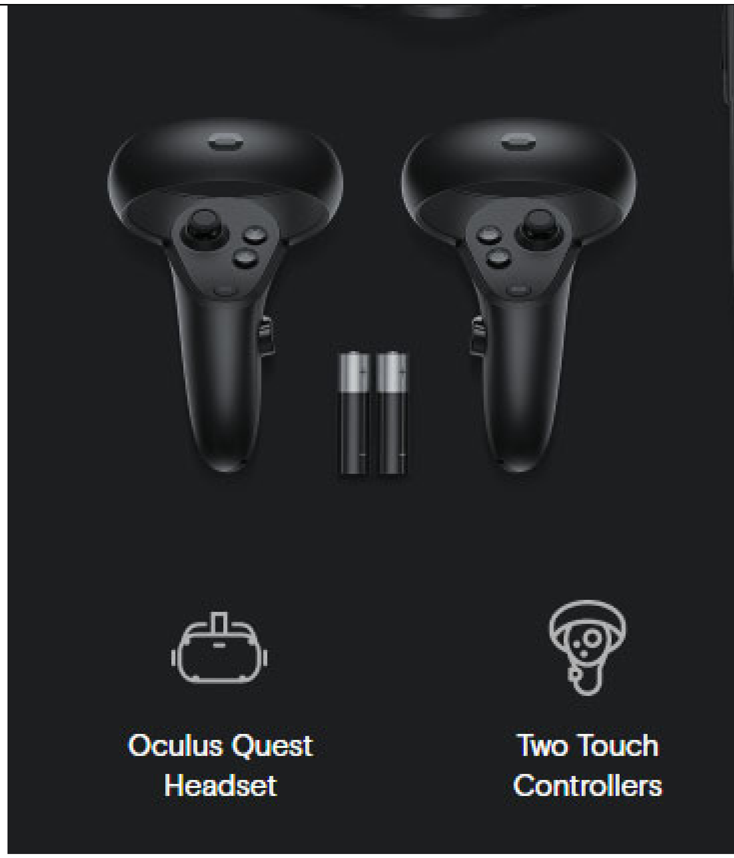
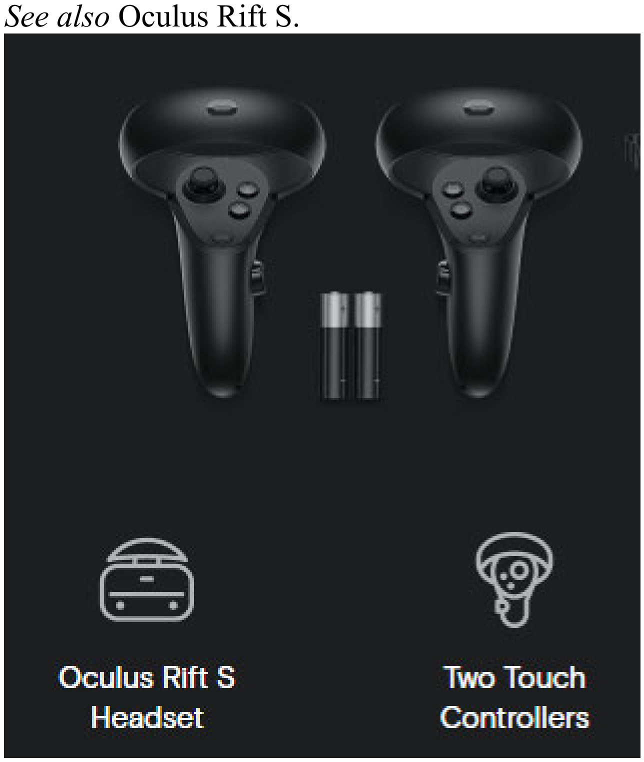
	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also From the Lab.*

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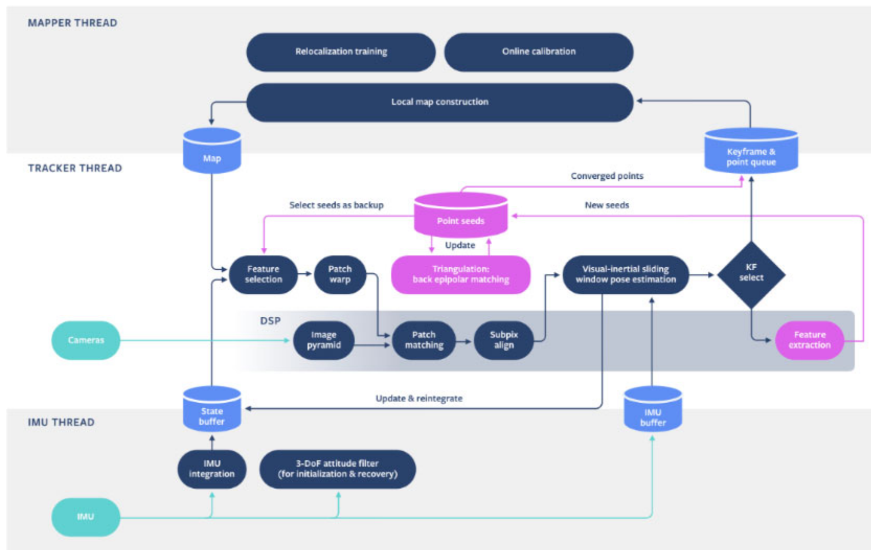
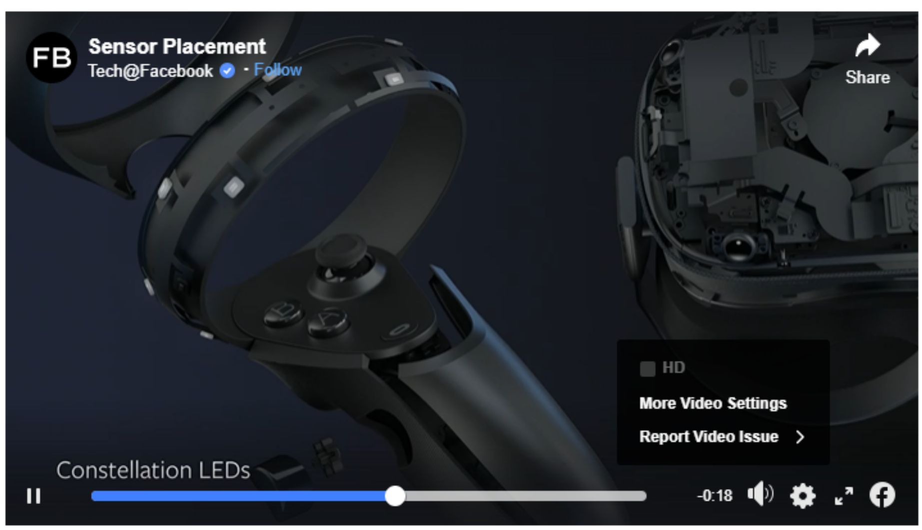
	Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR. *See also id.* **Headset tracking compute architecture**  *Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.* *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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See also id.

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<tr><td></td><td>The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.

The IMU in the current Touch controllers for Rift S and Quest

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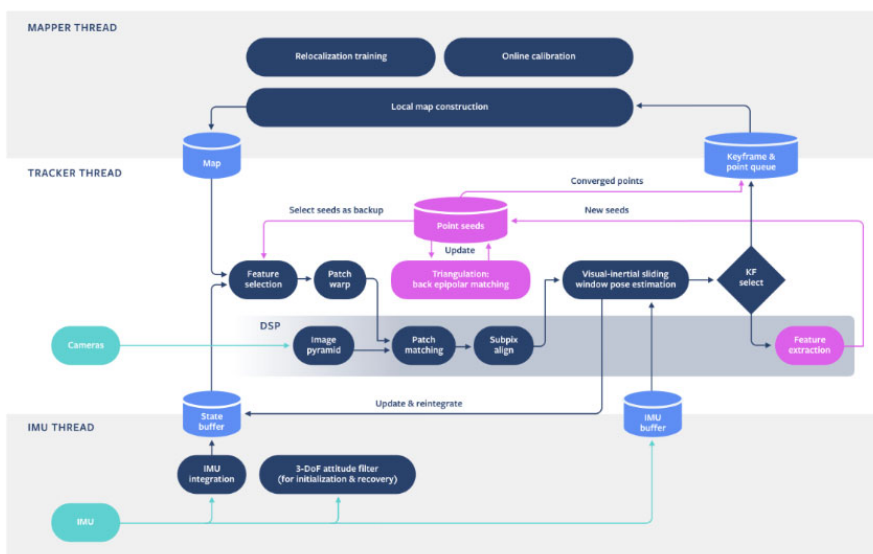

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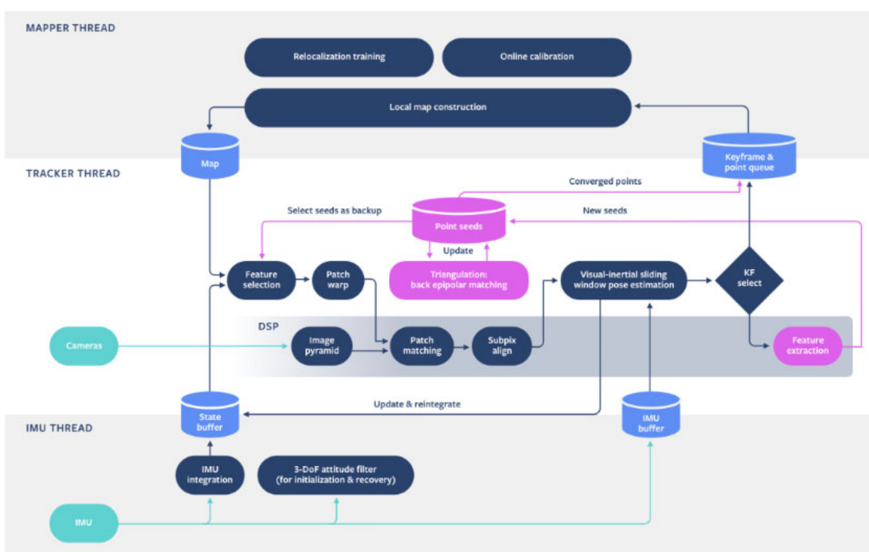

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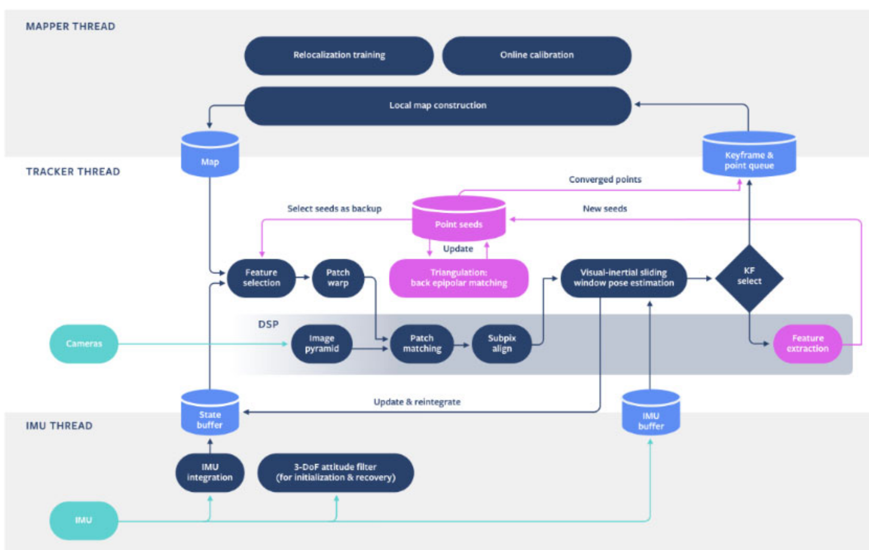
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



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See also Heaney.

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More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

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<tr><td colspan="2">Claim 55</td></tr>
<tr><td>(55) The method of claim 54 wherein one of the components of the distributed Kalman filter is associated with a subset of sensor modules consisting of sensor modules that are affixed to a tracked object.</td><td>

See supra claims 47, 51, 52, 54. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 54 in which one of the components of the distributed Kalman filter is associated with a subset of sensor modules consisting of sensor modules that are affixed to a tracked object, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a distributed Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). One of the components of the distributed Kalman filter are associated with the sensor modules corresponding to the IMUs in the Oculus controller(s), which are tracked objects. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

See, e.g., Hand Tracking.

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See also id.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

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See also Powered by AI.

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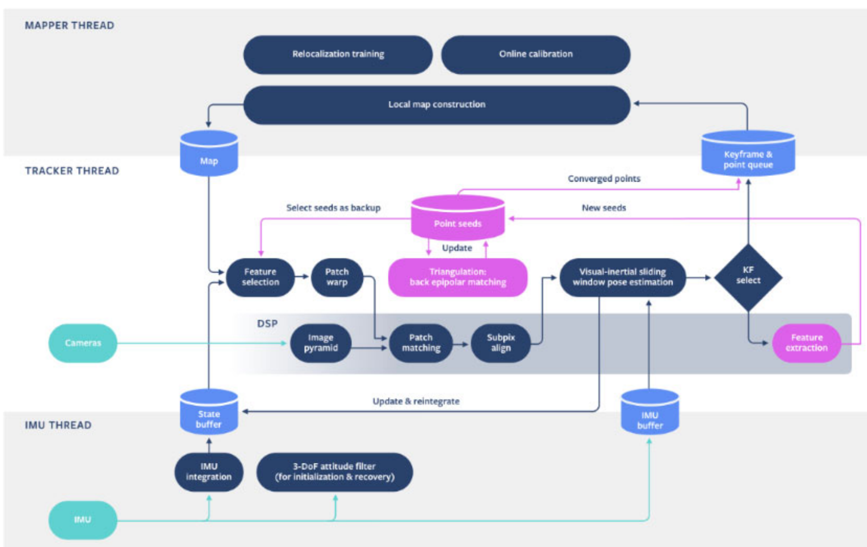

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Claim 57	
(57) The method of claim 54 wherein one of the components of the distributed Kalman filter is not associated with any sensor modules.	*See supra* claims 47, 51, 52, 54. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 54 in which one of the components of the distributed Kalman filter is not associated with any sensor modules, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a distributed Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). At least one of the components of the distributed Kalman filter is the predicted positions of the user's hand(s) and/or the Oculus controller(s), which are not associated with any sensor modules. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial. *See, e.g.*, Hand Tracking.

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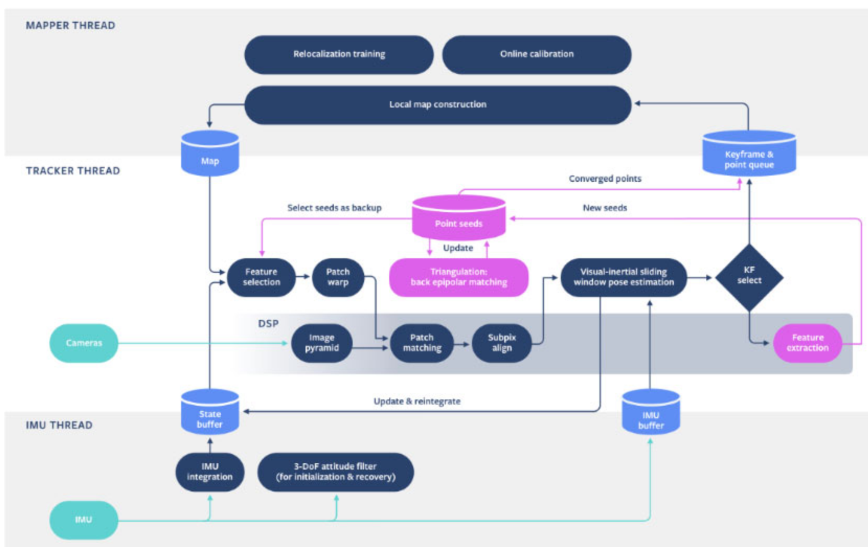
Headset tracking compute architecture



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</td></tr>
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<tr><td>(58) The method of claim 54 wherein implementing the distributed Kalman filter includes implementing a Federated Kalman Filter.</td><td>

See supra claims 47, 51, 52, 54. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 54 in which implementing the distributed Kalman filter includes implementing a Federated Kalman Filter, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a Federated Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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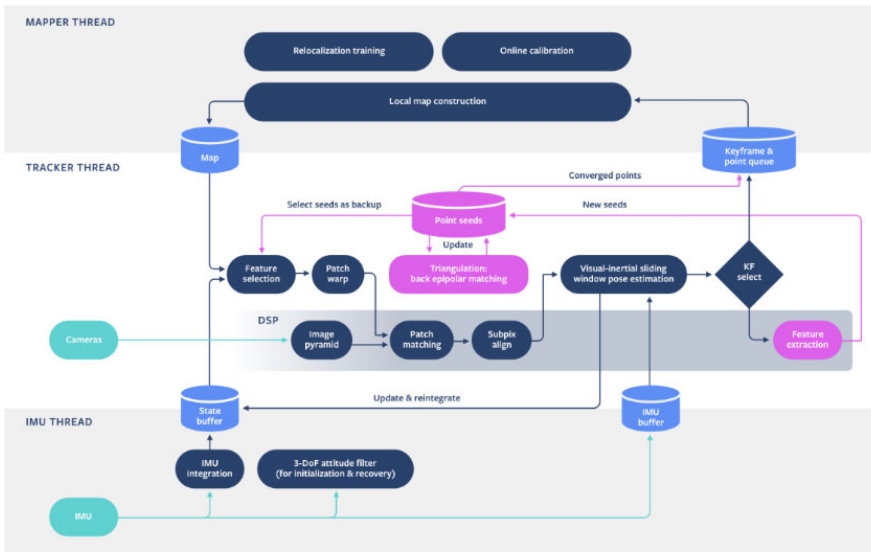
Headset tracking compute architecture



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See also Heaney.

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Facebook's VR controllers are tracked via infrared LEDs under the plastic</td></tr>
<tr><td colspan="2">Claim 59</td></tr>
<tr><td>(59) The method of claim 47 wherein providing configuration information from the sensor modules includes providing information characterizing a type of a sensor associated with a sensor module.</td><td>See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which providing configuration information from the sensor modules includes providing information characterizing a type of a sensor associated with a sensor module, and Facebook performs such step itself. For example, in the Accused Products, information regarding the type and characteristics of the available sensors associated with the sensor modules corresponding to different sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), is provided by the sensor modules to the Oculus Insight tracking system. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Oculus Insight tracking system in the Accused Products is then configured to use different sets of sensor modules coupled to it, corresponding to the sensors available at a given time. The configuration information characterizes the types of sensors associated with the software components. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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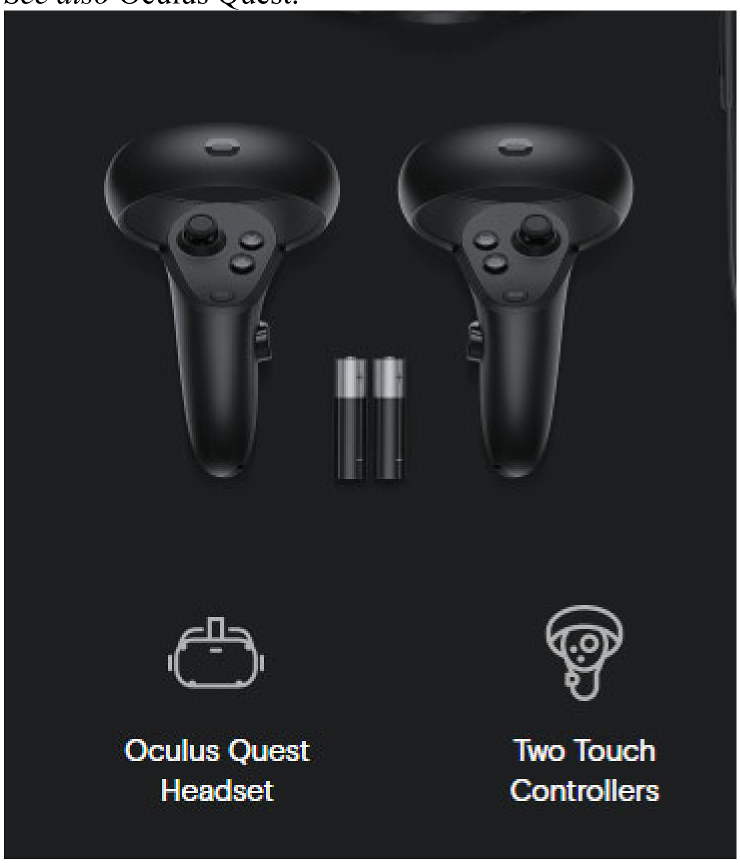

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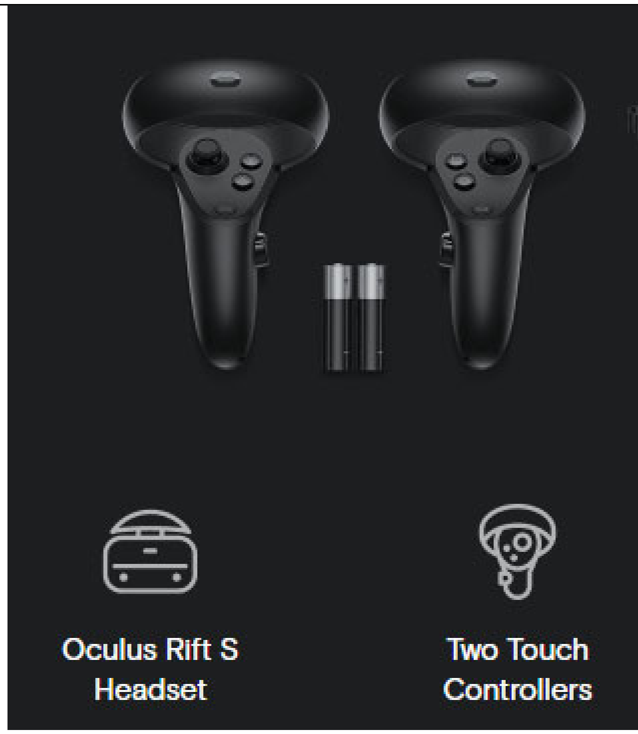

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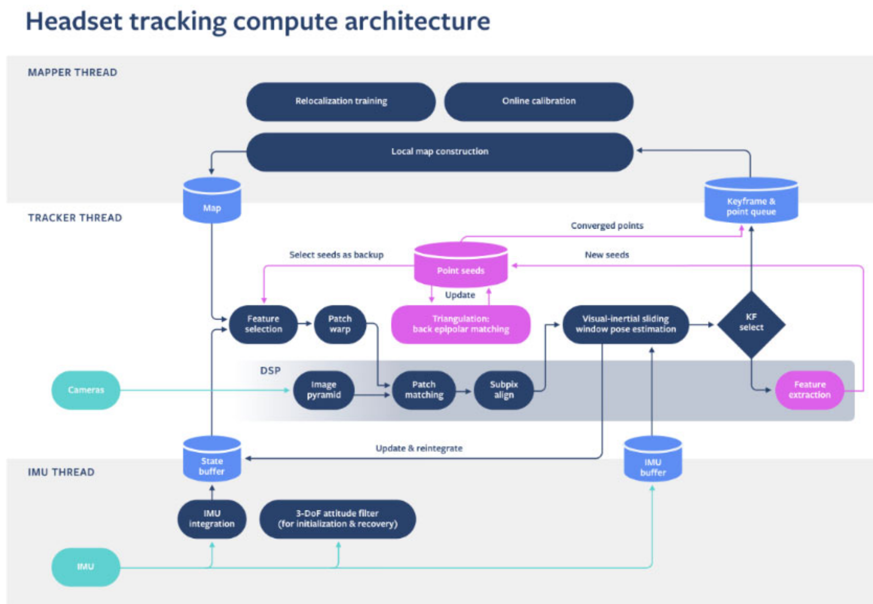

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See also From the Lab, Sensor Placement at 0:23.

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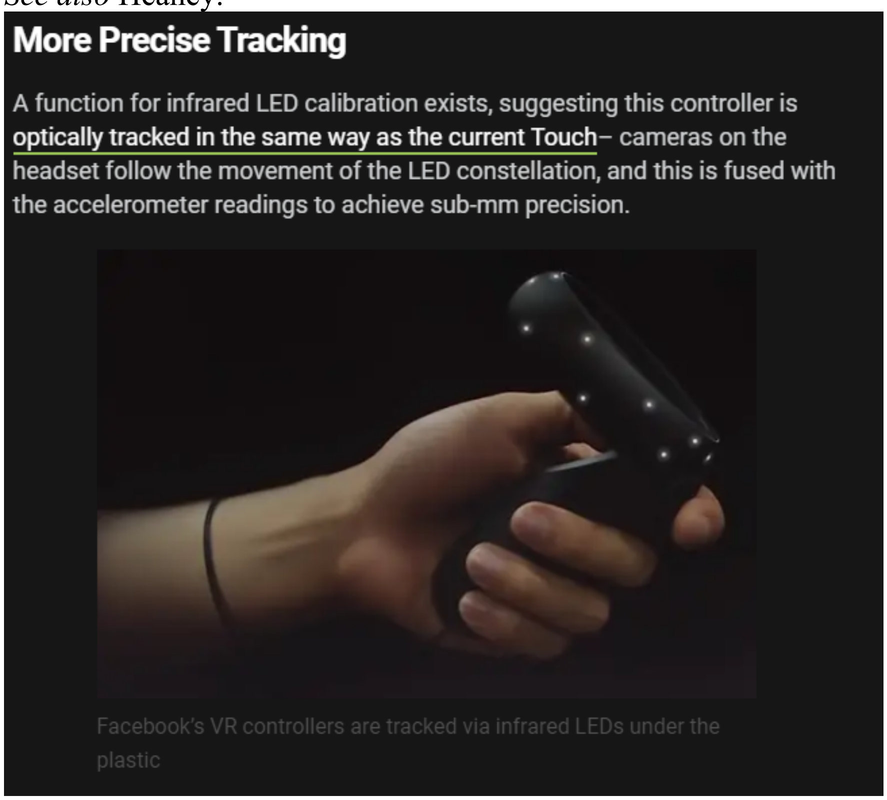
See also Heaney.



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See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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New comments cannot be posted and votes cannot be cast

SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

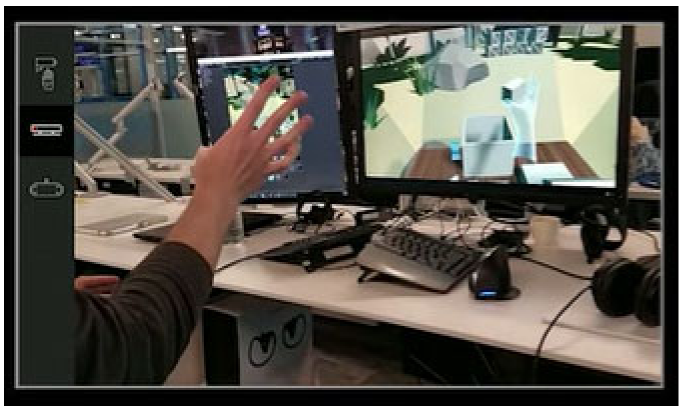
MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

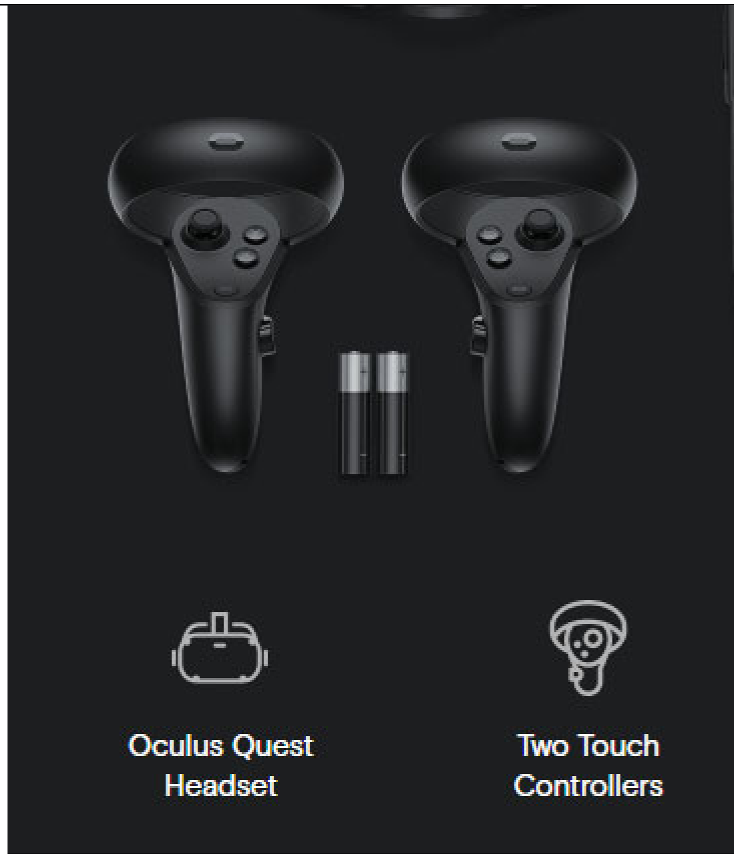
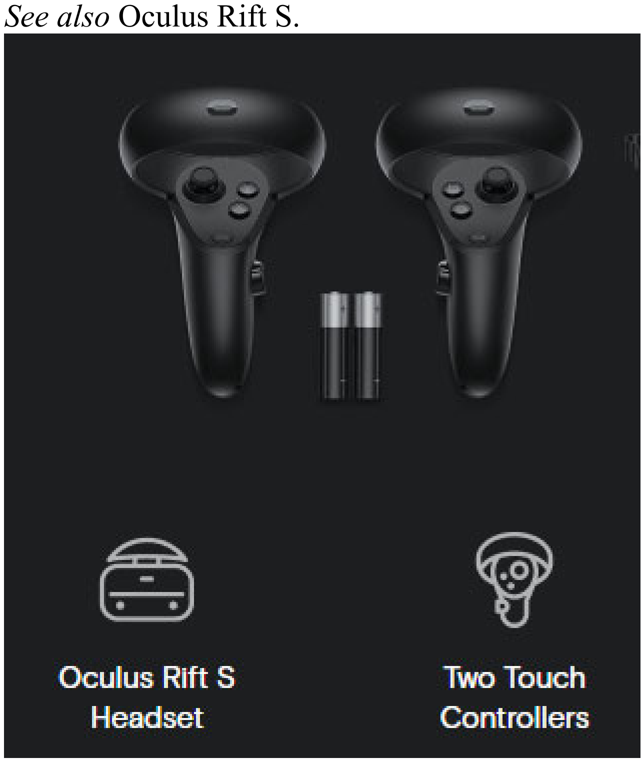
stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

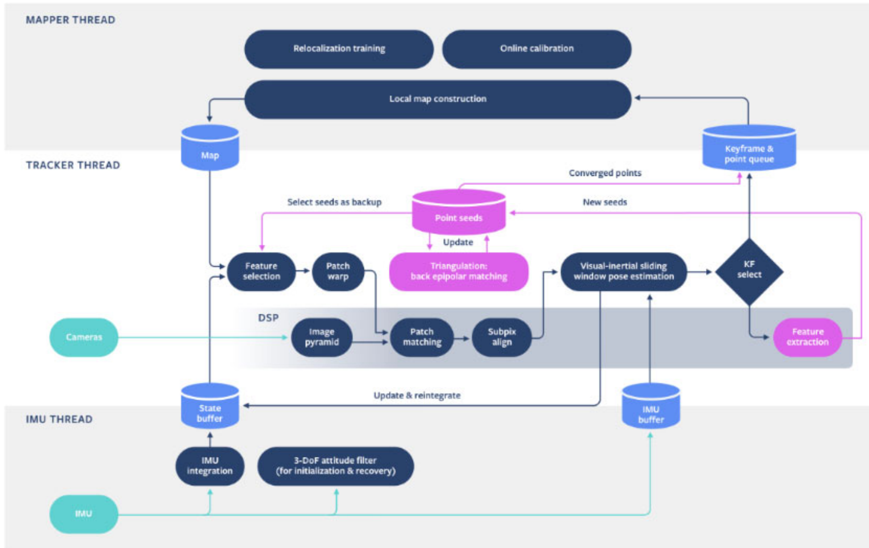
Claim 60	
(60) The method of claim 47 wherein providing configuration information from the sensor modules includes providing information characterizing a position or an orientation of a sensor associated with a sensor module.	*See supra* claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which providing configuration information from the sensor modules includes providing information characterizing a position or an orientation of a sensor associated with a sensor module, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, information characterizing the position and/or orientation of the available sensors associated with the sensor modules corresponding to different sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), is provided by the sensor modules to the Oculus Insight tracking system. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Oculus Insight tracking system in the Accused Products is then configured to use different sets of sensor modules coupled to it, corresponding to the sensors available at a given time. The configuration information includes information characterizing the position and orientation of the sensors. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands. **Designing for Hands** 

	See also Hand Tracking Deep Dive.  *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also id.*

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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See also From the Lab, Sensor Placement at 0:30.

See also Heaney.

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A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

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See also Expert Mode at 2:36.

Claim 61	
(61) The method of claim 47 wherein providing configuration information from the sensor modules includes providing information characterizing one or more calibration parameters of a sensor associated with a sensor module.	*See supra* claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which providing configuration information from the sensor modules includes providing configuration information from the sensor modules includes providing information characterizing one or more calibration parameters of a sensor associated with a sensor module, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, information characterizing calibration parameters of the available sensors associated with the sensor modules corresponding to different sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), is provided by the sensor modules to the Oculus Insight tracking system. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Oculus Insight tracking system in the Accused Products is then configured to use different sets of sensor modules coupled to it, corresponding to the sensors available at a given time. The configuration information includes information characterizing the calibration parameters of the sensors, including parameters to calibrate for measurement discrepancies, such as drift. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive.

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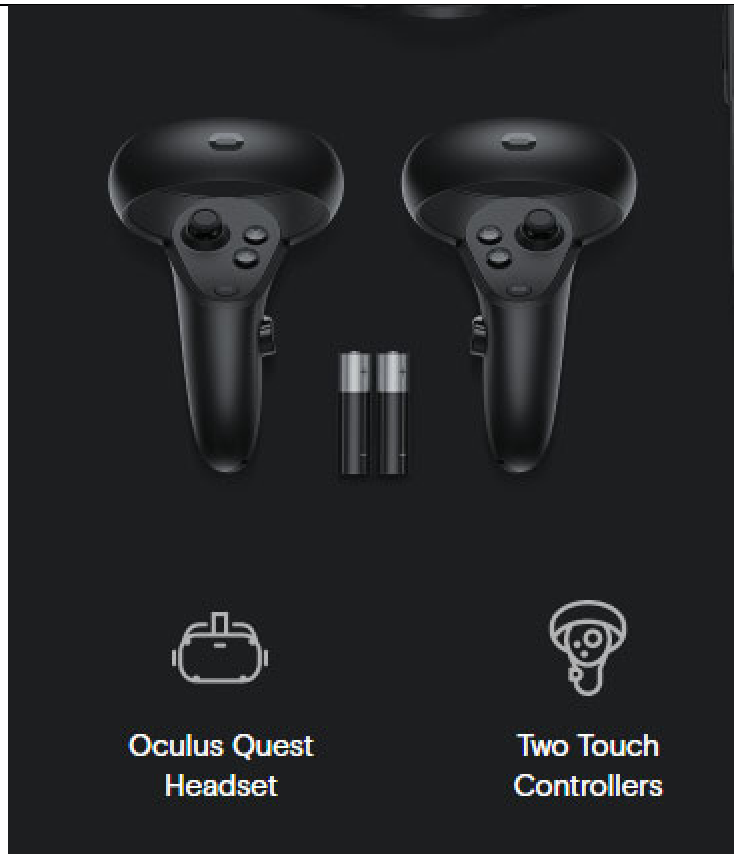
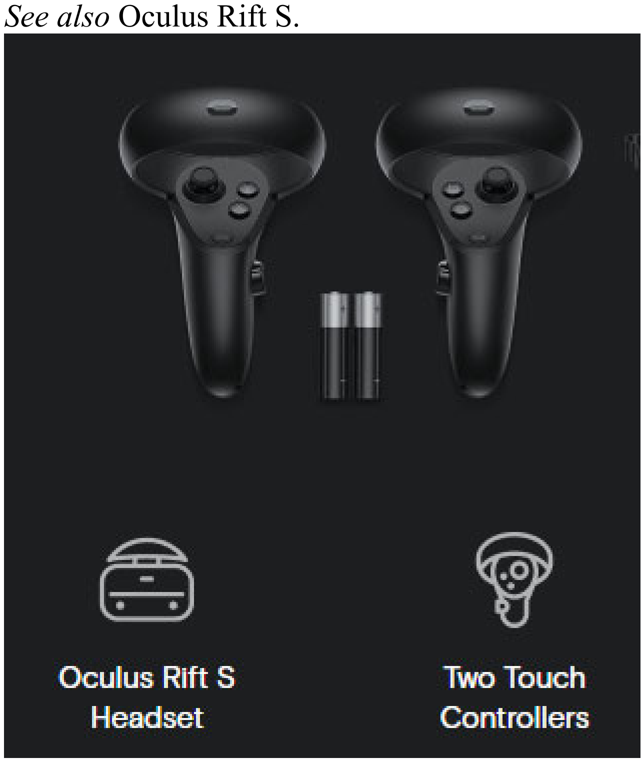
	 *See also* Oculus Rift S.  *See also From the Lab.*

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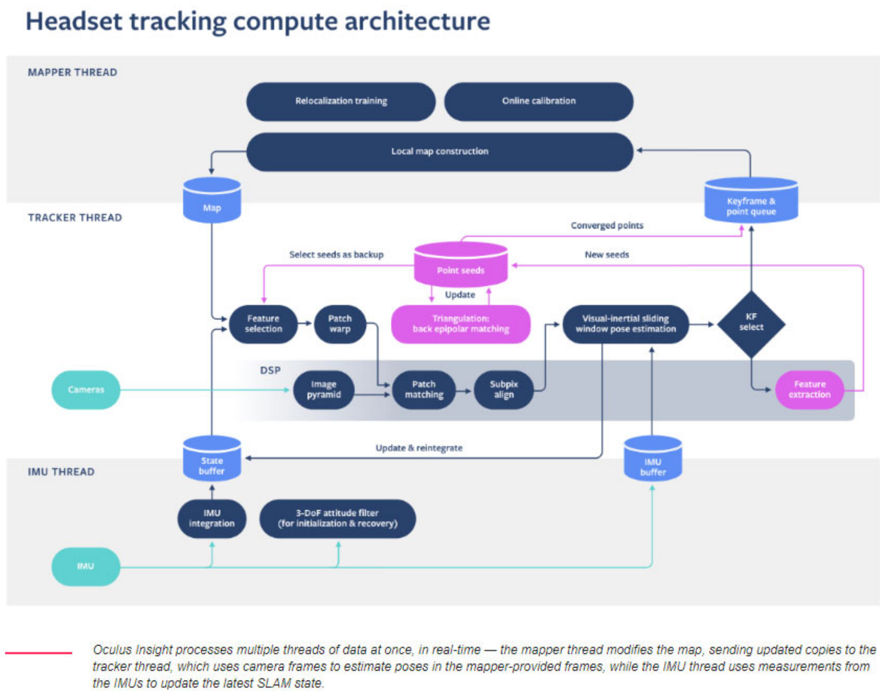

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See also Expert Mode at 2:36.

Claim 66	
(66a) A method comprising: receiving sensor configuration information indicating a set of sensing elements available to a tracking or navigation system;	Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. For example, the Oculus Insight tracking system in the Accused Products is configured using the configuration information of the sensors available at a given time. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation). *See, e.g.*, Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands. **Designing for Hands**  *See also* Hand Tracking Deep Dive at 4:00–10:00.

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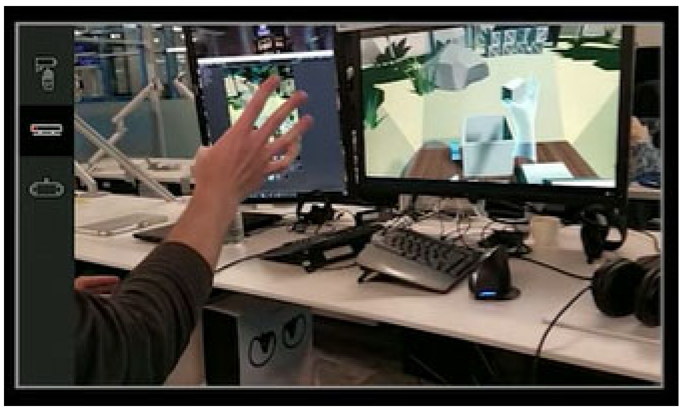

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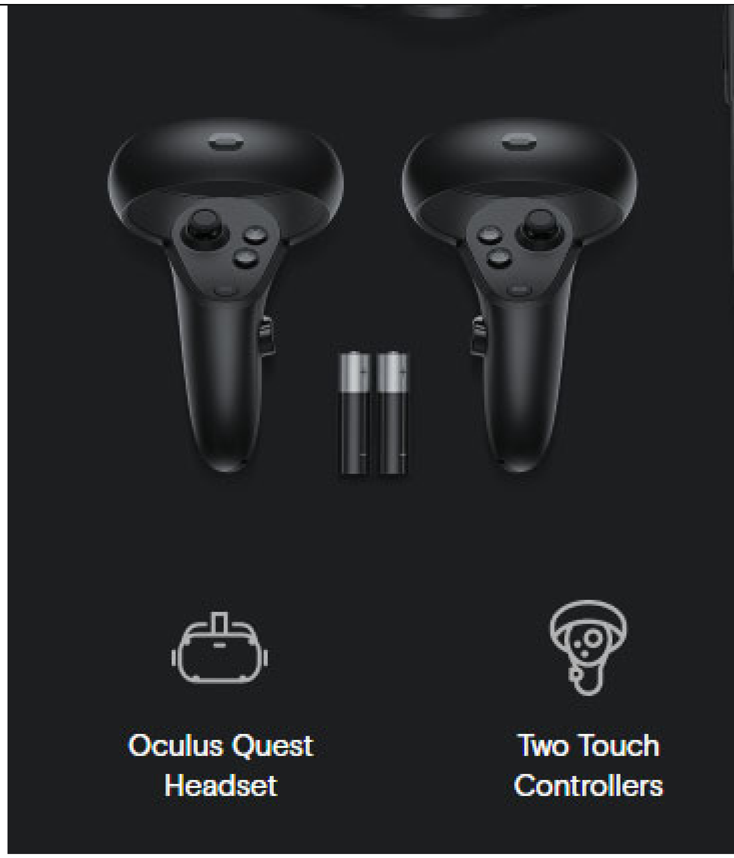
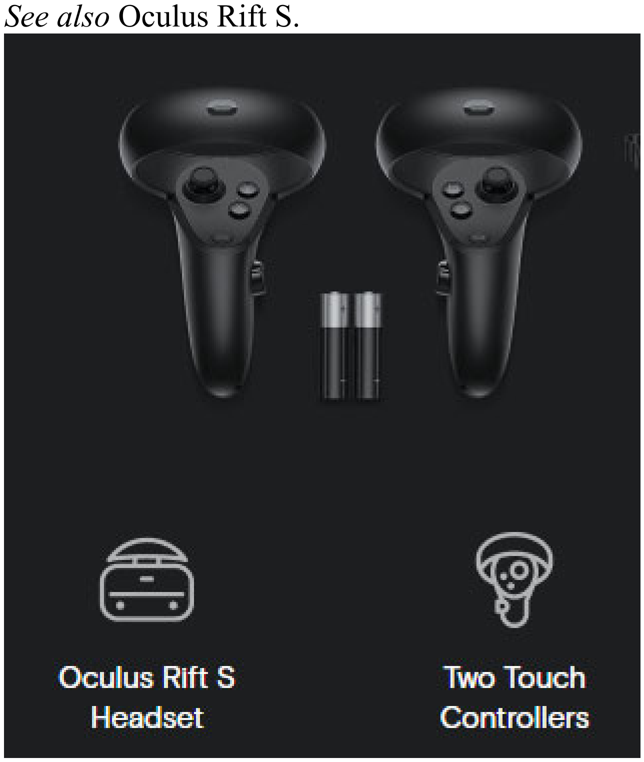
	 *See also* Oculus Rift S.  *See also From the Lab.*

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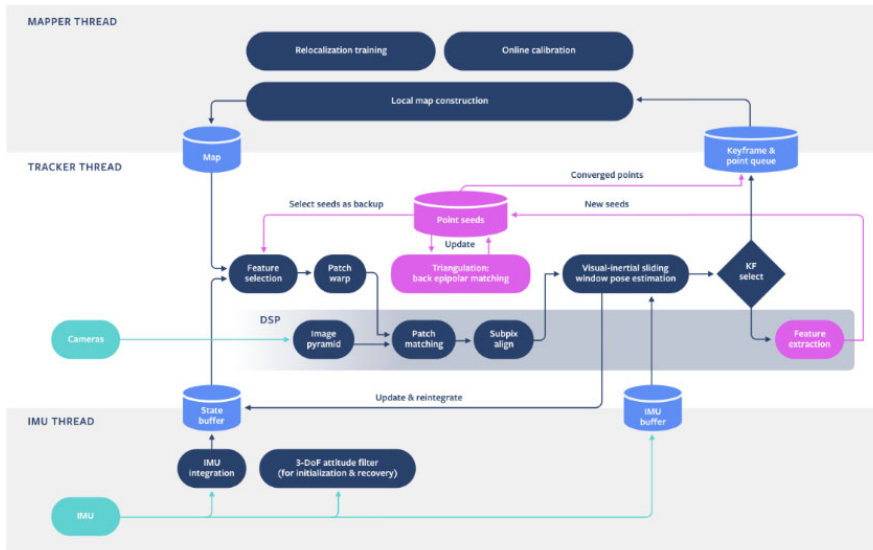
Headset tracking compute architecture



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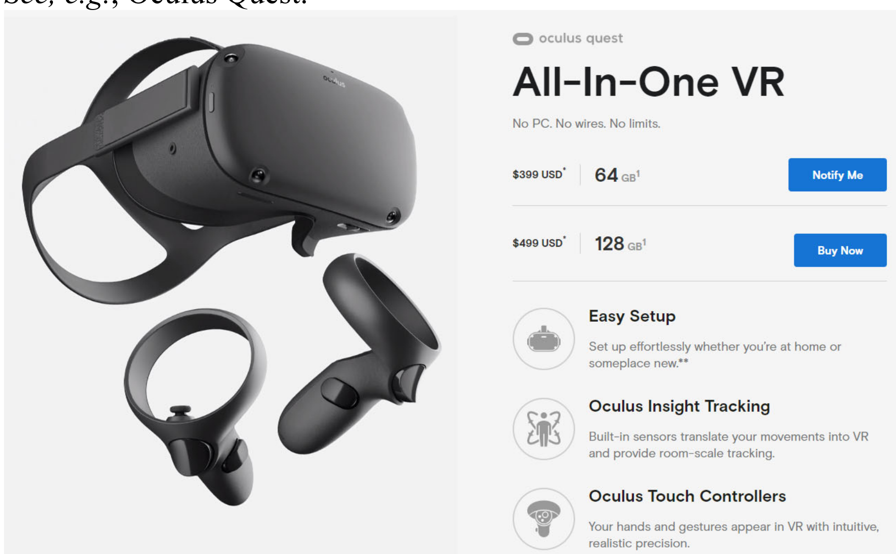
(66b) configuring a data processing module of the tracking or navigation system based on the sensor configuration information to selectively perform one of (a) receiving data from at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the inside-out bearing sensor, (b) receiving data from at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the outside-in bearing sensor, and (c) receiving data from at least one inside-out bearing sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the outside-in bearing sensor and the inside-out bearing sensor.	Facebook encourages, directs, or promotes users to use the Accused Products to perform this step, and Facebook performs such step itself. For example, the Accused Products configure a data processing module of the Oculus Insight tracking system based on the configuration of the sensors to receive data from the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, which are inside-out bearing sensors. The Accused Products update an estimated pose of an object, such as the user's head, the user's hand(s), and/or the Oculus controller(s), based on the sensor data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.  *See also* Oculus Quest Features.  *See, e.g.*, Hand Tracking.

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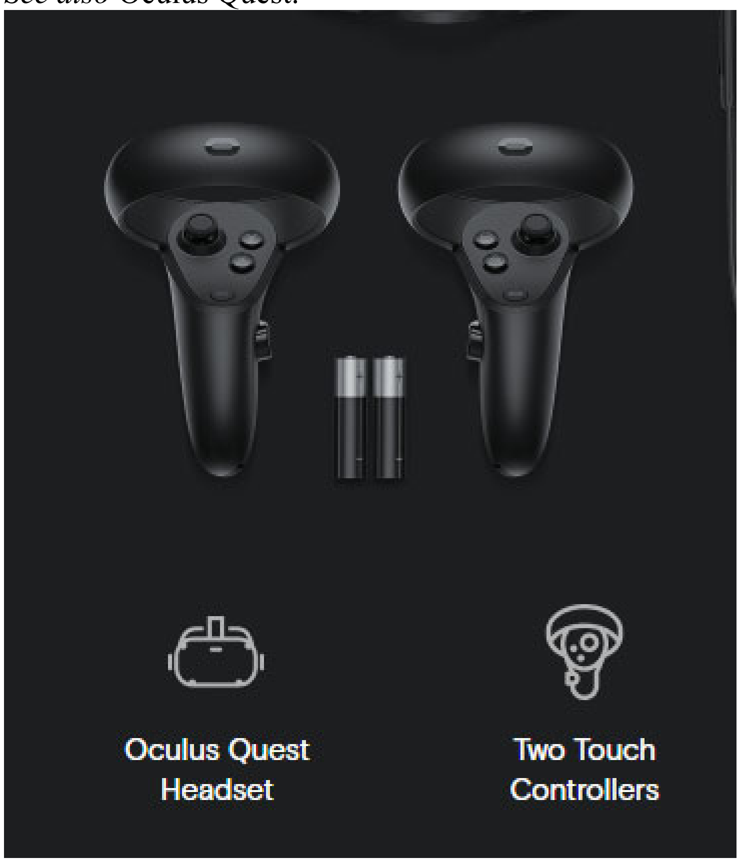
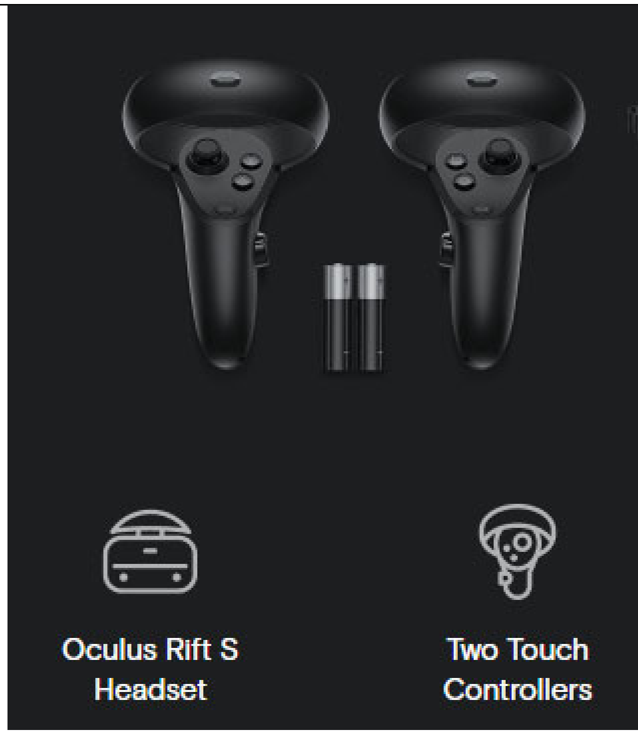
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



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	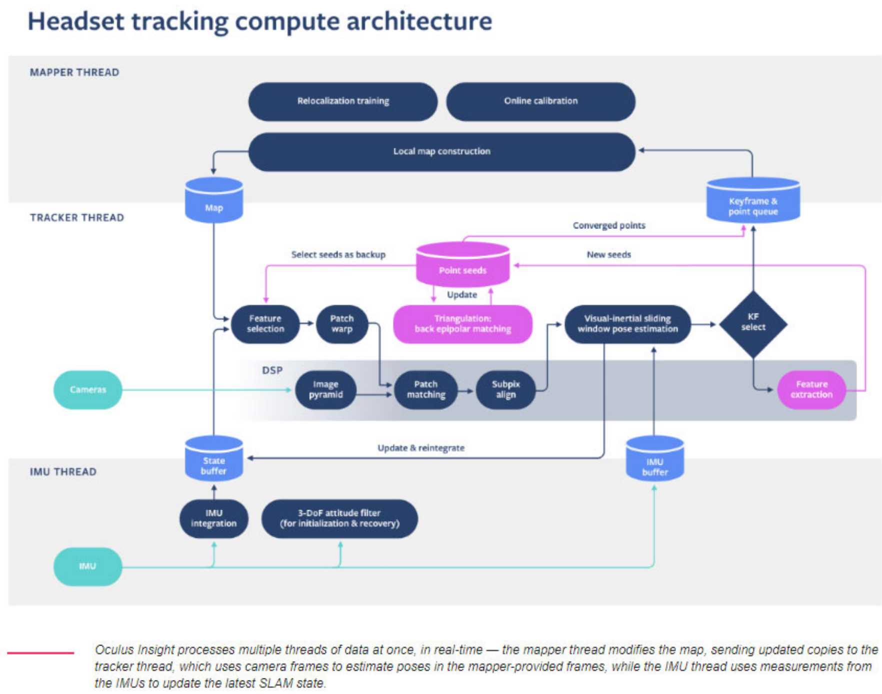 *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

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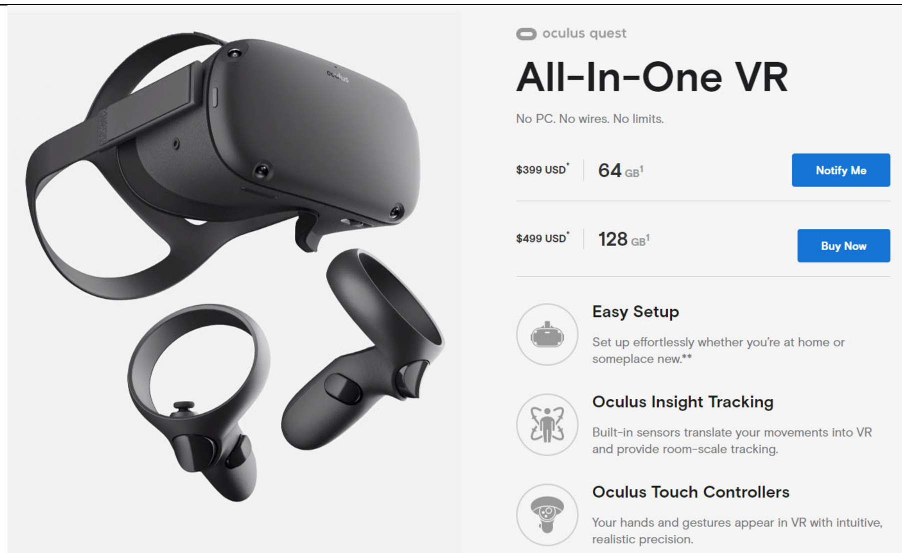
	The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer. Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.  The IMU in the current Touch controllers for Rift S and Quest *See also* ICM-20601 Specification.
Claim 67	
(67) The method of claim 66 further comprising configuring the data processing module to selectively perform one of (d) receiving data from at least one range sensor, and updating an estimated pose of an object based on data received from the range sensor, (e) receiving data from at least one range sensor and at least one inside-out bearing sensor, and updating an estimated	*See supra* claim 66. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 66, further comprising this step, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products configure a data processing module of the Oculus Insight tracking system to selectively receive data from at least one range sensor in the headset and the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, which are inside-out bearing sensors. The Accused Products combine or "fus[e]" all the sensor data received and update an estimated pose of an object, such as the user's head, the user's hand(s), and/or the Oculus controller(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use. *See, e.g.*, Oculus Quest.

<table>
<tr>
<td>pose of an object based on data received from the range sensor and the inside-out bearing sensor,
(f) receiving data from at least one range sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the range sensor and the outside-in bearing sensor, and
(g) receiving data from at least one range sensor, at least one outside-in bearing sensor, and at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the range sensor, the inside-out bearing sensor, and the outside-in bearing sensor.</td>
<td>

See also Oculus Quest Features.


See, e.g., Hand Tracking.
The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

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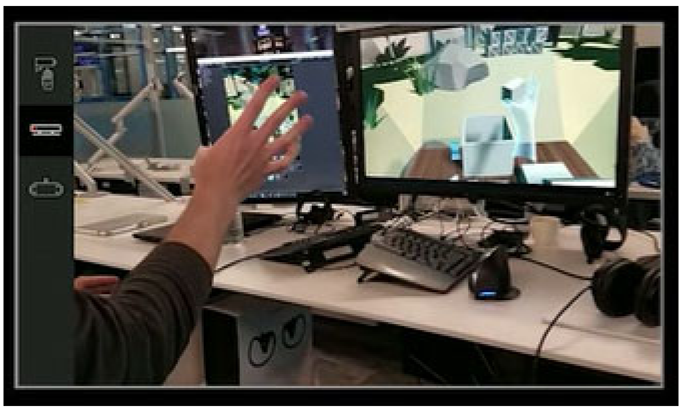

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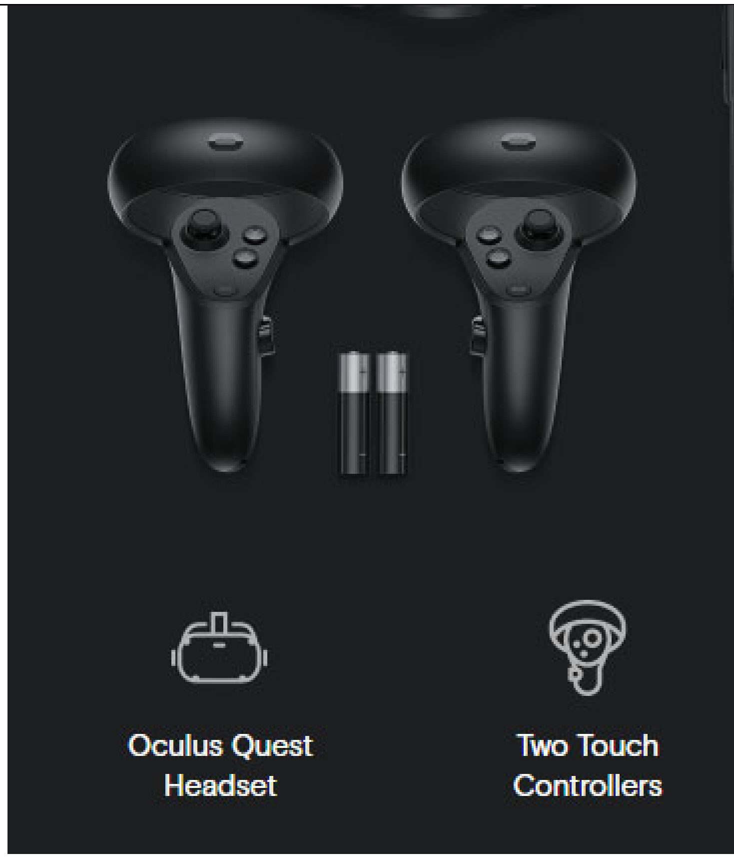
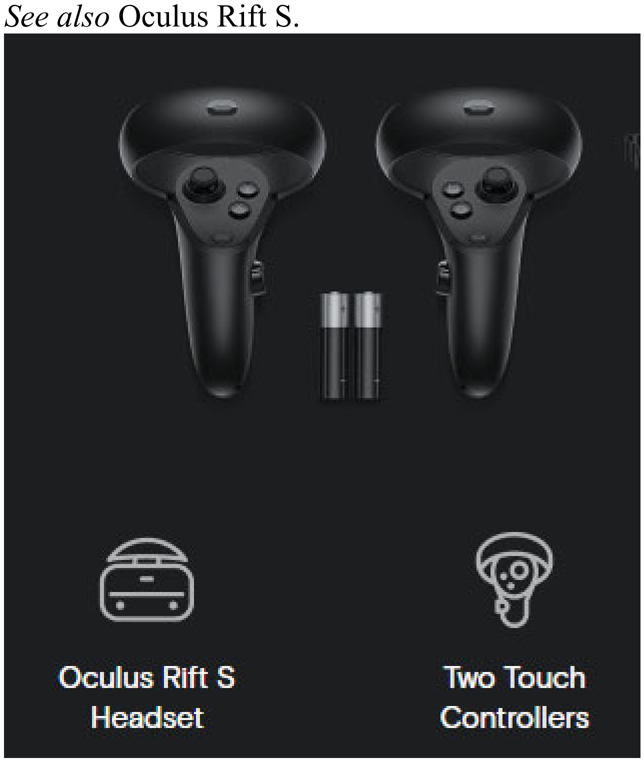
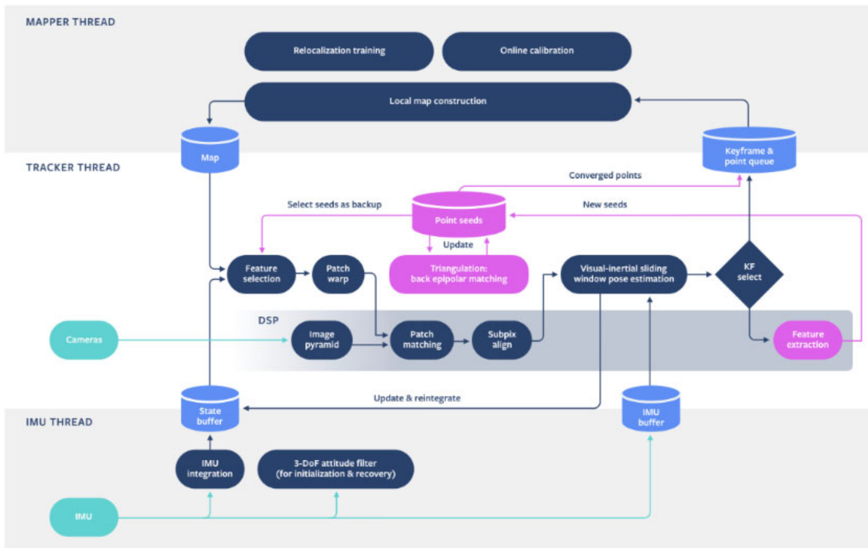
	 *See also* Oculus Rift S.  *See also From the Lab.*

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also From the Lab.* **Taking SLAM technology ...** The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision. "A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems. To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices. *See also Powered by AI.* visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. *See also Powered by AI.* headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also Powered by AI.*

	Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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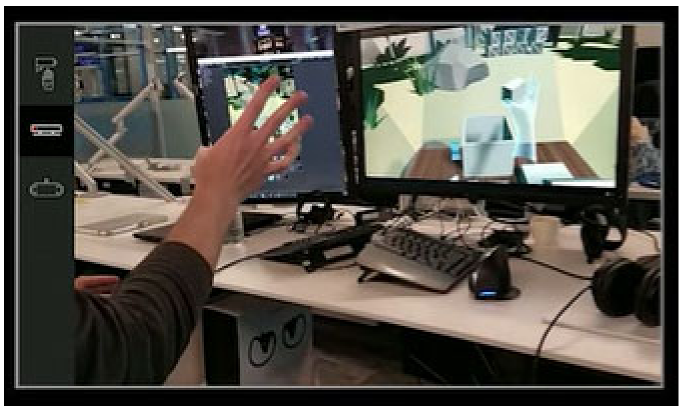
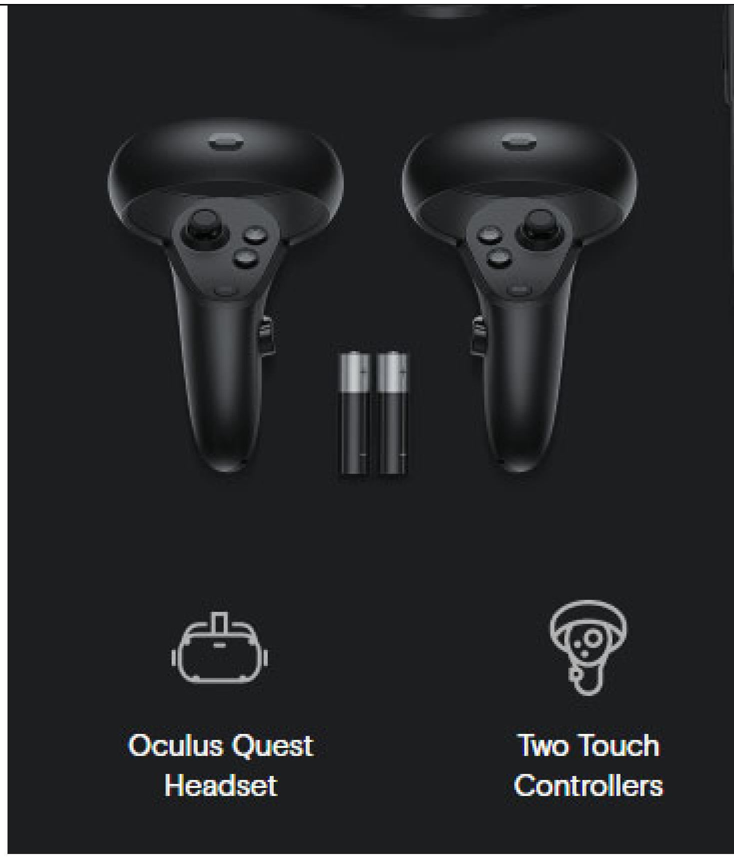
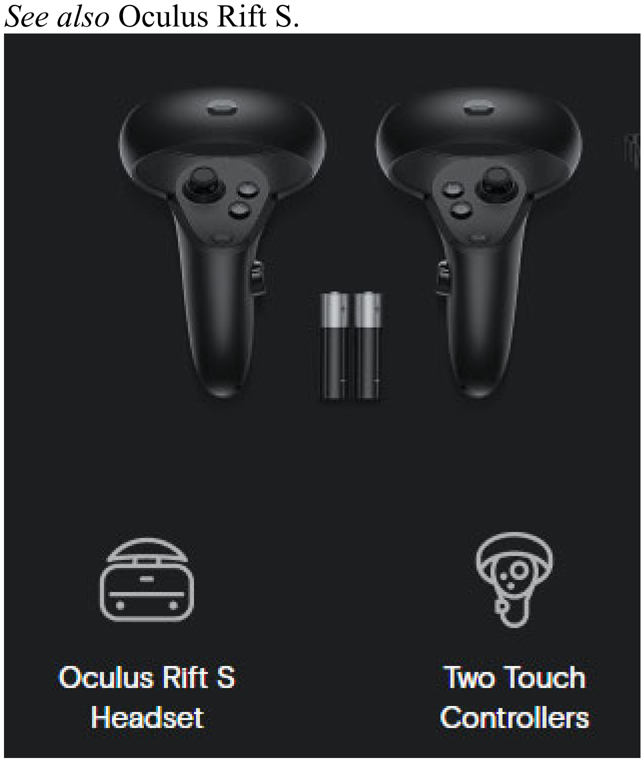
Claim 68	
(68) An apparatus comprising: an estimation module to estimate a pose of an object based on measurement data from sensing elements, the estimation module configured to enable selective performance of (a) receiving data from at least one inside-out bearing sensor, and updating an estimated pose of an object based on the data received from the inside-out bearing sensor, (b) receiving data from at least one	Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise the claimed estimation module. In particular, the Accused Products comprise the Oculus Insight tracking system, which estimates a pose of an object (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)) based on measurement data from sensing elements (e.g., cameras and/or IMUs within the HMD, the IMUs within the Oculus controller(s), and/or the Oculus controller(s)). The Oculus Insight tracking system is configured to receive data from the aforementioned sensing elements, which comprise at least one inside-out bearing sensor, and update an estimated pose of the object based on the data received. Facebook encourages, directs, or promotes users to use the estimation module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the estimation module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

outside-in bearing sensor, and updating an estimated pose of an object based on the data received from the outside-in bearing sensor, and (c) receiving data from at least one inside-out bearing sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on the data received from the outside-in bearing sensor and the inside-out bearing sensor.	*See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands. **Designing for Hands**  *See also* Hand Tracking Deep Dive at 4:00–10:00.

	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

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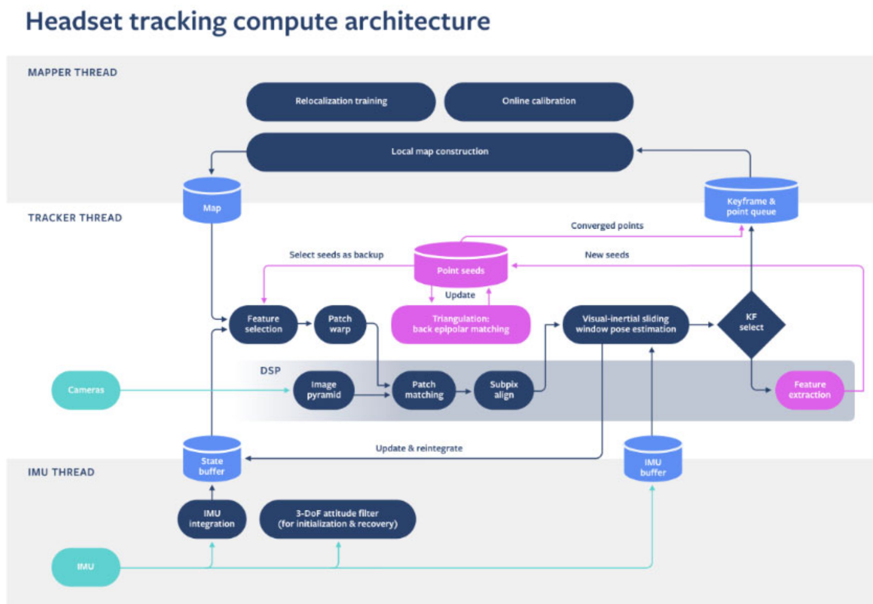

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The IMU in the current Touch controllers for Rift S and Quest

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FEATURES

- 3-Axis Gyroscope with Programmable FSR of ±500dps, ±100dps, ±2000dps and ±4000dps
- 3-Axis Accelerometer with Programmable FSR of ±4*g*, ±8*g*, ±16*g*, and ±32*g*
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I^2C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

11 Comments Share Save Hide Report 78% Upvoted

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SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

<table>
<tr><th colspan="2">Claim 69</th></tr>
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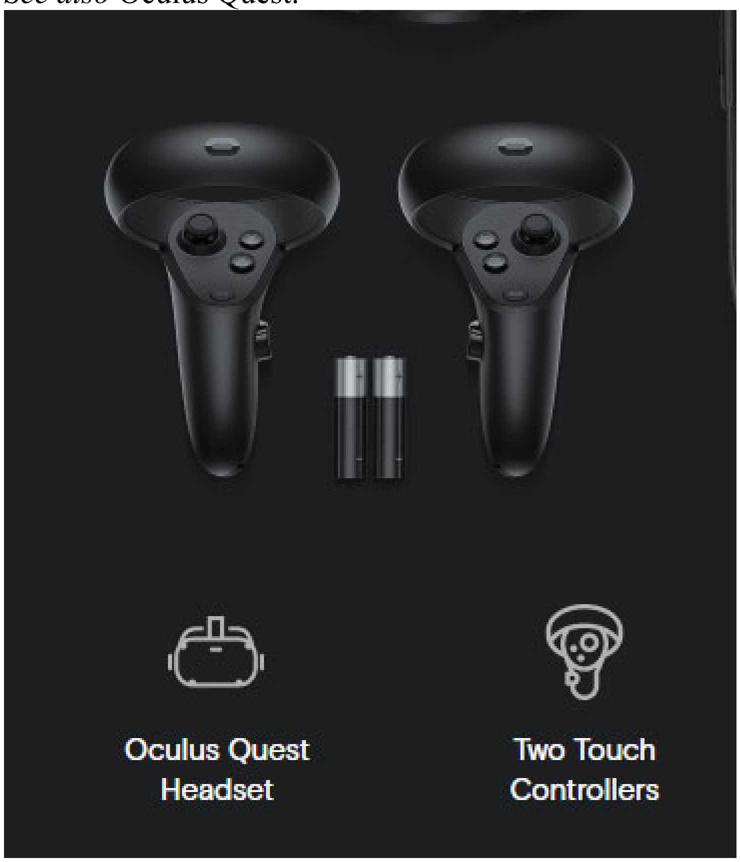
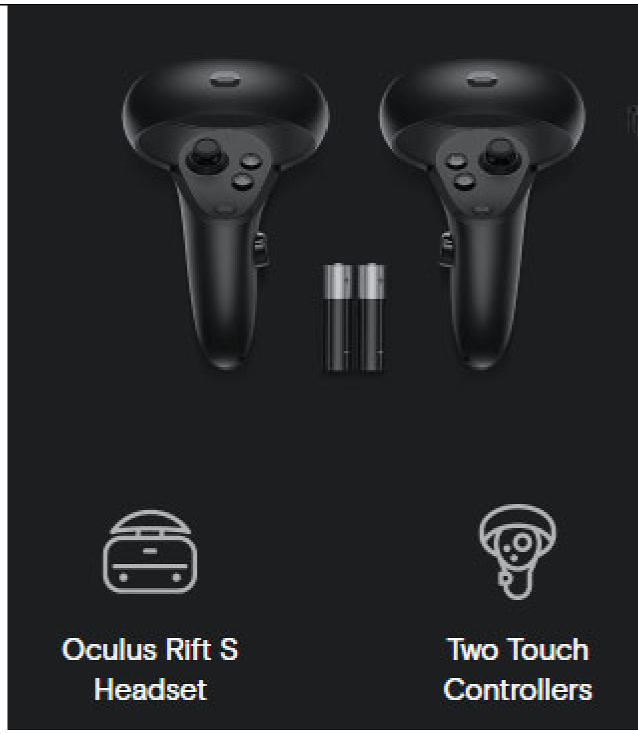
	 *See also* Oculus Quest.  *See also* Oculus Rift S.



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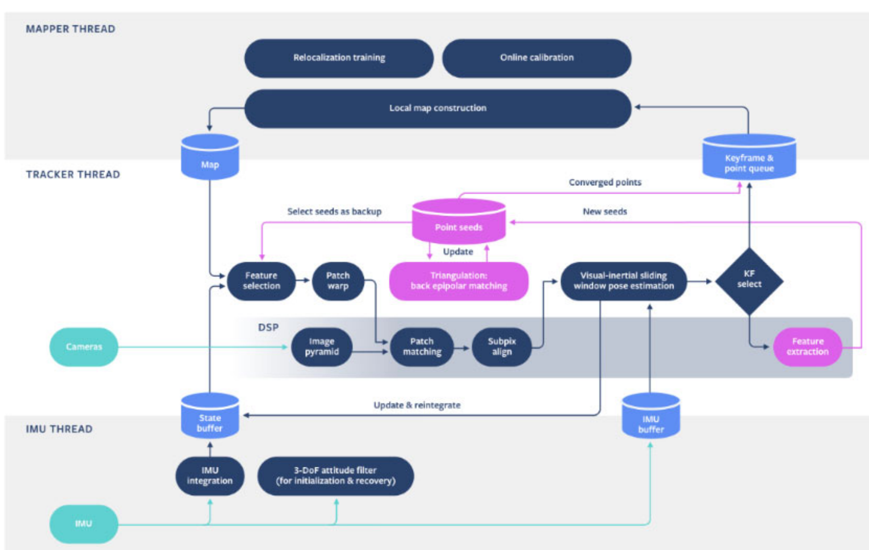

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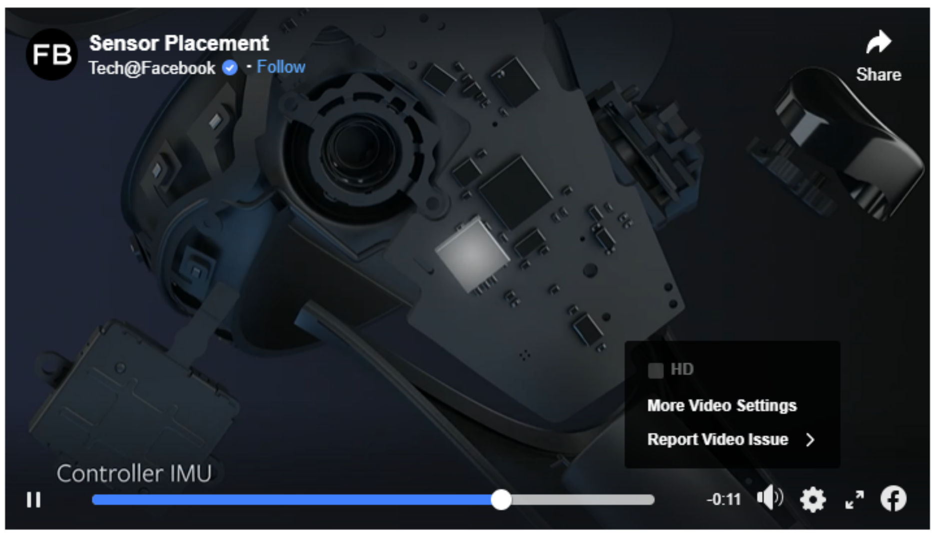
	See also From the Lab, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.  *See also* Heaney.

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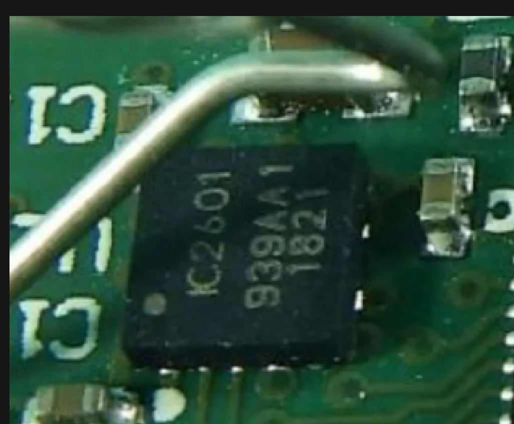

The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

	FEATURES • 3-Axis Gyroscope with Programmable FSR of ±500dps, ±100dps, ±2000dps and ±4000dps • 3-Axis Accelerometer with Programmable FSR of ±4*g*, ±8*g*, ±16*g*, and ±32*g* • User-programmable interrupts • Wake-on-motion interrupt for low power operation of applications processor • 512 byte FIFO buffer enables the applications processor to read the data in bursts • On-Chip 16-bit ADCs and Programmable Filters • Host interface: 8 MHz SPI or 400k Hz Fast Mode I^2C • Digital-output temperature sensor • VDD operating range of 1.71 to 3.45V • MEMS structure hermetically sealed and bonded at wafer level • RoHS and Green compliant *See also* Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

Exhibit 5

Gentex Corporation and Indigo Technologies, LLC (collectively, "Gentex") presently contend that Facebook, Inc. and Facebook Technologies, LLC (collectively, "Facebook") infringe claims 1-4 and 6-9 (the "Asserted Claims") of U.S. Patent No. 7,725,253, directly and/or indirectly, either literally or under the doctrine of equivalents. This chart sets forth Gentex's preliminary infringement contentions relating to the Asserted Claims and the accused products, i.e., the Oculus Rift S, Oculus Quest, and Oculus Quest 2 (collectively, the "Accused Products"). In the event Facebook releases new products or services that infringe the '253 patent, or further investigation reveals that other products or services infringe the '253 patent, Gentex reserves the right to update these contentions as appropriate under the Order Governing Proceedings.

These contentions articulate the structure and acts that constitute direct and/or indirect infringement of the '253 patent and identify specifically where each element of each asserted claim is found within each Accused Product. Exemplary references to publicly available information concerning the Accused Products is provided where appropriate. Exemplary references to specific Accused Products are not intended and should not be read to exclude Accused Products not exemplified. On information and belief, the Accused Products are materially the same with respect to the claims of the '253 patent discussed below, except the contentions below regarding hand tracking, which is performed by the Oculus Quest and Oculus Quest 2, but based on present information, is not performed by the Oculus Rift S. This disclosure is not intended to describe all acts of direct, induced, or contributory infringement Facebook has and continues to commit by making, using, selling, providing, developing, installing, testing, deploying, and/or directing the use of the Accused Products by customers and end users. The parties have not engaged in any discovery. The parties also have not discussed proposed constructions for, and the Court has not yet construed, any of the claims of the '253 patent. As a result, and consistent with the Order Governing Proceedings, Gentex reserves the right to modify, amend, or otherwise supplement these initial infringement contentions as discovery and the pre-trial phase of the litigation proceed and as additional information comes to light, including with respect to which claims Gentex is asserting, the infringement analysis for one or more of the claims, and whether and how limitations of one or more claims are met literally or under the doctrine of equivalents.

U.S. Patent 7,725,253	
Claim 1	
Claim Limitation	**Accused Products**
(1pre) A tracking system comprising:	Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise a tracking system. For example, the Accused Products comprise a tracking system comprising a headset and zero or more controllers. The tracking system estimates the position and orientation of the head-mounted display ("HMD"), one or more Oculus controllers, and/or the user's head and hands based on measurement data from sensing elements, such as the HMD cameras and the inertial measurement units ("IMUs") of the HMD and controllers. Facebook encourages, directs, or promotes users to use the tracking system within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the tracking system within the Accused Products. Facebook further provides or sells the Accused Products to third

parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

See, e.g., *Compare Headsets*, https://www.oculus.com/compare/?products=quest%2Cquest-2.

Oculus Quest
All-In-One VR Gaming

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

Oculus Quest 2
Advanced All-In-One VR Gaming

Starting At **$299 USD**[*]

BUY NOW

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

Oculus Rift S
PC-Powered VR Gaming

TRACKING

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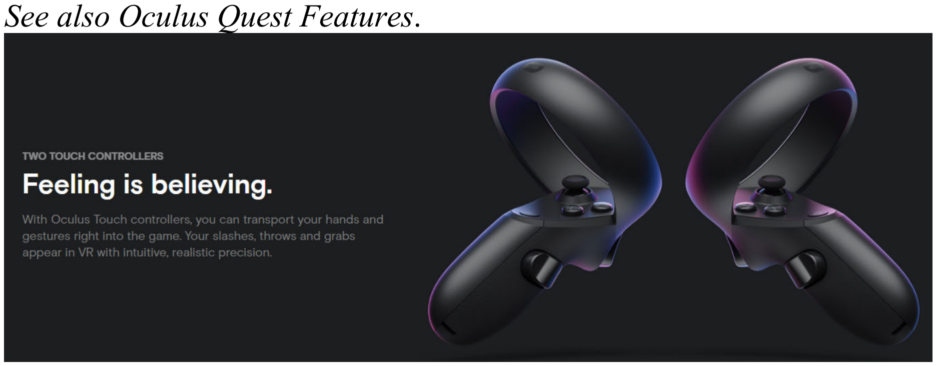
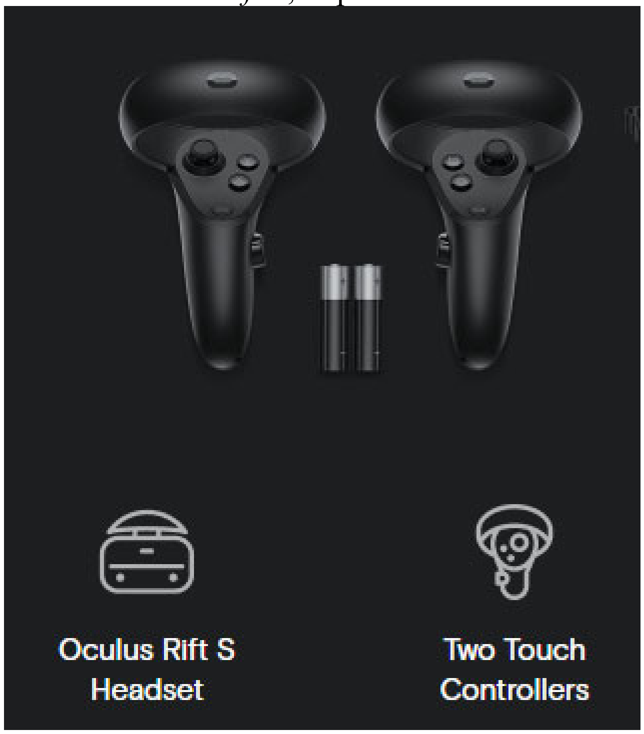
See also Oculus Quest Features.



See also Oculus Rift S, https://www.oculus.com/rift-s/.



See also Tech@facebook, *From the Lab to the living room: The story behind Facebook's Oculus Insight technology and a new era of consumer VR* (Aug. 22, 2019), https://tech.fb.com/the-story-behind-oculus-insight-technology/, Sensor Placement at 0:15 (hereinafter "*From the Lab*").

Taking SLAM technology ...

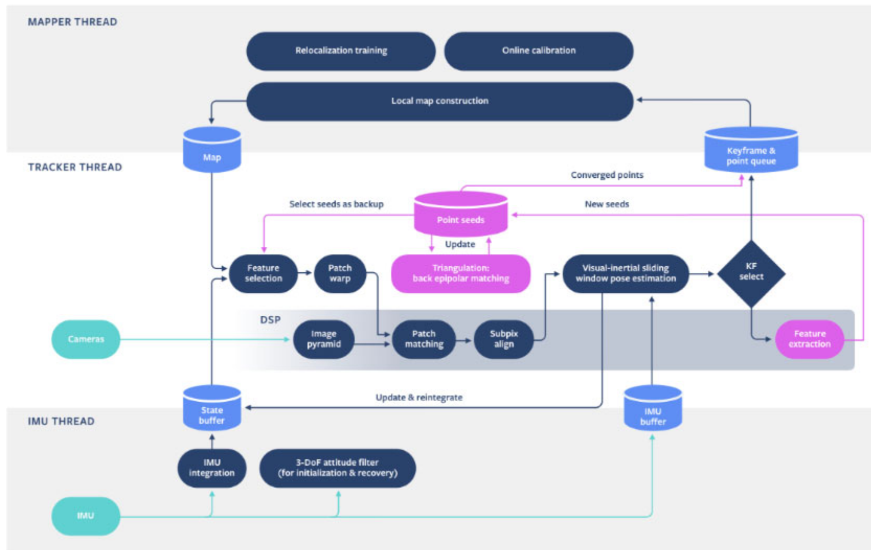
The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems.

See also id.

	There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also id.* Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up. *See also* Oculus Blog, *Powered by AI* (Aug. 22, 2019), https://ai.facebook.com/blog/powered-by-ai-oculus-insight/ (hereinafter "*Powered by AI*"). headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: 1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency. 2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking). 3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs. *See also id.* At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM. *See also id.*

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also Ben Lang, *Quest Teardown Shows How Oculus Crammed Cooling & Cameras Inside* (July 17, 2019), https://www.roadtovr.com/oculus-quest-teardown-disassembly/ (hereinafter "Lang").

Image courtesy BadVR, Jad Meouchy

Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

See also David Heaney, Oculus Firmware Reveals New Touch Controllers, Referencing Improvements to Tracking, Finger Sensing, Haptics (Apr. 16, 2020), https://uploadvr.com/oculus-jedi-controller-driver-found/ (hereinafter "Heaney").

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Heaney.

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FEATURES

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(1a) an estimation subsystem; and

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The Accused Products further comprise an estimation subsystem. For example, the Accused Products comprise the Oculus Insight tracking system, which operates on either the device processor or the processor for the user's computer. The Oculus Insight tracking system estimates the position and orientation of the HMD, one or more Oculus controllers, and/or the user's head and hands based on measurement data from sensing elements, such as the HMD cameras and the IMUs of the HMD and controllers.

See, e.g., *From the Lab*.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

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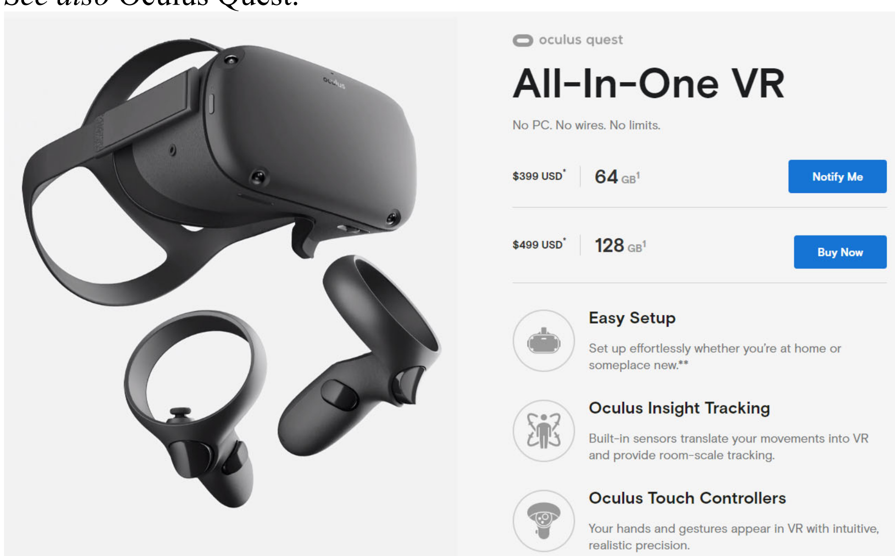
See also Powered by AI.

To unlock the full potential of virtual reality (VR) and augmented reality (AR) experiences, the technology needs to work anywhere, adapting to the spaces where people live and how they move within those real-world environments. When we developed Oculus Quest, the first all-in-one, completely wire-free VR gaming system, we knew we needed positional tracking that was precise, accurate, and available in real time — within the confines of a standalone headset, meaning it had to be compact and energy efficient.

See also Oculus Quest.



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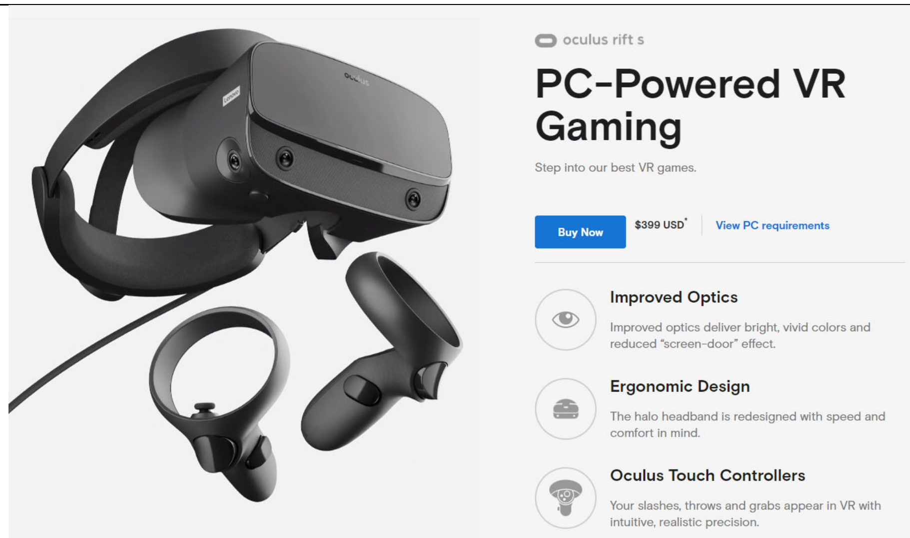

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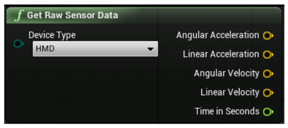
See also Get Raw Sensor Data, Oculus Documentation, https://developer.oculus.com/documentation/unreal/unreal-blueprints-get-raw-sensor-data/?locale=en_US.

Overview

This blueprint reports raw sensor data from the headset, such as its angular acceleration or linear velocity. If the headset does not support a sensor data reading, then that result will return as zero.

Blueprint



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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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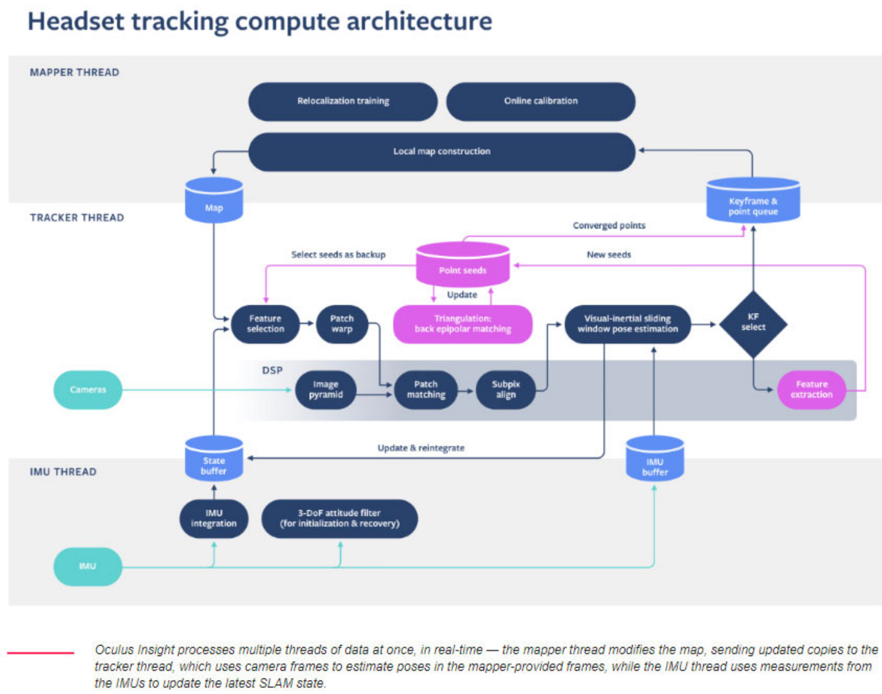

See also From the Lab, Sensor Placement at 0:23.

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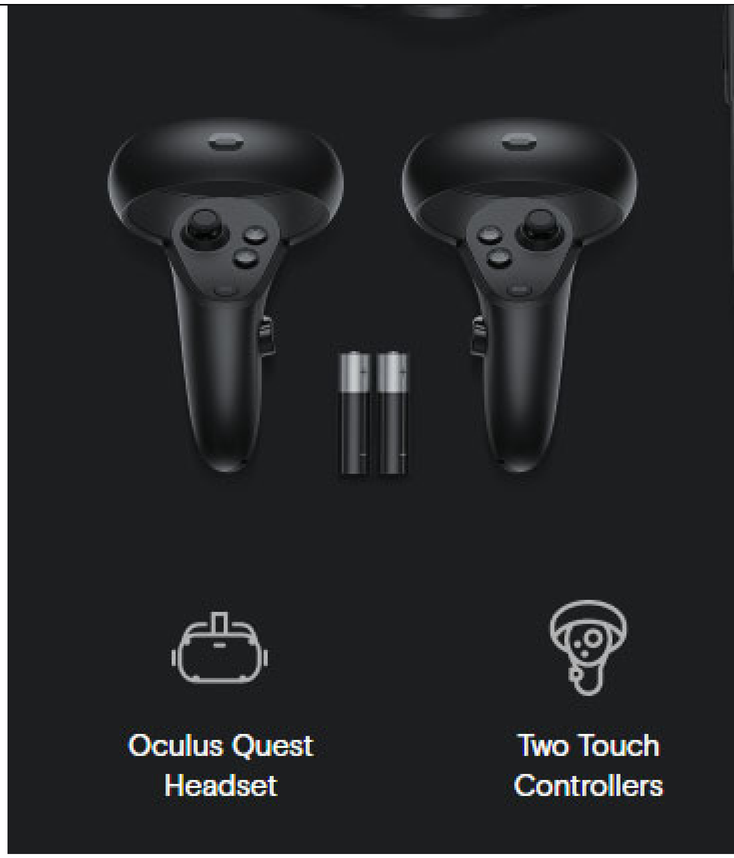
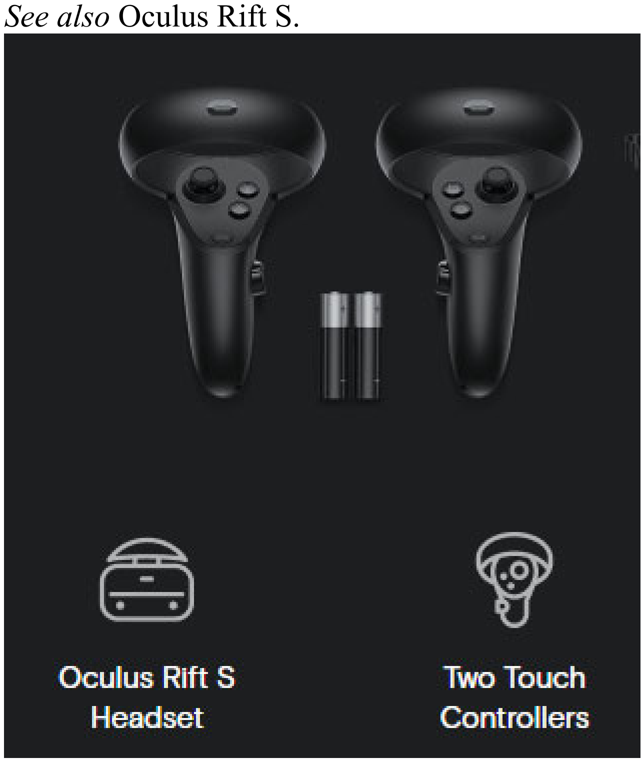
Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

See also Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI.*

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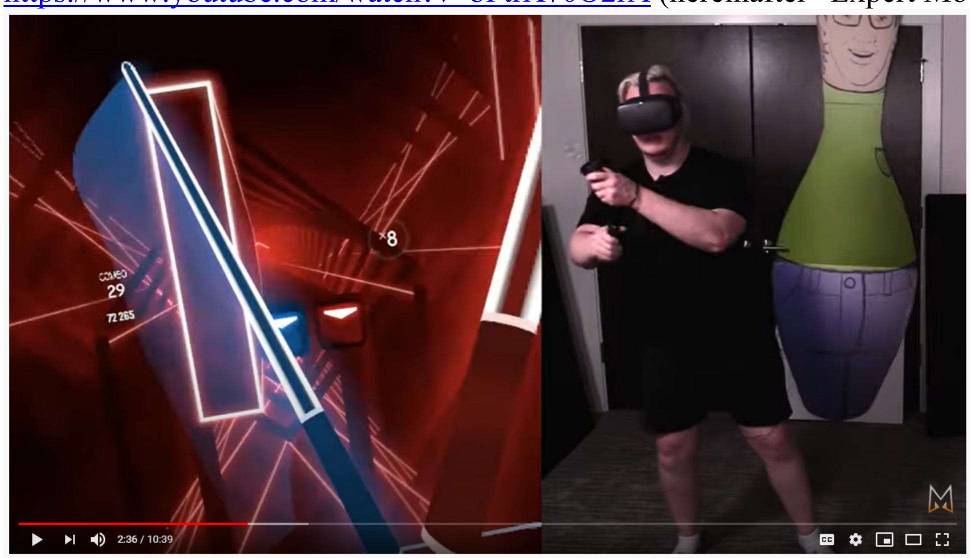
See also EXPERT MODE on Beat Saber [ft Oculus Quest!] at 2:36, https://www.youtube.com/watch?v=bPtrX70O2rA (hereinafter "Expert Mode").



(1c) wherein the estimation subsystem is configured to update a location estimate for the object based on configuration data and measurement information accepted from the sensor subsystem.	The estimation subsystem in the Accused Products is configured to update a location estimate for the object based on configuration data and measurement information accepted from the sensor subsystem. For example, the estimation subsystem in the Accused Products (e.g., the Oculus Insight tracking system) is configured to update a location estimate for the object (e.g., the HMD, one or more Oculus controllers, and/or the user's head and hands). The location estimate is based on configuration data (e.g., data about how the sensors are configured) and measurement information (e.g., data from the sensors) accepted from the sensor subsystem (e.g., the cameras and IMUs, such as accelerometers and gyroscopes, within the HMD, and the IMUs within the Oculus controllers, along with the software components associated with these sensors). When the Accused Products are in the no controller configuration, only the HMD cameras are used to track hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers and the HMD receives inertial signals from the controller IMUs to determine the hand's or hands' location. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

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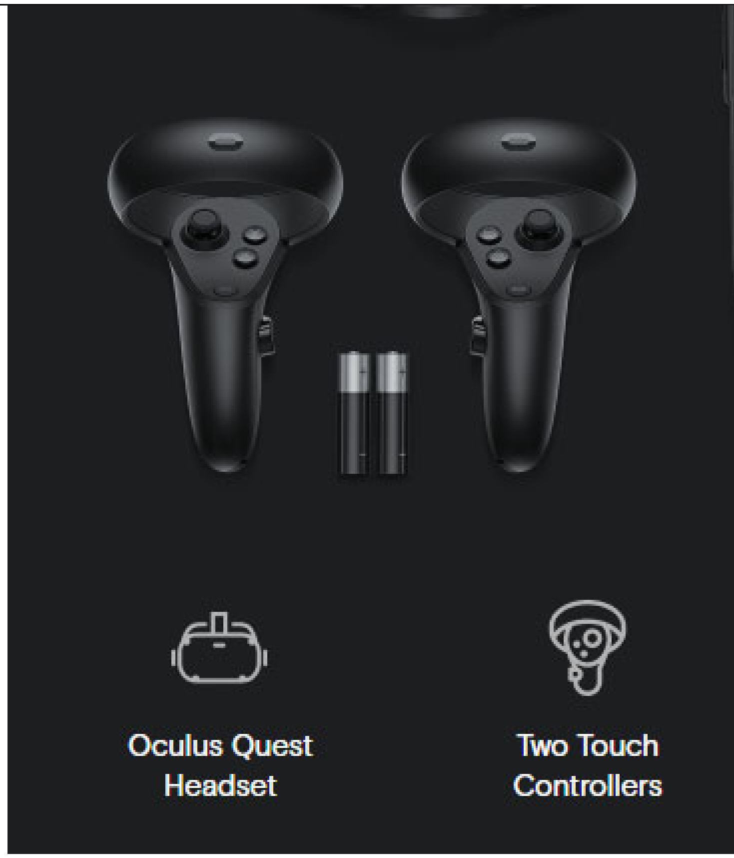
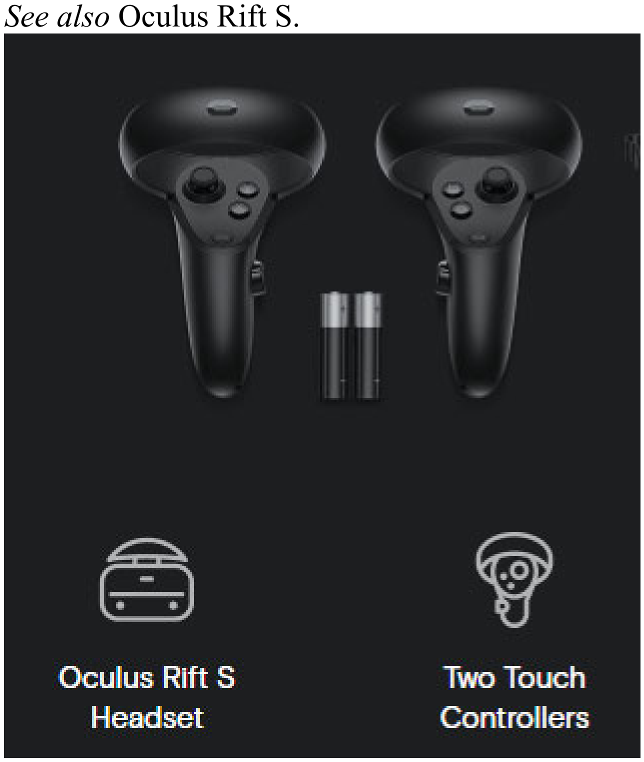
	 *See also* Oculus Rift S.  *See also Powered by AI.*

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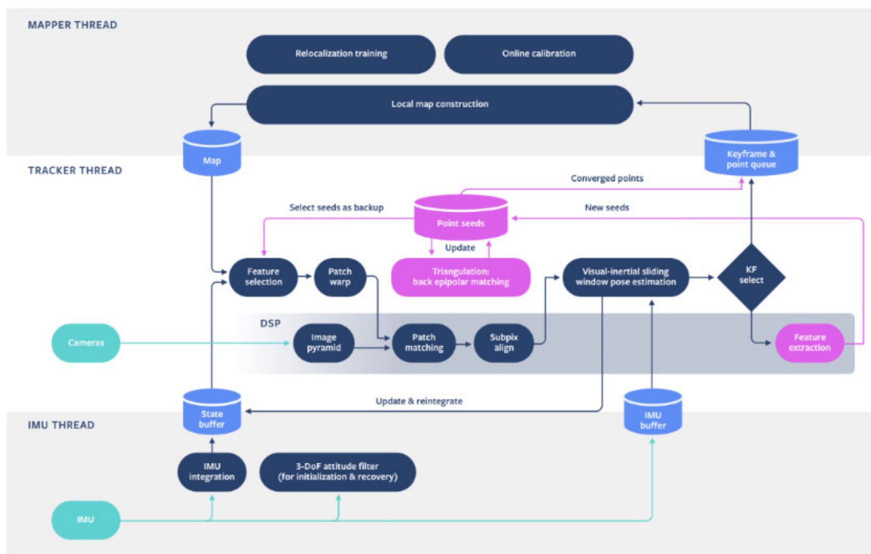
	Headset tracking compute architecture  *Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.* *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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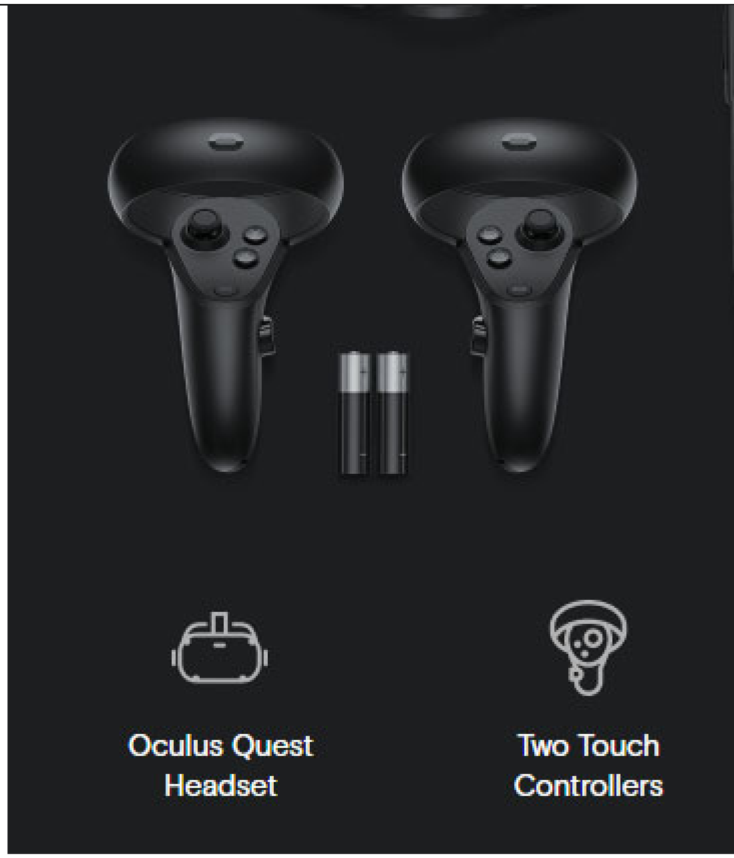
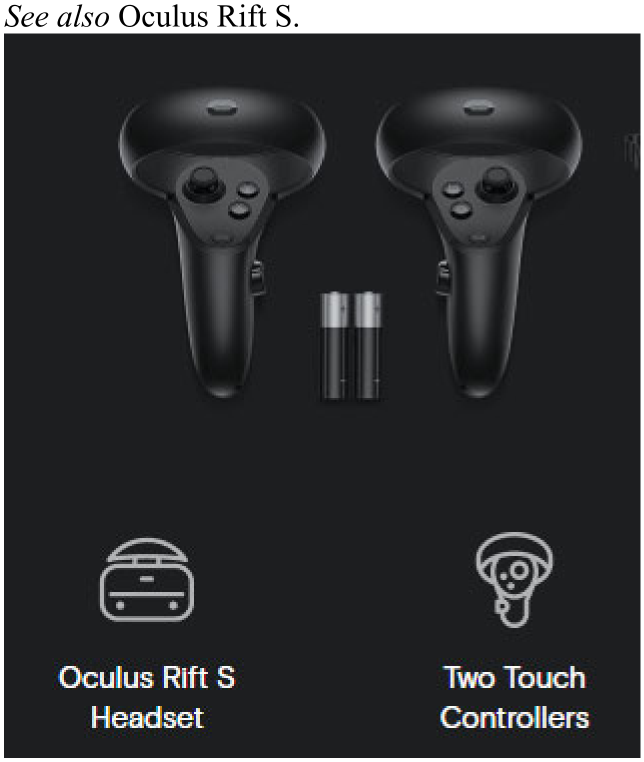
	 *See also* Oculus Rift S.  *See also Powered by AI*.

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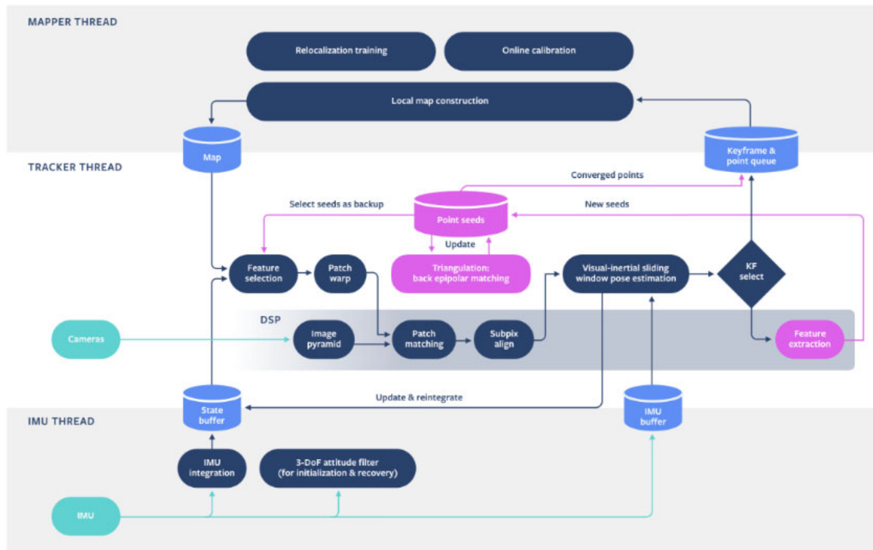

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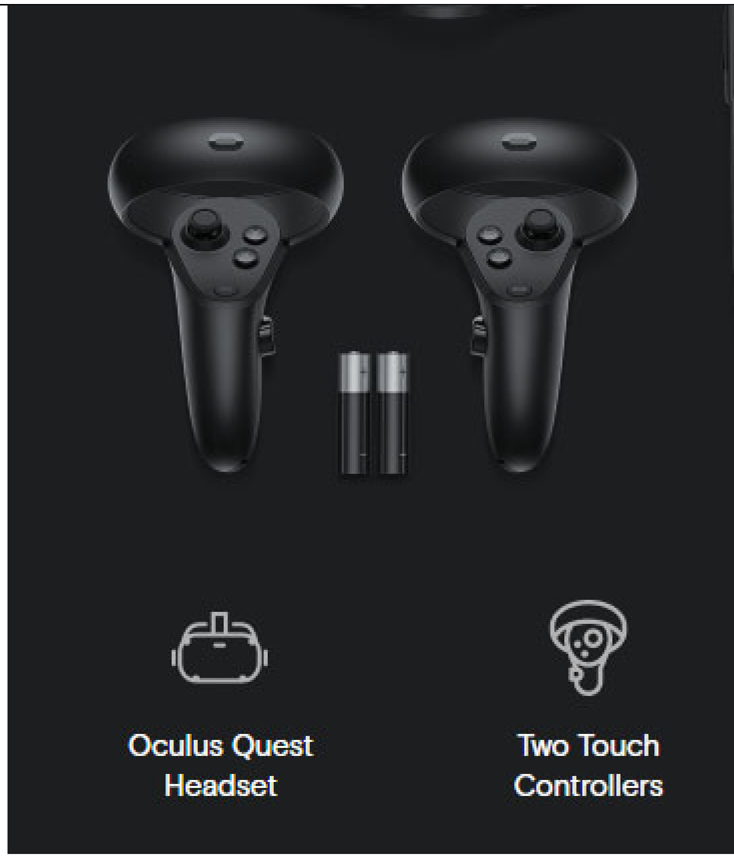
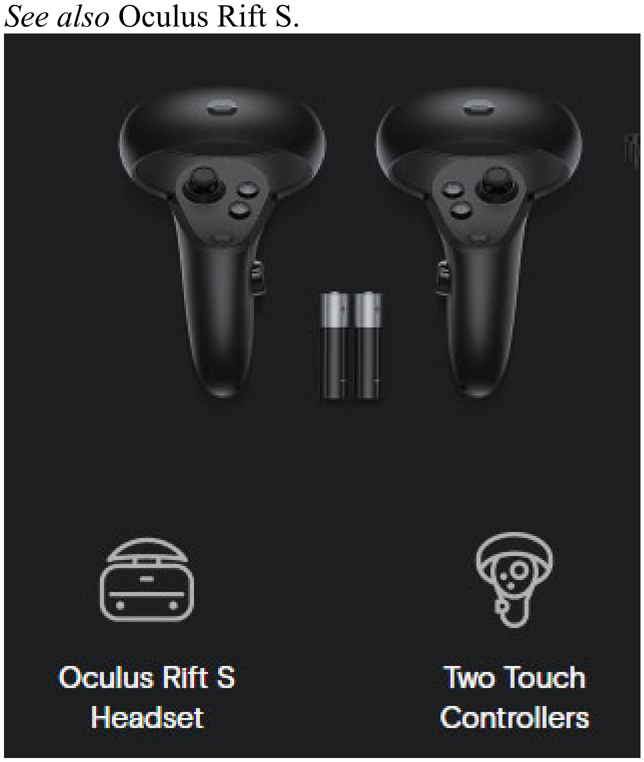
	 *See also* Oculus Rift S.  *See also Powered by AI*.

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	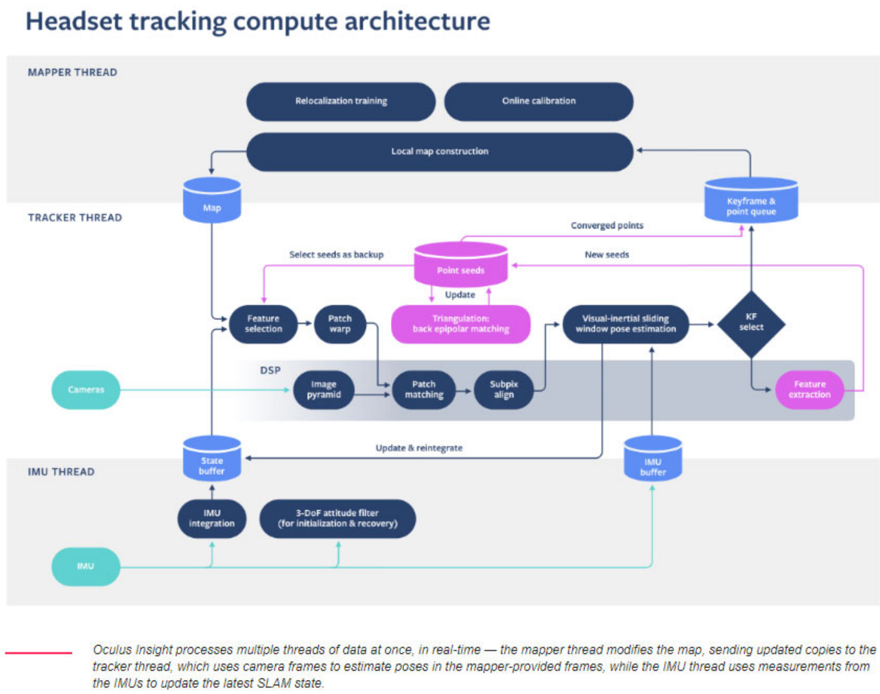 *See also From the Lab*, Sensor Placement at 0:23.  *See also From the Lab*, Sensor Placement at 0:30.

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- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
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See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

Claim 4	
(4) The system of claim 2 wherein the interface enables the estimation subsystem to perform computations independently of an implementation of the sensor modules.	*See supra* claims 1, 2. Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, in which the interface for each sensor module included in the sensor subsystem to interact with a corresponding set of one or more sensing elements enables the estimation subsystem to perform computations independently of an implementation of the sensor modules. For example, in the Accused Products, the interfaces between each sensor module (e.g., software components, such as the IMU thread) and a corresponding set of one or more sensing elements (e.g., the cameras and IMUs, such as accelerometers and gyroscopes, within the HMD, and the IMUs within the Oculus controllers) enable the estimation subsystem (e.g., the Oculus Insight tracking system) to perform computations (e.g., updating a location estimate for the user's hands, the user's head, the HMD, and/or the Oculus controllers) independently of the implementation of the sensor modules. Facebook encourages, directs, or promotes users to use the tracking system within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the tracking system within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

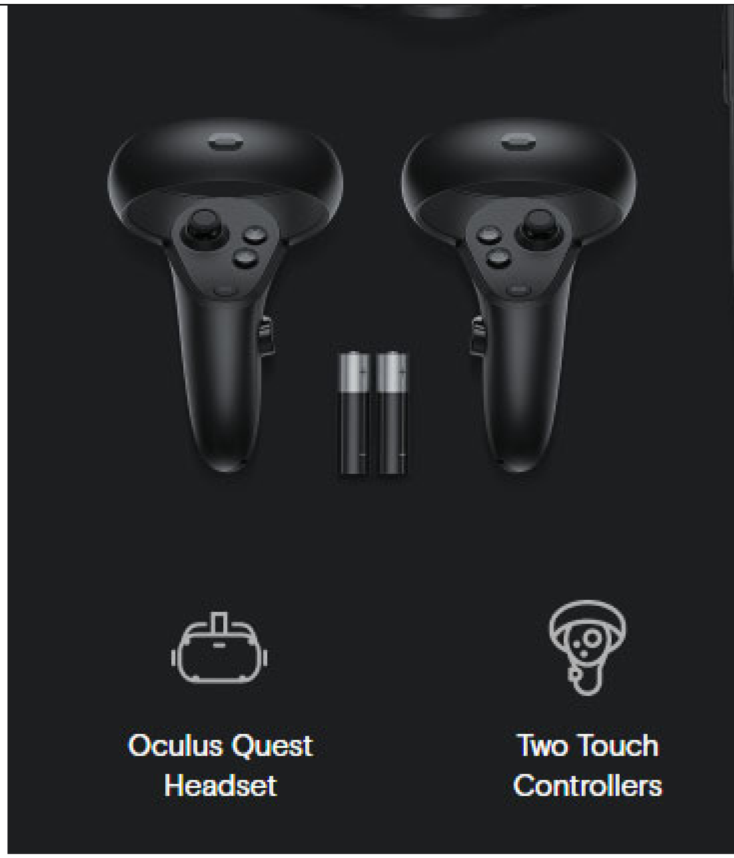
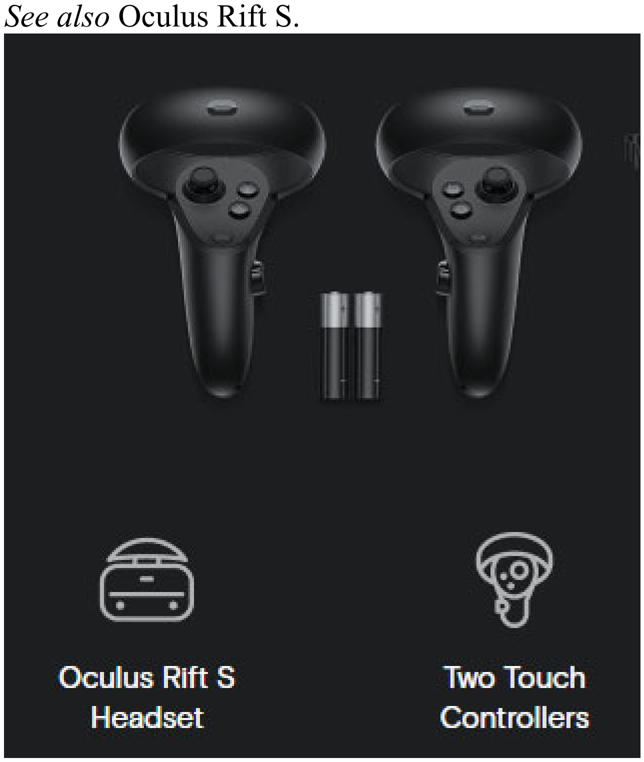
See also Designing for Hands.

Designing for Hands

See also Hand Tracking Deep Dive at 4:00–10:00.

See also id. at 4:00–10:00.

See also Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

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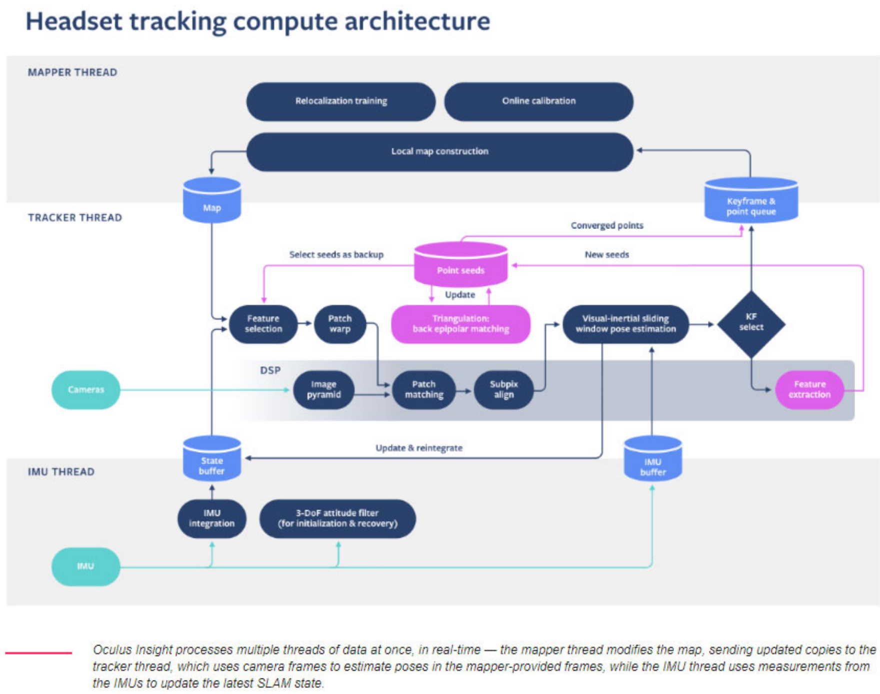

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Claim 6	
(6pre) A method comprising:	As set forth below, Facebook encourages, directs, or promotes users to carry out the claimed method with the Accused Products, and Facebook performs the claimed method. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation). *See, e.g.*, *Compare Headsets*.  **Oculus Quest** All-In-One VR Gaming **TRACKING** **Six Degrees of Freedom** With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

Oculus Quest 2

Advanced All-In-One VR Gaming

Starting At **$299 USD***

BUY NOW

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

Oculus Rift S
PC-Powered VR Gaming

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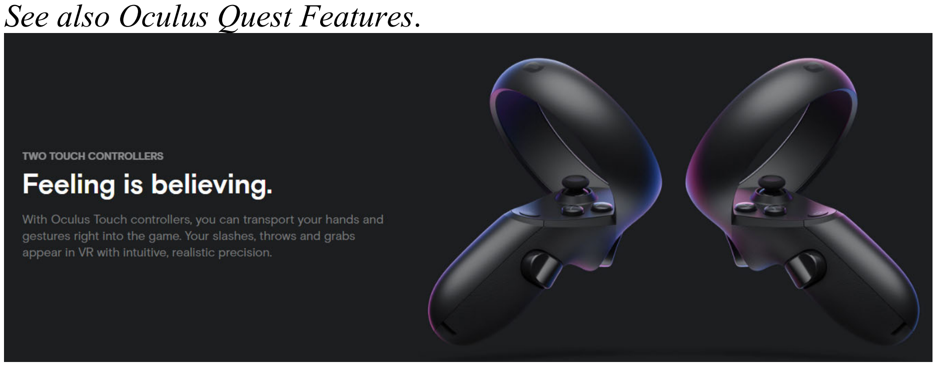
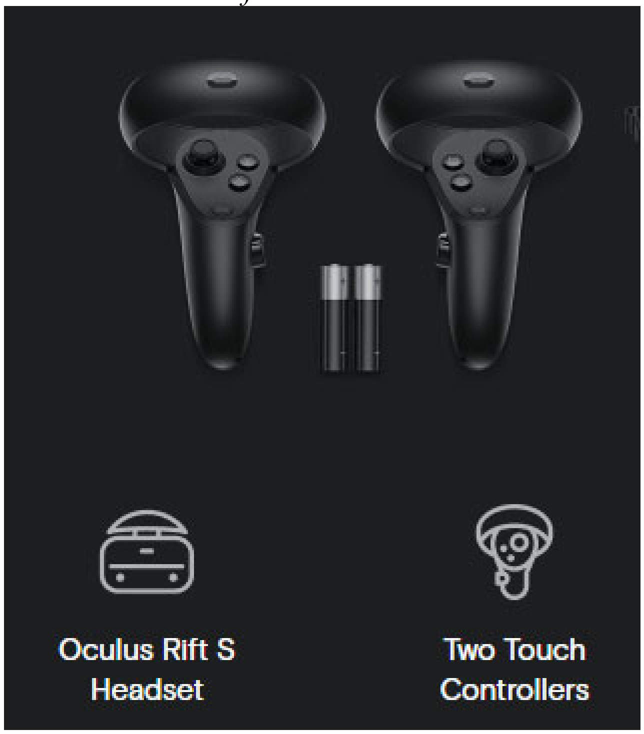
See also Oculus Quest Features.



	See also Oculus Rift S. 
(6a) enumerating sensing elements available to a tracking system that includes an estimation subsystem that estimates a position or orientation of an object; and	Facebook encourages, directs, or promotes users to use the Accused Products to enumerate sensing elements (e.g., cameras and/or IMUs within the HMD, the IMUs within the Oculus controller(s), and/or the Oculus controller(s)) available to a tracking system (e.g., the headset and/or controllers) that includes an estimation subsystem (e.g., the Oculus Insight tracking system) that estimates a position or orientation of an object (e.g., the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. For example, the Accused Products enumerate sensing elements available to the headset and/or controllers. When the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s). As a further example, the tracking system in the Accused Products enumerates the sensing elements available, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation). *See, e.g., From the Lab.*

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See also Oculus Rift S.

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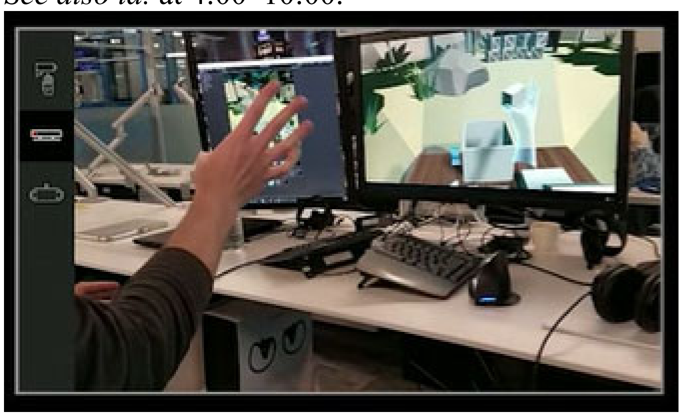
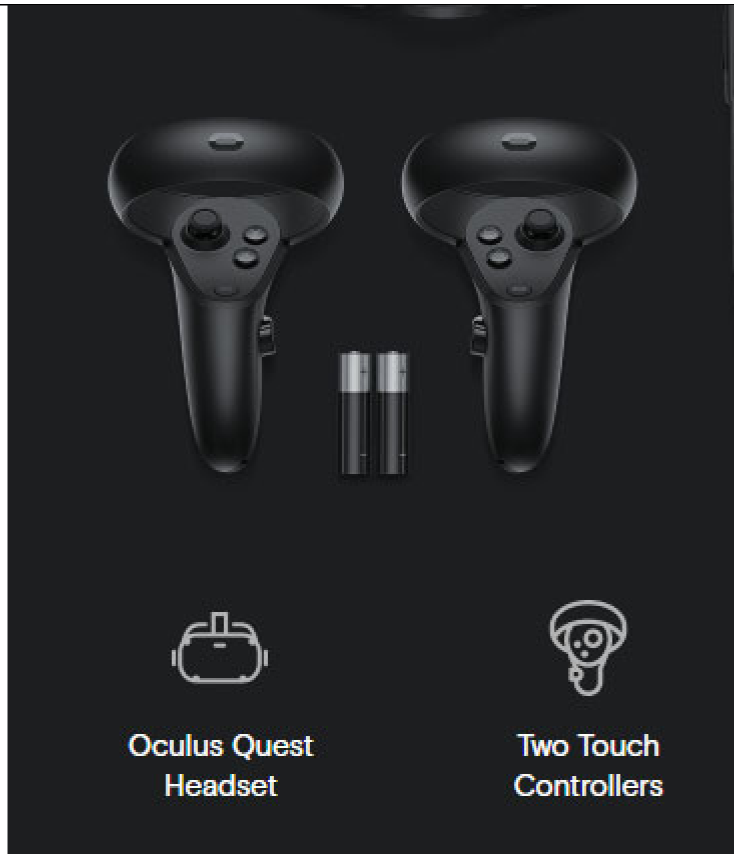
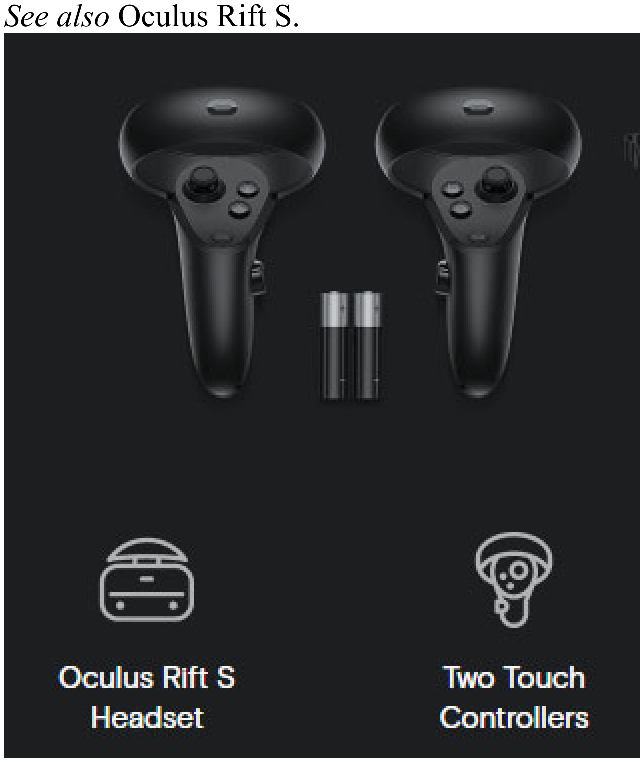
	 *See also id.* at 4:00–10:00.  *See also* Oculus Quest.

	 *See also* Oculus Rift S.  *See also Powered by AI*.

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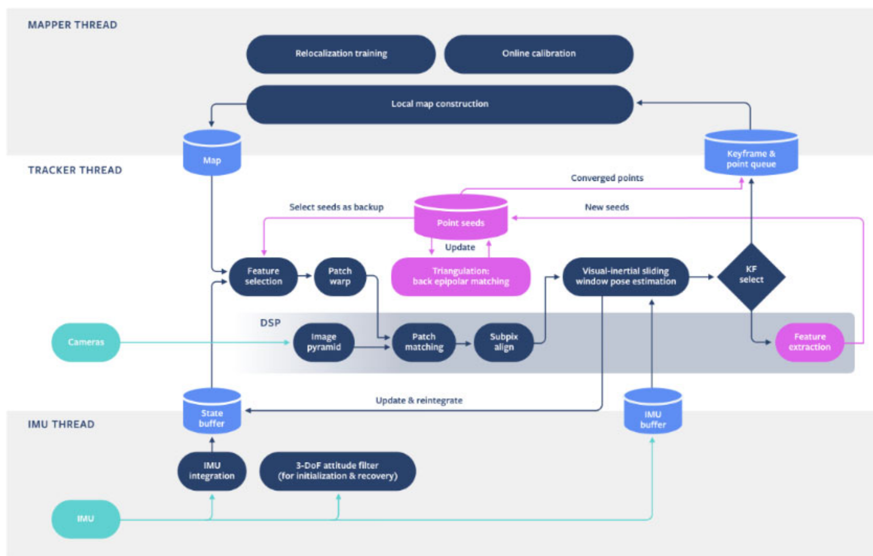
Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.

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See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch– cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.

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See also ICM-20601 Specification.

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(6b) providing parameters specific to the enumerated sensing elements to the tracking system to enable the estimation subsystem to be configured based on the parameters specific to the enumerated sensing elements to enable the estimation subsystem to estimate the position or orientation of the object.	Facebook encourages, directs, or promotes users to use the Accused Products to provide parameters specific to the enumerated sensing elements (e.g., the characteristics of the sensing elements and/or the number of controllers in use at a particular time) to the tracking system to enable the estimation subsystem to be configured based on the parameters specific to the enumerated sensing elements to enable the estimation subsystem (e.g., the Oculus Insight tracking system) to estimate the position or orientation of the object (e.g., the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. For example, when the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s) and/or the Oculus controller(s). As a further example, in the Accused Products, parameters specific to the sensing elements enumerated, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), are provided to the tracking system so that the Oculus Insight tracking system can be configured based on parameters specific to the sensing elements enumerated. Configuring the Oculus Insight tracking system based on these parameters enables it to estimate the position or orientation of the user's hand(s) and/or the Oculus controller(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation). *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

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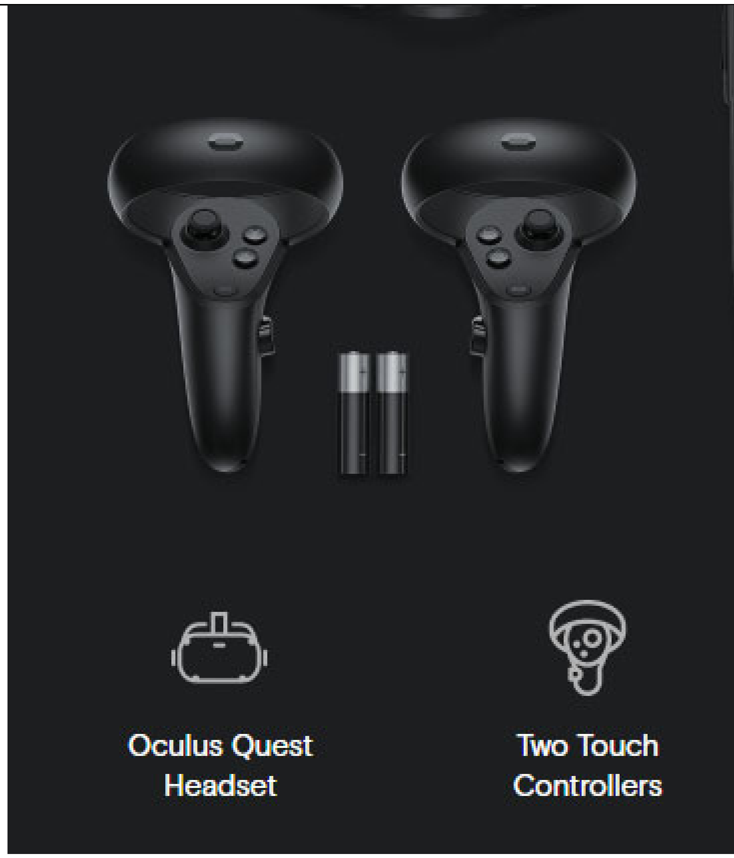
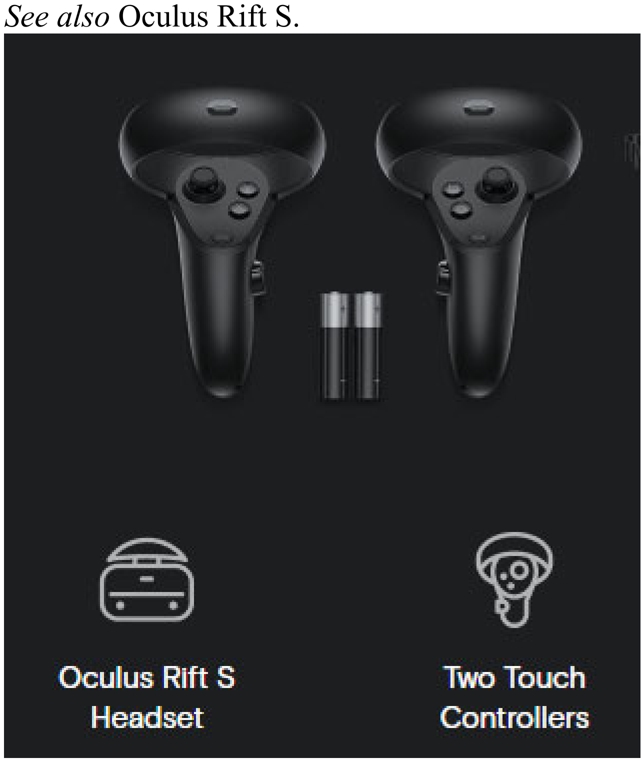
	 *See also* Oculus Rift S.  *See also Powered by AI.*

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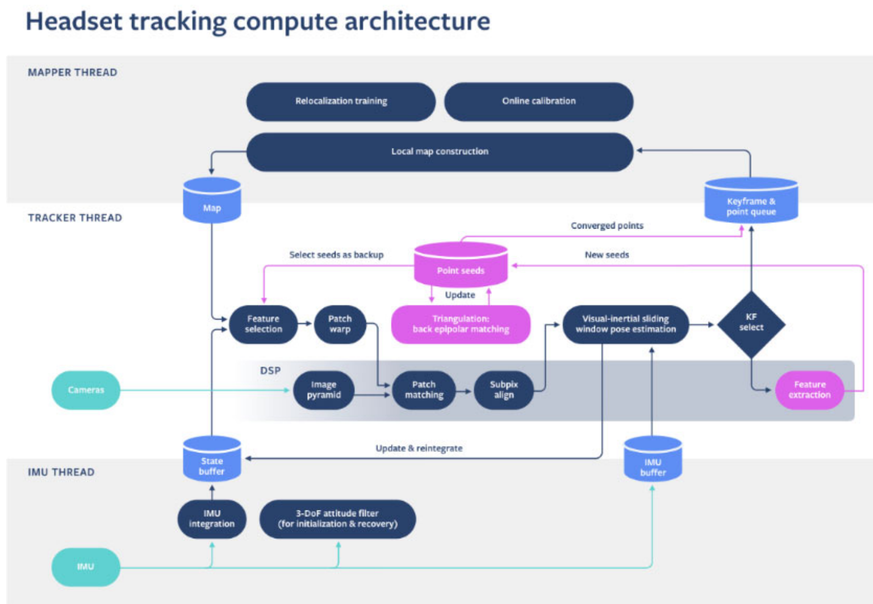

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See also From the Lab, Sensor Placement at 0:30.

See also Heaney.

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Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

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The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

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- Wake-on-motion interrupt for low power operation of applications processor
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- Host interface: 8 MHz SPI or 400k Hz Fast Mode I^2C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

https://imgur.com/a/1dLoatG

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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New comments cannot be posted and votes cannot be cast

SORT BY BEST

maltakan0 6 points · 1 year ago
Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago
Quest is a bit heavier too if that is a factor

stigzcousin 1 point · 1 year ago
This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago
Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

META 1012
META V. THALES

Claim 7	
(7) The method of claim 6, further comprising selecting a pair of sensing elements from a sequence of candidates of pairs of sensing elements, the selected pair of sensing elements being ready to make a measurement at the time of selection of the pair or at a predefined time after the time of selection of the pair, the selected pair having a highest expected utility of a measurement among the sequence of candidates.	*See supra* claim 6. Facebook encourages, directs, or promotes users to perform the method of claim 6, further comprising selecting a pair of sensing elements from a sequence of candidates of pairs of sensing elements, the selected pair of sensing elements being ready to make a measurement at the time of selection of the pair or at a predefined time after the time of selection of the pair, the selected pair having a highest expected utility of a measurement among the sequence of candidates, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products select a pair of sensing elements (e.g., the camera on the headset and an infrared LED on an Oculus controller) that are ready to make a measurement at the time of selection based on the pair having the highest expected utility of a measurement among a sequence of candidate pairs of sensing elements (e.g., the camera on the headset and a marker on the user's hand). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

	Designing for Hands  *See also* Hand Tracking Deep Dive at 4:00–10:00.  *See also id.* at 4:00–10:00.  *See also Powered by AI*.

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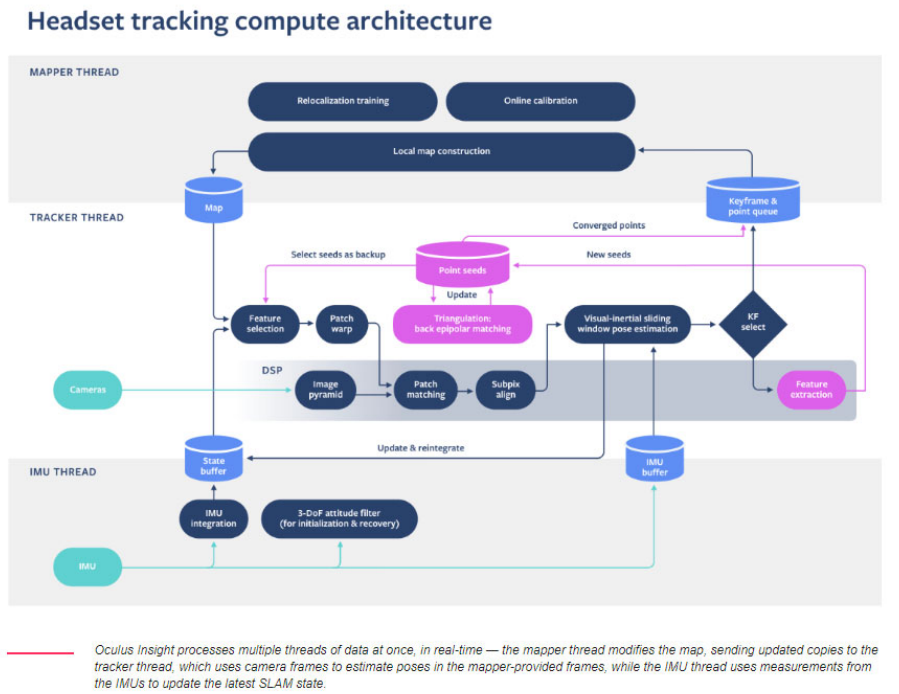

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Claim 8	
(8) The method of claim 6 wherein the set of sensing elements comprises at least one sensor and at least one target, the sensor making a measurement with respect to the target.	*See supra* claim 6. Facebook encourages, directs, or promotes users to perform the method of claim 6 in which the set of sensing elements comprises at least one sensor and at least one target, the sensor making a measurement with respect to the target, and Facebook performs such step itself. For example, the set of sensing elements in the Accused Products comprises at least one sensor (e.g., cameras and/or IMUs within the HMD, and/or the IMUs within the Oculus controllers) and at least one target (e.g., the user's head, the user's hand(s), the Oculus controller(s), and/or objects in the environment). The sensors in the Accused Products make measurements with respect to the targets. For example, the HMD cameras make measurements with respect to the user's hand location based on features on the hands, to the infrared LEDs on the Oculus controllers, and to the objects in the environment. The IMUs within the headset make measurements with respect to the user's head, and the IMUs within the Oculus controllers make measurements with respect to the user's hand(s) and/or the Oculus controllers. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also* Oculus Rift S. **Is your PC VR Ready?** Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware. *See also* Hand Tracking. The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold. The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic. Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking. *See also* Designing for Hands.

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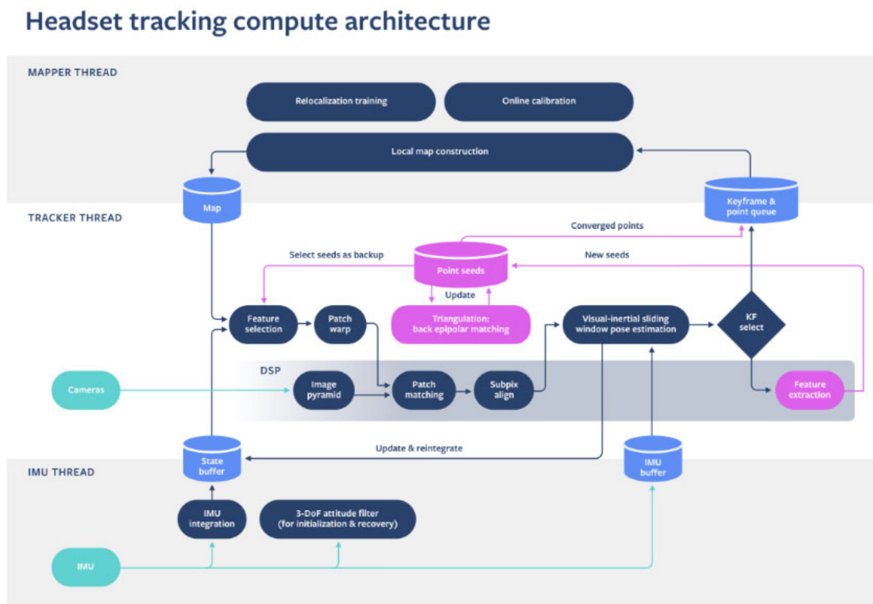

Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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Claim 9	
(9) The method of claim 8 wherein the target comprises a natural feature in an environment.	*See supra* claims 6, 8. Facebook encourages, directs, or promotes users to perform the method of claim 8 in which the target comprises a natural feature in an environment (e.g., landmarks like the corners of furniture or the patterns on the floor), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products upon this method and establishes the manner or timing of that use. *See, e.g.*, *From the Lab*. There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset. *See also Powered by AI*. Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of SLAM for AR on mobile devices which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers. The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware: *See also id.* At last year's Oculus Connect event we shared some details about Oculus Insight, the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM. *See also id.*

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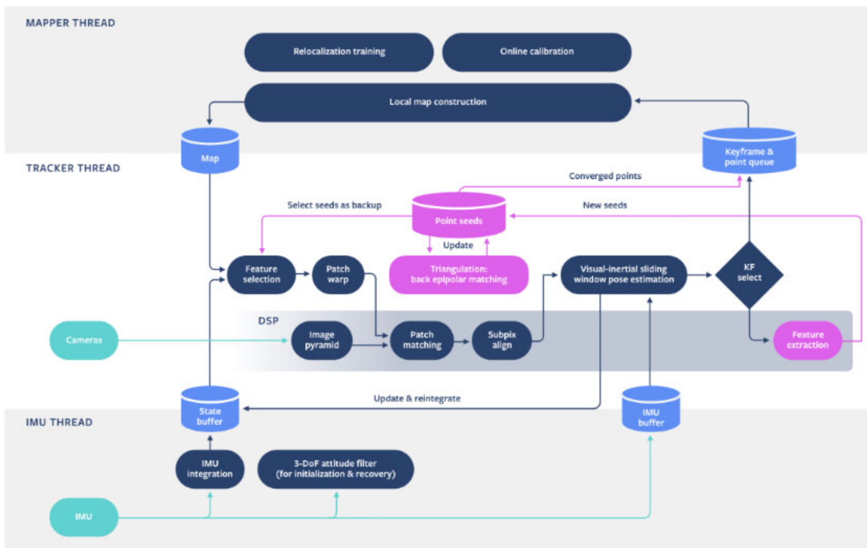

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