

A MAP OF APPLE HEALTH

The Apple Watch Series 9 health and fitness system as a map of technical, sociopolitical, and environmental connections

INFO 200

December 7, 2023

INTRODUCTION

Wearable technologies have become increasingly prevalent, particularly in the domain of health and wellbeing. They have taken the form of headbands, sociometric badges, camera clips, smartwatches, and sensors embedded in clothing¹, and can be used for prevention, maintenance, monitoring, and management². While initially used in clinical settings, wearables have saturated the consumer market, where 1 in 6 (15%) of consumers in the United States currently use some form of the technology³. Leading players in the technology industry including Samsung, Sony, and Apple have introduced commercialized wearables, most commonly being smartwatches⁴. Given the pervasiveness of wearables, it is thus useful to understand where this data goes, how it is being used, and what its many implications may be for broader society. This study examines the Apple Watch Series 9 health and fitness system through the sociotechnical lens of information organization to explore its limitations and potential improvements, with aims of understanding the connected systems that are part of its creation and increasing transparency to this black box system to ensure quality health wearables.

REVERSE ENGINEERING PROCESS

Our primary point of access to the Apple Watch Series 9 was online sources. We used online sources to retrieve and organize system information according to the three tiers established by Glushko (2016)⁵, in which presentation includes software and hardware for user

¹ Piwek, Lukasz, David A. Ellis, Sally Andrews, and Adam Joinson. "The rise of consumer health wearables: promises and barriers." *PLoS medicine* 13, no. 2 (2016): e1001953. <https://doi.org/10.1371/journal.pmed.1001953>

² Wu, Min, and Jake Luo. "Wearable technology applications in healthcare: a literature review." *Online J. Nurs. Inform* 23, no. 3 (2019).

³ Piwek et al. (2016)

⁴ Jung, Yoonhyuk, Seongcheol Kim, and Boreum Choi. "Consumer valuation of the wearables: The case of smartwatches." *Computers in Human Behavior* 63 (2016): 899-905. <https://doi.org/10.1016/j.chb.2016.06.040>

⁵ Glushko, Robert J. *The discipline of organizing: professional edition*. "O'Reilly Media, Inc.", 2016. 50. <https://schoolsinc.wildapricot.org/Discipline-of-Organizing-Professional>

interaction as well as how the system is viewed in society, logic involves how health and fitness data is calculated with algorithms are organized in apps, and storage encompasses where health and fitness data is stored on device and externally on servers. Much of the technical research for hardware, software, data collection, and privacy was identified via Apple Inc. documentation and reports. Furthermore, to understand certain flows of data through and from the Apple Watch Series 9, we utilized Xcode to access Apple HealthKit, a central repository where health and fitness data is stored on iPhone and Apple Watch, used by third-party developers in creating external applications⁶. In regard to the system's broader implications, government reports, legal cases, and other news sources were used. We then documented potential errors and improvements for the organization system, focusing on how the system could be developed in a more user-centric approach.

FINDINGS

Supply Chain. When the Apple Watch Series 9 is assembled, individual supply chains made of materials, suppliers, and labor are embedded in the device, i.e. supply chains within supply chains⁷. Apple's global supply chain⁸ spans over three million people, fifty countries and regions, and thousands of businesses and facilities⁹. Each individual within the overall supply chain can be considered an *agent*, any entity capable of autonomous and intentional action on a system¹⁰, from miners, smelters, and refiners of rare earth elements, to manufacturers, assemblers, distributors, transportation workers, and designers, developers, and engineers.

⁶ "HealthKit." Apple Developer Documentation, 2023. <https://developer.apple.com/documentation/healthkit>

⁷ Crawford, Kate, and Vlado Joler. "Anatomy of an AI System." *Anatomy of an AI System* (2018).

⁸ Information regarding supply chains specific to the Apple Watch Series 9 was unable to be identified through online sources; we assume that the product does not use an entirely different global supply chain.

⁹ Apple Supplier Responsibility 2023 Progress Report. PDF file. Apple Incorporated. https://www.apple.com/supplier-responsibility/pdf/Apple_SR_2023_Progress_Report.pdf

¹⁰ Glushko, Robert J. *The discipline of organizing: professional edition*. "O'Reilly Media, Inc.", 2016. 50. <https://schoolsinc.wildapricot.org/Discipline-of-Organizing-Professional>

Moreover, the agents within Apple's global supply chain operate within various infrastructures which contain the properties of being embedded, learned, linked with practice, transparent, and large in scale and scope¹¹. Transportation workers rely on road networks and shipping routes, manufacturers, assemblers, and distributors require energy systems in addition to databases and communication structures¹², and the work of designers, developers, and engineers involves the Internet and computer networks. It may also be likely that nearly all of these agents use telecommunication systems for their work which are infrastructures of their own. Apple's supply chains, their agents, and the infrastructures acted upon support the entire product cycle from beginning to end (see Appendix I).

Technical Specifications. The health and fitness system of the Apple Watch Series 9 collects the following information for a user: activity with total calories, steps, and workouts, sleep stages and duration, blood oxygen, heart rate, respiratory rate, wrist temperature, electroencephalogram (ECG), geolocation; users can also log menstrual cycle, mental health, and medical record information¹³. This data is stored in iCloud and is end-to-end encrypted¹⁴ where encryption keys are stored on trusted devices¹⁵. Apple has indicated that iCloud metadata and encryption keys for certain data categories such as photos, notes, and calendars on its own servers while files encrypted in "chunks" are stored anonymously on third-party servers such as Amazon S3 and Google Cloud¹⁶. See Appendix II for the flow of data. For Apple Watch health

¹¹ Star, Susan Leigh, and Karen Ruhleder. "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7, no. 1 (1996): 111–34. <http://www.jstor.org/stable/23010792>.

¹² National Research Council. "Information Technology and Manufacturing: A Preliminary Report on Research Needs." (1993). pp. 31-41

¹³ Apple Watch User Guide. PDF file. Apple Incorporated.
https://help.apple.com/pdf/watch/9/en_US/apple-watch-user-guide-watchos9.pdf

¹⁴ Health Privacy Overview. PDF file. Apple Incorporated.
https://www.apple.com/ios/health/pdf/Health_Privacy_White_Paper_May_2023.pdf

¹⁵ "iCloud Data Security Overview - Apple Support (CA)." Apple Support. November 17, 2023.
<https://support.apple.com/en-ca/102651>

¹⁶ Fleishman, Glenn. 2018. "How to Find out Where Apple Stores Your iCloud Data (Spoiler: You Can't Exactly)." Macworld. May 21, 2018. <https://www.macworld.com/article/231380/where-does-apple-stores-your-icloud-data.html>.

and fitness apps created by third-party developers, HealthKit is used to store data, which is stored on device and not in iCloud¹⁷ (see Appendix III for details on HealthKit). Ko (2023) cites Buckland (1991) to define information systems as the coordination of people, data and information technology to “facilitate information creation, storage, and access^{18, 19}.” With this definition, the Apple Watch can be considered an information system—coordinating a user, their personal data, and the device’s software and hardware to create, store, and allow users to access their health and fitness information.

Apple Watch Series 9 uses watchOS 10, the most recent update to its operating system. Its hardware features a 4-core neural engine for faster machine learning tasks, a blood oxygen sensor, electrical heart sensor for ECG, third-generation optical heart sensor, high-g accelerometer for fall and crash detection, high dynamic range gyroscope for motion-based information, and GPS^{20, 21}. See Appendix IV for device schematics. Based on the connectivity and networks required between sensors, communication protocol, algorithms and data measurements as part of the device and its operating system, in addition to the global supply chain network used for its complete assembly, it can also be determined that the device is an infrastructure in itself—containing the properties of being embedded, learned, linked with practice, transparent, and large in scale and scope throughout its entire creation and usage process.

Environmental Impact. Apple has claimed that its Series 9 Watch is its first carbon neutral product, citing renewable energy sources, a decreased carbon footprint, and notable use of recycled materials retrieved from its Material Recover Lab where autonomous systems instead

¹⁷ HealthKit.” Apple Developer Documentation, 2023. <https://developer.apple.com/documentation/healthkit>.

¹⁸ Amy J. Ko (2023). *Foundations of Information*. <https://faculty.washington.edu/ajko/books/foundations-of-information/>.

¹⁹ Michael K. Buckland (1991). Information and information systems. *ABC-CLIO*.

²⁰ “Apple Watch - Compare Models.” 2023. Apple (CA). 2023. <https://www.apple.com/ca/watch/compare/>.

²¹ “Gyroscope and Accelerometer.” 2023. Apple Developer Documentation. 2023. <https://developer.apple.com/design/human-interface-guidelines/gyro-and-accelerometer>.

of human labor are used to recover rare earth elements²². A report by the Institute of Environmental and Public Affairs (IPE), however, details the apparent “smokescreen” of this claim given that carbon emissions from some of its suppliers have increased or decreased only slightly—not reflecting a genuine and substantial reduction, in part due to Apple no longer requiring suppliers to publicly disclose greenhouse gas emission data²³. In other words, transparency is lacking in the specific ways the Watch is carbon neutral. Furthermore, it has been noted that the product cycle from manufacturing to waste always leaves a mark on the planet and therefore cannot truly be carbon neutral, i.e. ceasing to generate more carbon and cause more harm to the planet²⁴. It can perhaps be inferred that these claims of carbon neutrality are attempts to increase profit and drive revenue as a result of sociocultural pressure on climate action.

Furthermore, Apple’s widely purported usage of planned obsolescence (deliberately shortening the durability of products²⁵) to maximize profit has allowed the corporation to dominate the consumer market, going against genuine claims of carbon neutrality by encouraging the continuous cycle of manufacturing, buying, and disposing. The corporation’s usage of planned obsolescence and monopolization, as deterrents of sustainability, has led to legal action and public policy. *Bilic et al. v. Apple Inc. (2018)* held that Apple violated state statutes regarding consumers’ right to be informed about practices of decreasing performance capabilities²⁶, and *AliveCor Inc. v. Apple Inc. (2022)* accused Apple of monopolizing the market

²² Apple. 2023. “Environment.” Apple. 2023. <https://www.apple.com/environment/>.

²³ “Apple’s Carbon Neutral Smokescreen.” The Institute of Public and Environmental Affairs. September 2023. <https://www.woa.ipe.org.cn/Upload/2023092501470562833c6e7b6ad04041d98774440d17cee175.pdf>.

²⁴ Barber, Gregory. 2023. “Your New Apple Watch Won’t Be Carbon Neutral.” Wired. <https://www.wired.com/story/new-apple-watch-series-9-wont-be-carbon-neutral/>.

²⁵ Stamboulos, Aphrodite. 2023. “The Product Ecosystem and Planned Obsolescence: Apple’s Threats to Consumer Rights – Fordham Undergraduate Law Review.” The Fordham University Undergraduate Law Review. 2023. <https://undergradlawreview.blog.fordham.edu/consumer-protection/the-product-ecosystem-and-planned-obsolescence-apples-threats-to-consumer-rights/>.

²⁶ *In re Apple Inc. Device Performance Litigation*, 347 F. Supp. 3d 434 (N.D. Cal. 2018).

for heart-rate monitoring technology with the Apple Watch^{27, 28}. In the European Union, planned obsolescence has been banned to reduce consumer products' impact on the environment²⁹, and more recently in the United States, an executive order was given to promote competition with the right to repair^{30, 31}. The interconnections between environment, commerce and economics, and politics and power are invisibly linked to the Apple Watch Series 9 and therefore also to us as consumers.

Privacy and Ethical Concerns. With a vast amount of personal health data being collected by the Apple Watch Series 9, concerns have arisen around “under-the-skin surveillance,” i.e. allowing devices to read and track our bodies and emotions³². Moreover, it has been observed that digitizing the world inherently necessitates surveilling it by recording, tagging, and tracking³³. The Apple Watch Series 9 thus poses significant concerns regarding both data security and consumer privacy. In 2021, a non-password protected database was found containing over 61 million records related to health and fitness tracking devices, particularly the Apple Watch and its use of HealthKit³⁴. Many of these records also included personally

²⁷ Stempel, Jonathan. 2021. “Lawsuit Claims Apple Monopolizes Heart-Rate Technology for Apple Watch.” *Reuters*, May 26, 2021, sec. Technology.

<https://www.reuters.com/technology/lawsuit-claims-apple-monopolizes-heart-rate-technology-apple-watch-2021-05-26/>.

²⁸ *AliveCor, Inc. v. Apple Inc.*, 592 F. Supp. 3d 904 (N.D. Cal. 2022).

²⁹ Elissaiou, Annita. 2023. “Lawmakers Back EU Ban on Planned Obsolescence, Destruction of Unsold Goods.” *Euractiv*, June 15, 2023.

<https://www.euractiv.com/section/circular-economy/news/lawmakers-back-eu-ban-on-planned-obsolescence-destruction-of-unsold-goods/>.

³⁰ The White House. 2023. “Readout of the White House Convening on Right to Repair.” The White House. October 25, 2023.

<https://www.whitehouse.gov/briefing-room/statements-releases/2023/10/25/readout-of-the-white-house-convening-on-right-to-repair/>.

³¹ The White House. 2021. “FACT SHEET: Executive Order on Promoting Competition in the American Economy.” The White House. July 9, 2021.

<https://www.whitehouse.gov/briefing-room/statements-releases/2021/07/09/fact-sheet-executive-order-on-promoting-competition-in-the-american-economy/>.

³² Véliz, Carissa. 2021. “We Need to Talk about How Apple Is Normalising Surveillance.” *Wired UK*. November 10, 2021. <https://www.wired.co.uk/article/apple-surveillance-technology>.

³³ Véliz (2021)

³⁴ Fowler, Jeremiah. 2021. “Report: Fitness Tracker Data Breach Exposed 61 Million Records and User Data Online.” *Website Planet*. September 13, 2021. <https://www.websiteplanet.com/blog/gethealth-leak-report/>.

identifiable user data such as name, geolocation, date of birth, height, weight, and gender³⁵.

While the Health Insurance Portability and Accessibility Act (HIPAA) in the United States, and the Personal Information Protection and Electronic Documents Act (PIPEDA) in Canada, are meant to protect consumers' personal data, regulations are somewhat ambiguous regarding wearable technologies, and no uniform national policy currently exists for self-generated health data^{36,37}. In the United States, the landmark case *Katz v. United States* (1967) held that the government's eavesdropping activities violated the petitioner's privacy, thus establishing a constitutionally protected reasonable expectation of privacy³⁸. Yet, lines of privacy have become increasingly blurred with wearable technology and how its data is stored, leading to questions of if traditional notions of reasonable expectations of privacy can still exist. Wearables such as the Apple Watch Series 9 will thus continue to shift and shape expectations of privacy in daily life.

The Apple Watch Series 9 uses machine learning algorithms to analyze ECG data, blood oxygen data, as well as the “double-tap” mechanism which detects subtle movements and changes in blood flow when users tap fingers together^{39,40,41}. These algorithms are proprietarily protected and little information is disclosed about training data and training processes. This system can thus be viewed as black box in which only the inputs and outputs are seen without need to understand its internal complexity because of its successful performance⁴². With the system's success comes a heightened obscurity, and the potential for undisclosed biases and

³⁵ Fowler (2021)

³⁶ Health Insurance Portability and Accountability Act. Pub. L. No. 104-191, § 264, 110 Stat.1936. (1996).

³⁷ Personal Information Protection and Electronic Documents Act, SC 2000, c 5, <<https://canlii.ca/t/541b8>>

³⁸ *Katz v. United States*, 389 U.S. 347, 88 S. Ct. 507, 19 L. Ed. 2d 576 (1967).

³⁹ Walsh, Paul. 2018. “How Apple Watch Uses Deep Learning to Analyse ECG Data.” LinkedIn. September 20, 2018. <https://www.linkedin.com/pulse/how-apple-watch-uses-deep-learning-analyse-ecg-data-paul-walsh/>.

⁴⁰ Apple. 2022. “Blood Oxygen App on Apple Watch.” Apple Incorporated. https://www.apple.com/healthcare/docs/site/Blood_Oxygen_app_on_Apple_Watch_October_2022.pdf.

⁴¹ Cherney, Max. 2023. “AI Quietly Reshapes Apple iPhones, Watches.” *Reuters*, September 12, 2023, sec. Technology. <https://www.reuters.com/technology/ai-quietly-reshapes-apple-iphones-watches-2023-09-12/>.

⁴² Bruno Latour (1999). *Pandora's hope: essays on the reality of science studies*. Cambridge, Massachusetts: Harvard University Press.

defects. In *Morales v. Apple Inc. (2023)*, Apple was accused of the Watch's blood oxygen sensor being racially biased against people with darker skin tones, with significantly less accurate results in measuring blood oxygen levels⁴³. Algorithmic bias may thus be present in blood oxygen measurements, i.e. bias from who built the algorithms, how it was developed, and how it is used⁴⁴. It remains difficult, however, to evaluate how the system may be susceptible to such bias and where bias may occur given that it operates within a proprietary black box.

CRITICAL REVIEW

To address concerns about planned obsolescence, a modular design and construction of the Apple Watch Series 9 so that devices can be easily repaired instead of fully replaced may be a potential opportunity. With planned obsolescence being linked to environmental and sustainability impact, in addition to the global supply chain and hardware components, modularity poses a significantly beneficial possibility to Apple in regards to its overall strategy. However, the likelihood of such an immense reconstruction occurring, not only of product design but also general operations, is slim considering Apple's focus on profit maximization and pressure to continually increase revenue. See Appendix V for a constructed ethical matrix.

In regards to privacy concerns, federal regulation may be valuable. Clearer inclusion of wearables under HIPAA and similar privacy acts, for example, may help to ensure consumer privacy. For ethical matters surrounding bias, federal regulation may also be significant to require transparency from companies regarding algorithms and training processes. The challenge with this is that policymakers often lack a strong technical understanding of how these

⁴³ *Morales v. APPLE, INC.*, No. 22-cv-10872 (JSR) (S.D.N.Y. Aug. 29, 2023).

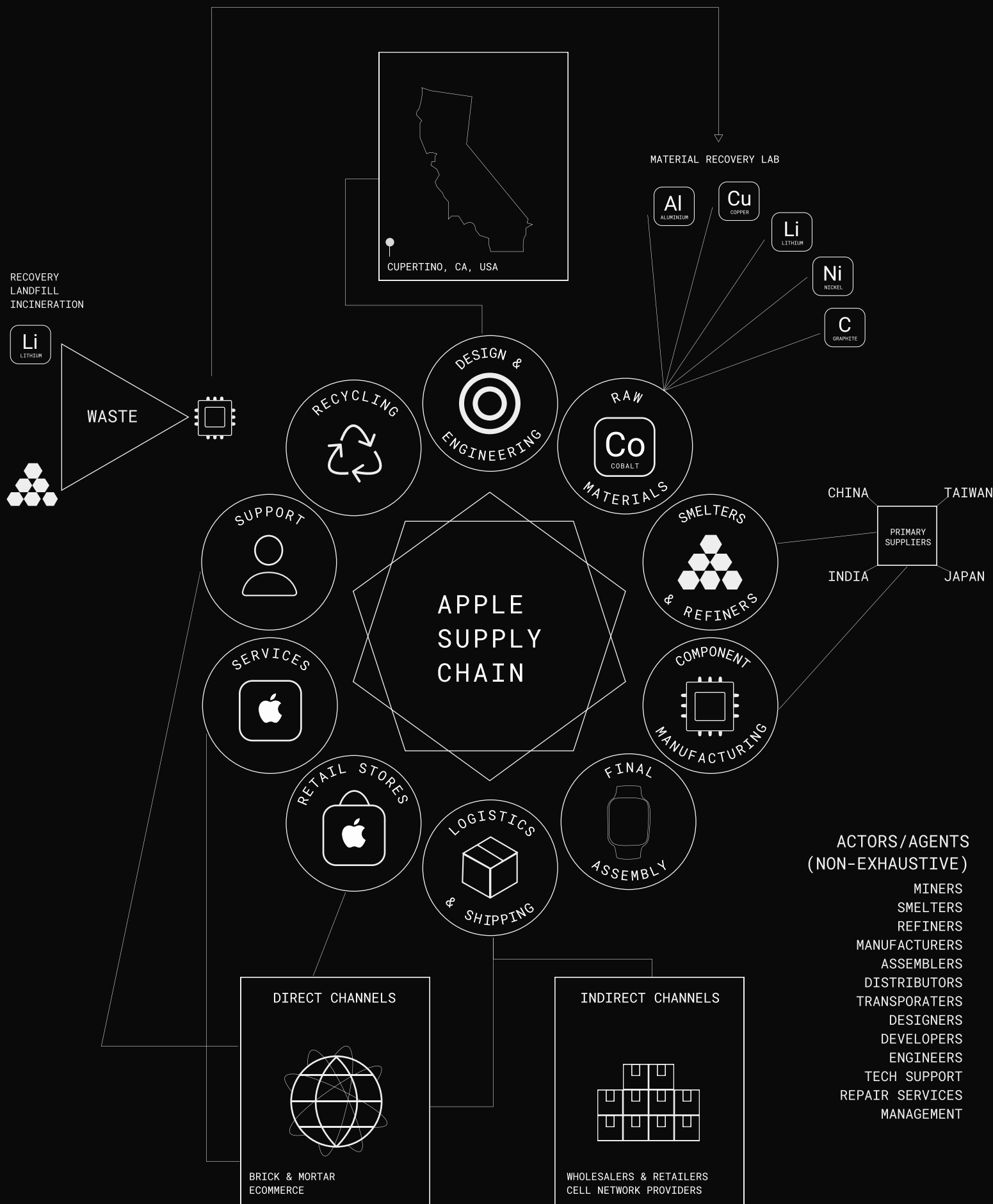
⁴⁴ Heilweil, Rebecca. 2020. "Why Algorithms Can Be Racist and Sexist." Vox. February 18, 2020. <https://www.vox.com/recode/2020/2/18/21121286/algorithms-bias-discrimination-facial-recognition-transparency>.

technologies perform and how they are implemented, which may lead to slower policy developments.

At the present moment, it is clear that what is needed to interact with the Apple Watch Series 9 goes far beyond the traditional notion of a “technical stack.” There lies complex and cyclical interconnections between the system’s many facets—environmental, social, political, economic, and legal—yet are invisible to us as we continue to use the watch everyday.

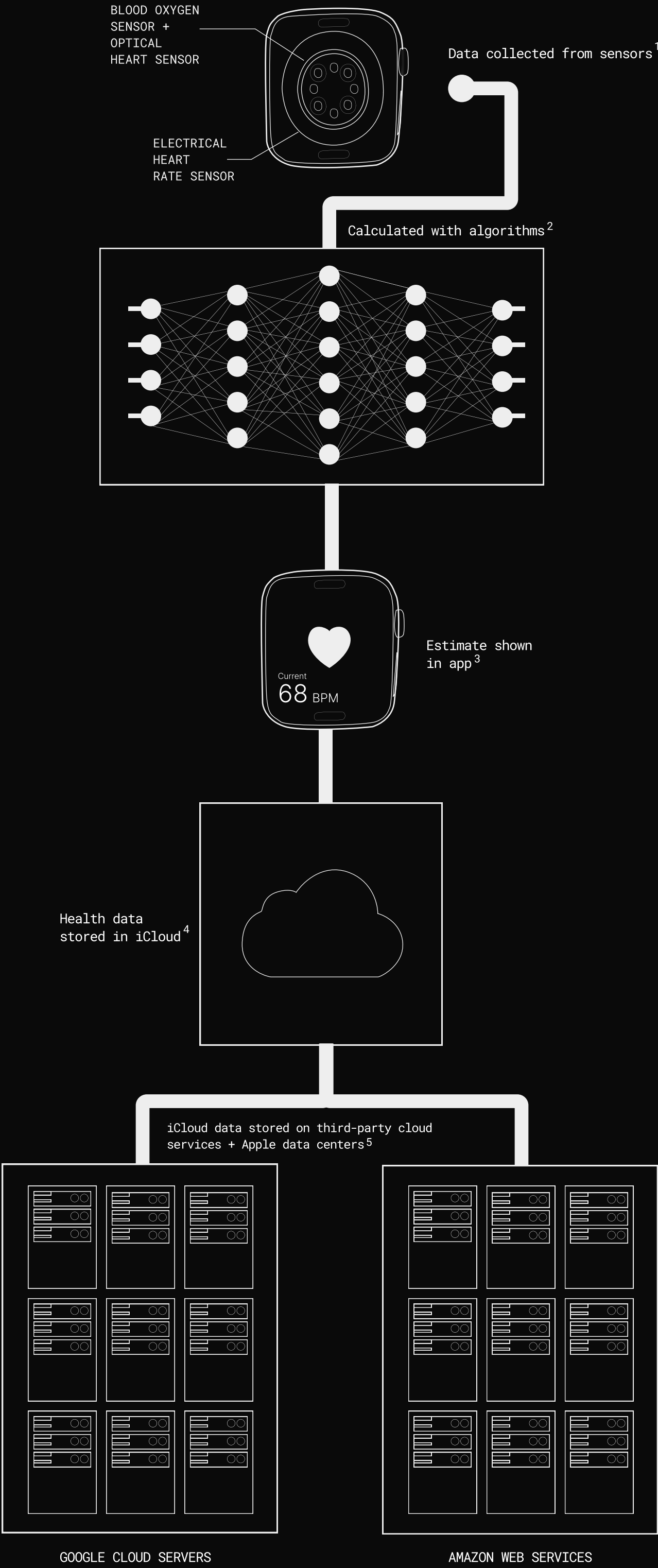
APPENDIX I

APPLE'S GLOBAL SUPPLY CHAIN



APPENDIX II

FLOW OF DATA - DATA LIFECYCLE



¹ Adapted from Apple. 2023c. "Your Apple Watch." Apple Support. 2023. <https://support.apple.com/en-is/guide/watch/apd2054d0d5b/watchos>.

² Walsh, Paul. 2018. "How Apple Watch Uses Deep Learning to Analyse ECG Data." LinkedIn. September 20, 2018. <https://www.linkedin.com/pulse/how-apple-watch-uses-deep-learning-analyse-ecg-data-paul-walsh/>.

³ Adapted from Jones, Jada. 2023. "Apple's WatchOS 10 Gets New APIs and Designs to Build Next-Gen Watch Apps." ZDNET. June 27, 2023. <https://www.zdnet.com/article/apples-watchos-10-gets-new-apis-and-design-capabilities-to-build-next-generation-watch-apps/>.

⁴ Health Privacy Overview. PDF file. Apple Incorporated. https://www.apple.com/ios/health/pdf/Health_Privacy_White_Paper_May_2023.pdf

⁵ Fleishman, Glenn. 2018. "How to Find out Where Apple Stores Your iCloud Data (Spoiler: You Can't Exactly)." Macworld. May 21, 2018. <https://www.macworld.com/article/231380/where-does-apple-stores-your-icloud-data.html>.

APPENDIX III

APPLE HEALTHKIT

HEALTHKIT - CENTRALIZED REPOSITORY FOR THIRD PARTY DEVELOPERS TO STORE USER HEALTH AND FITNESS DATA

PERMISSIONS - APPS NEED EXPLICIT USER PERMISSION TO ACCESS HEALTHKIT DATA

```
func requestAuthorization()  
//Message on APP: *This app requires access  
to your health data*
```

HEALTH RECORDS API -
ALLOWS USERS TO VIEW AND
STORE MEDICAL RECORDS

QUERIES - RETRIEVE
SPECIFIC SETS OF
HEALTH DATA

STATISTICS - REQUEST HEALTH DATA STATS
(E.G. DAILY STEP COUNT)

```
func calculatingSteps(completion: @escaping (HKStatisticsCollection)
```

HEALTHSTORE - PROVIDES FEATURES
& FUNCTIONALITY FOR HEALTH DATA

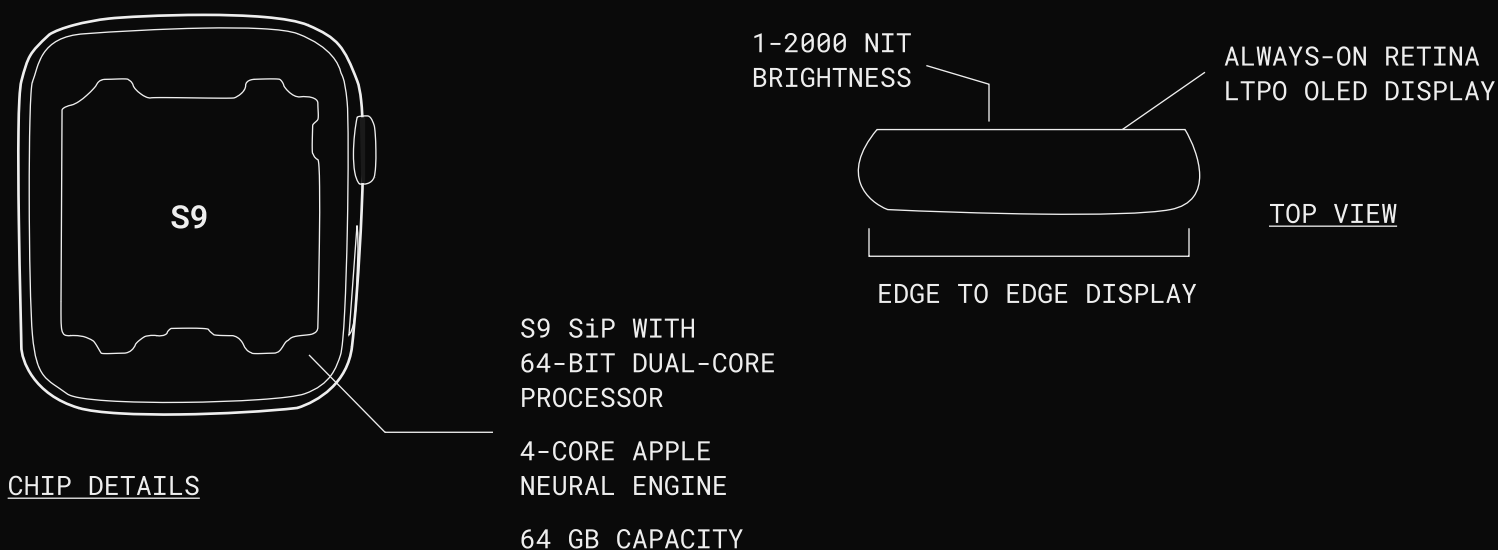
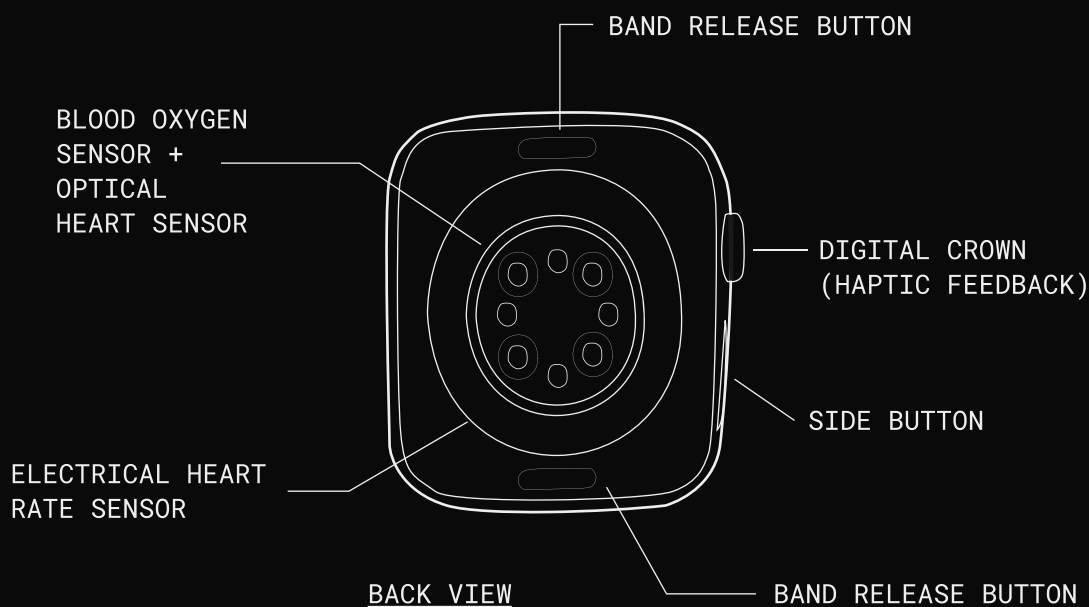
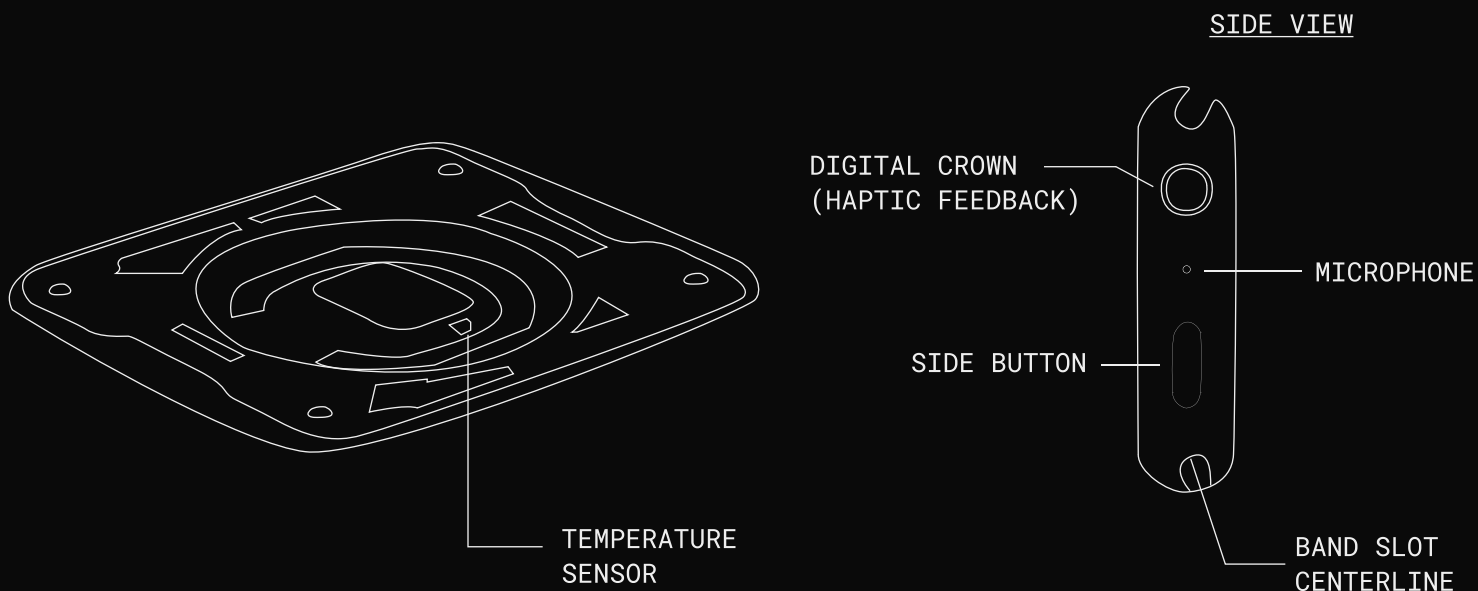
```
class HealthStore {  
    var healthStore: HKHealthStore?  
  
    init() {  
        if HKHealthStore.isHealthData() {  
            healthStore = HKHealthStore()  
        }  
    }  
}
```

DATA TYPES

```
HKQuantityType() dietaryChromium  
activeEnergyBurned dietaryCopper  
appleExerciseTime dietaryEnergyConsumed  
appleMoveTime dietaryFatMonounsaturated  
appleSleepingWristTemperature dietaryFatPolyunsaturated  
appleStandTime dietaryFatSaturated  
appleWalkingSteadiness dietaryFatTotal  
atrialFibrillationBurden dietaryFiber  
basalBodyTemperature dietaryFolate  
basalEnergyBurned distanceCycling  
bloodAlcoholContent distanceDownhillSnowSports  
bloodGlucose distanceSwimming  
bloodPressureDiastolic distanceWalkingRunning  
bloodPressureSystolic distanceWheelchair  
bodyFatPercentage electrodermalActivity  
bodyMass environmentalAudioExposure  
bodyMassIndex environmentalSoundReduction  
bodyTemperature flightsClimbed  
cyclingCadence heartRate  
cyclingFunctionalThreshold heartRateRecoveryOneMinute  
cyclingPower heartRateVariabilitySDNN  
cyclingSpeed height  
dietaryBiotin inhalerUsage  
dietaryCaffeine insulinDelivery  
dietaryCalcium leanBodyMass  
dietaryCarbohydrates nikeFuel  
dietaryChloride numberOfAlcoholicBeverages  
dietaryCholesterol
```


APPENDIX IV

APPLE WATCH SERIES 9 DEVICE SCHEMATICS



ADAPTED FROM

Apple. 2023a. "Apple Watch Series 9." Apple (Canada). 2023. <https://www.apple.com/ca/apple-watch-series-9/>.

Apple. 2023c. "Your Apple Watch." Apple Support. 2023. <https://support.apple.com/en-is/guide/watch/apd2054d0d5b/watchos>.

APPENDIX V

USER-CENTRIC ETHICAL MATRIX

ETHICAL MATRIX

RESPECT FOR	WELLBEING	AUTONOMY	FAIRNESS
Users	Health and fitness maintenance Efficacy, safety, and security	Right to system transparency Freedom to adopt or not adopt	Fair treatment in trade and law Fair treatment in technological development Fair treatment in data privacy
Apple Inc.	Commercial viability and alignment with values	Ability to innovate within the bounds of privacy policies, regulations, and competition laws	Right to equitable market Right to use personal data for fair purposes
Apple employees who work on Apple Watch	Safe and stable working conditions	Right to democratic decision making Right to product & system transparency	Right to a fair & ethical workplace Right to equal benefits and protection
Suppliers and manufacturers	Safe and stable working conditions Right to stable relationships within supply chain	Right to democratic decision making Right to product & system transparency	Right to a fair & ethical workplace Right to equal benefits and protection
Investors and board members	Commercial viability and return on investment	Right to democratic decision making in regard to revenue generation	Ethical and transparent rights as major stakeholders
Policymakers and courts	Right to informed decision-making to ensure safety and quality of life	Right to establish laws & regulations for data privacy & security	Responsibility to equitably and ethically protect citizen rights
Environment	Protection of the environment	Right to transparency on carbon neutrality	Sustainability of the environment