Heterogeneous Integration Roadmap Mobile Market

Benson Chan – Binghamton University

February 24, 2024

HIR Mobile Technical Working Group

William (Bill) Chen (HIR & ASE)

Benson Chan (Binghamton University)

Mark Christensen (Prismark Partners)

Mark Gerber (ASE)

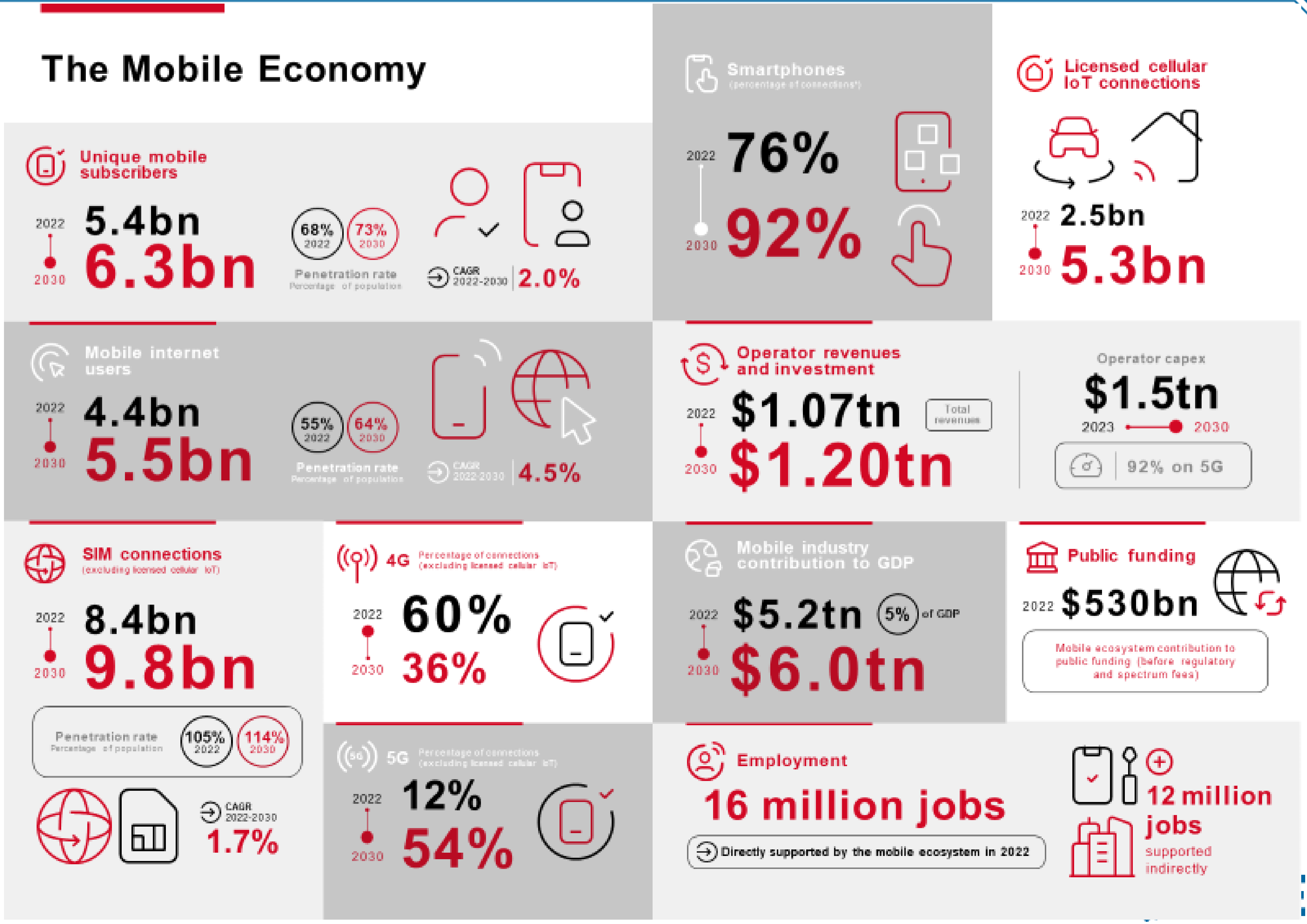
Joshua Ness (previously at Verizon 5G Labs)

Agenda

- Mobile is essential tool for consumers for daily lives
- Smart Phone growth in capabilities & features
- Advance Packaging
- Battery
- Beyond smartphones
- Summary

Mobile/Smart Phone: A Driving Force for Innovation

- **The Smart Phone is the main interface to technology and the web for the consumer – hub for linkage to smart watch, smart earphone, & smart glass (future).**
- **Smart Phone is favored by the latest Node Processor in every Product Generation. (It is out of date as soon as the consumer buys it).**
- **Functional increase while retaining same form factor drives miniaturization**
- **Customization & High Volume across all regions**
- **Cyber security across all phones 5G & Beyond**
- **Global sustainability**



The Mobile Economy

Unique mobile subscribers

2022 5.4bn

2030 6.3bn

68% 2022 | 73% 2030

Penetration rate

Percentage of population

CAGR 2022-2030 | 2.0%

Smartphones

(percentage of connections*)

2022 76%

2030 92%

Licensed cellular IoT connections

2022 2.5bn

2030 5.3bn

Mobile internet users

2022 4.4bn

2030 5.5bn

55% 2022 | 64% 2030

Penetration rate

Percentage of population

CAGR 2022-2030 | 4.5%

Operator revenues and investment

2022 $1.07tn Total revenues

2030 $1.20tn

Operator capex

$1.5tn

2023 – 2030

92% on 5G

SIM connections

(excluding licensed cellular IoT)

2022 8.4bn

2030 9.8bn

Penetration rate

Percentage of population

105% 2022 | 114% 2030

CAGR 2022-2030

1.7%

4G Percentage of connections (excluding licensed cellular IoT)

2022 60%

2030 36%

5G Percentage of connections (excluding licensed cellular IoT)

2022 12%

2030 54%

Mobile industry contribution to GDP

2022 $5.2tn 5% of GDP

2030 $6.0tn

Public funding

2022 $530bn

Mobile ecosystem contribution to public funding (before regulatory and spectrum fees)

Employment

16 million jobs

Directly supported by the mobile ecosystem in 2022

12 million jobs

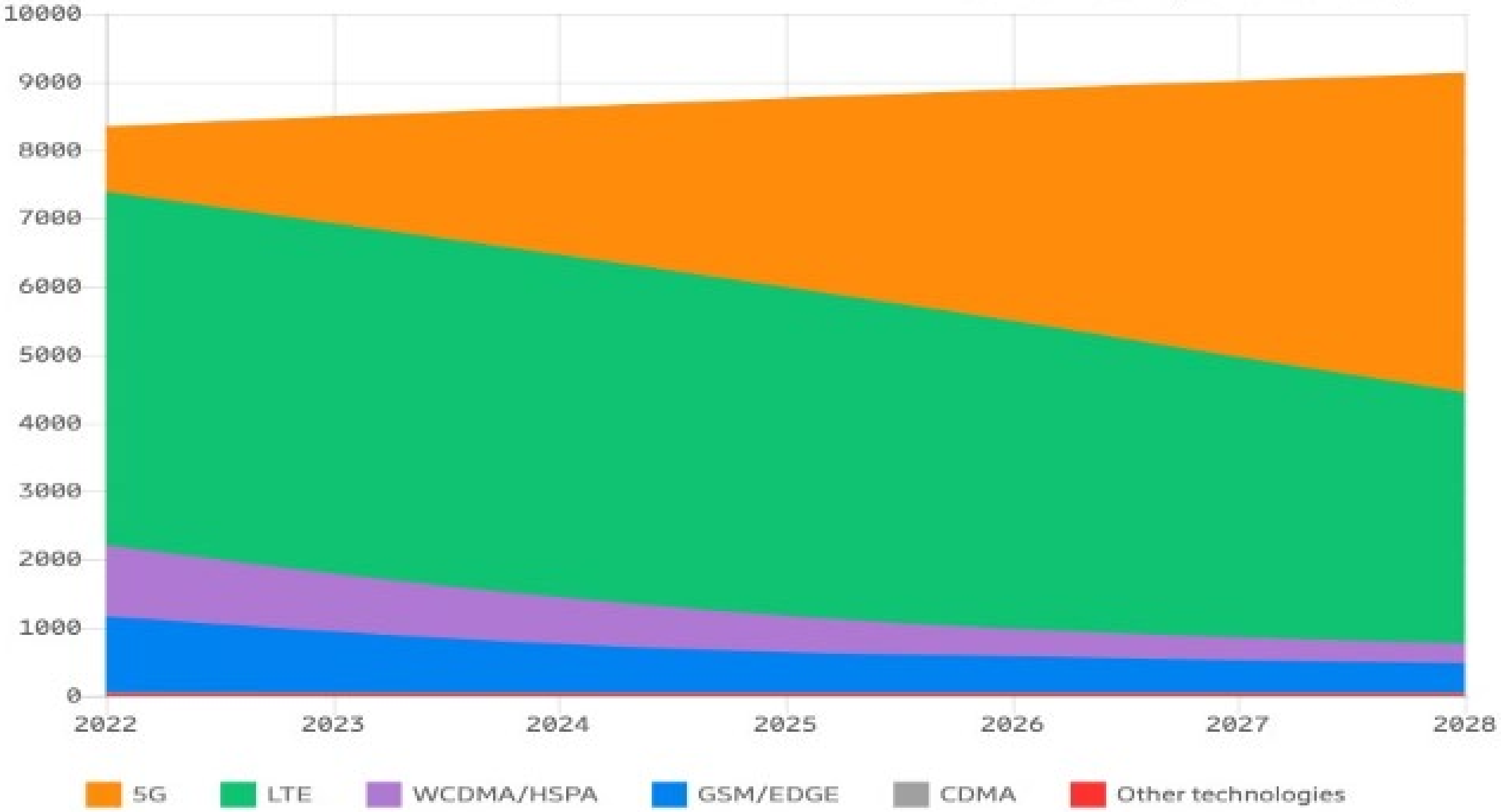
supported indirectly

GSMA Mobile Report 2023

Mobile subscriptions

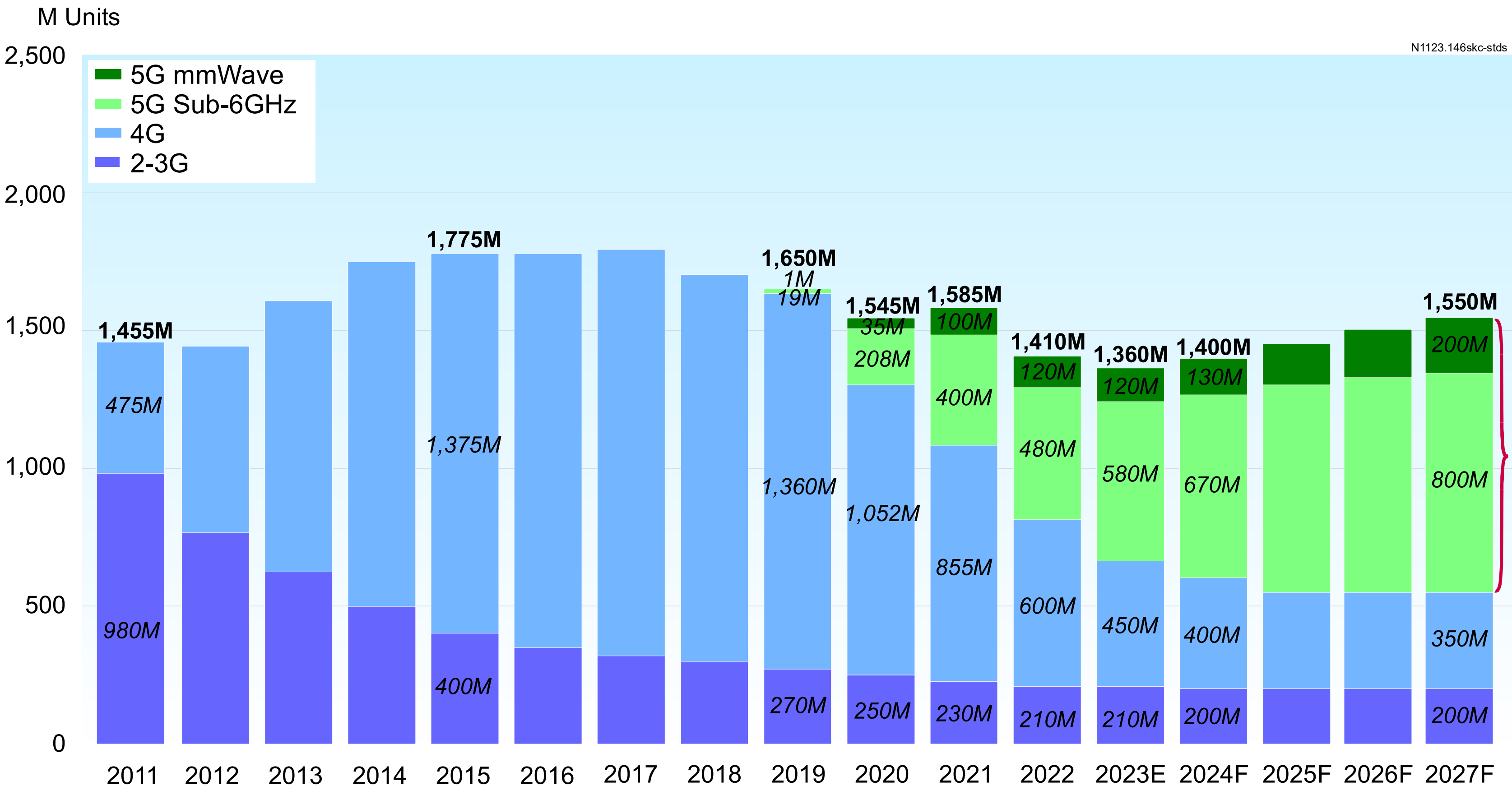
Unit: Million
5G | LTE | WCDMA/HSPA | GSM/EDGE | TD-SCDMA | CDMA | Other technologies
All devices
Year: 2022 - 2028

Source: Ericsson (November 2023)



https://www.ericsson.com/en/reports-and-papers/mobility-report/mobility-visualizer?f=1

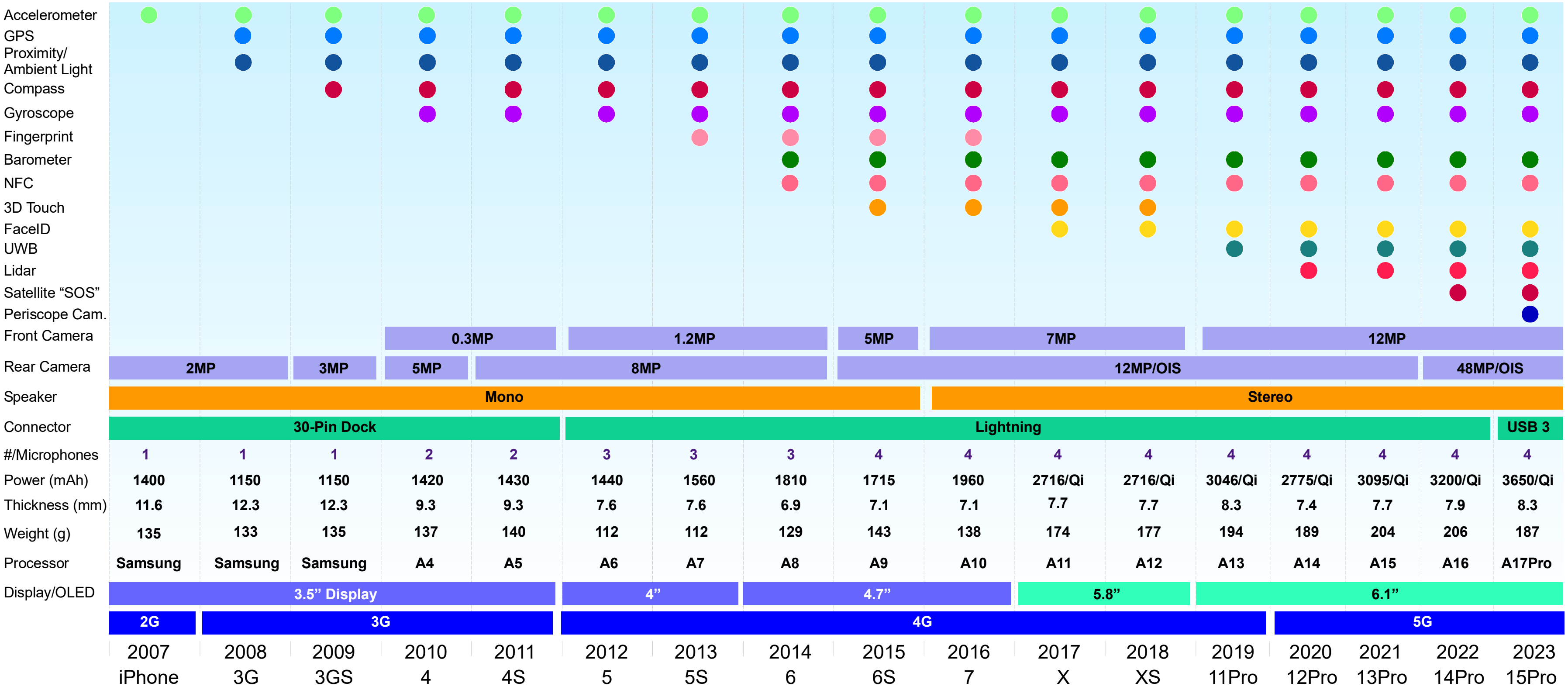
Mobile phone shipments by standard



Over 64% of phones sold in 2027 will be 5G

Apple iPhone Evolution

Kc923.146dw-iphone evolution3



	2007 iPhone	2008 3G	2009 3GS	2010 4	2011 4S	2012 5	2013 5S	2014 6	2015 6S	2016 7	2017 X	2018 XS	2019 11Pro	2020 12Pro	2021 13Pro	2022 14Pro	2023 15Pro
Accelerometer	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
GPS		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Proximity/ Ambient Light		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Compass			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Gyroscope				●	●	●	●	●	●	●	●	●	●	●	●	●	●
Fingerprint							●	●	●	●							
Barometer								●	●	●	●	●	●	●	●	●	●
NFC								●	●	●	●	●	●	●	●	●	●
3D Touch									●	●	●	●					
FaceID											●	●	●	●	●	●	●
UWB													●	●	●	●	●
Lidar														●	●	●	●
Satellite “SOS”																●	●
Periscope Cam.																	●
Front Camera				0.3MP		1.2MP			5MP	7MP			12MP				
Rear Camera	2MP		3MP	5MP	8MP				12MP/OIS							48MP/OIS	
Speaker	Mono									Stereo							
Connector	30-Pin Dock					Lightning											USB 3
#/Microphones	1	1	1	2	2	3	3	3	4	4	4	4	4	4	4	4	4
Power (mAh)	1400	1150	1150	1420	1430	1440	1560	1810	1715	1960	2716/Qi	2716/Qi	3046/Qi	2775/Qi	3095/Qi	3200/Qi	3650/Qi
Thickness (mm)	11.6	12.3	12.3	9.3	9.3	7.6	7.6	6.9	7.1	7.1	7.7	7.7	8.3	7.4	7.7	7.9	8.3
Weight (g)	135	133	135	137	140	112	112	129	143	138	174	177	194	189	204	206	187
Processor	Samsung	Samsung	Samsung	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17Pro
Display/OLED	3.5” Display					4”		4.7”			5.8”		6.1”				
	2G	3G				4G								5G			

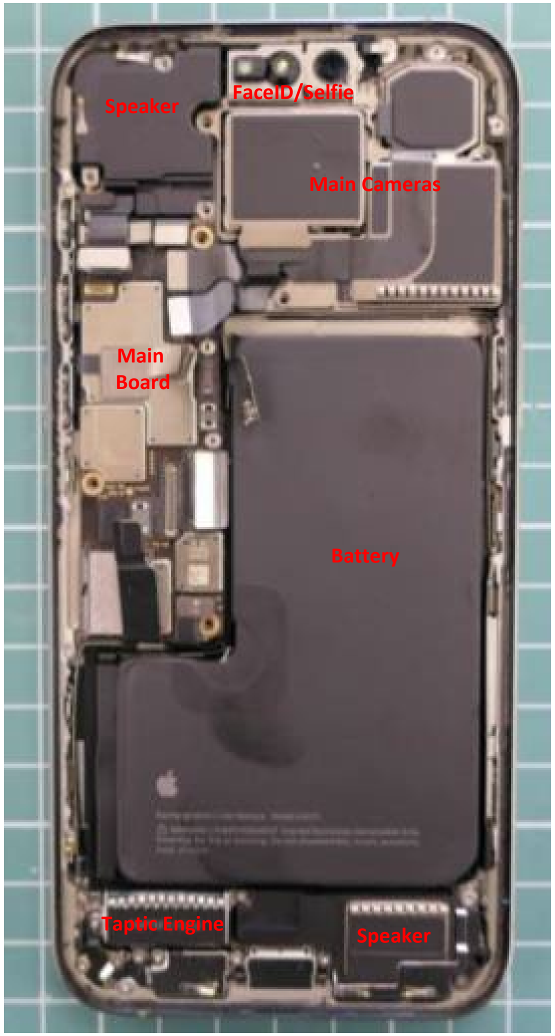
Note: Specs for main model - not larger display or lower priced versions

Courtesy Prismark Partners

Apple iPhone 14/15 pro max comparison

iPhone 14 Pro

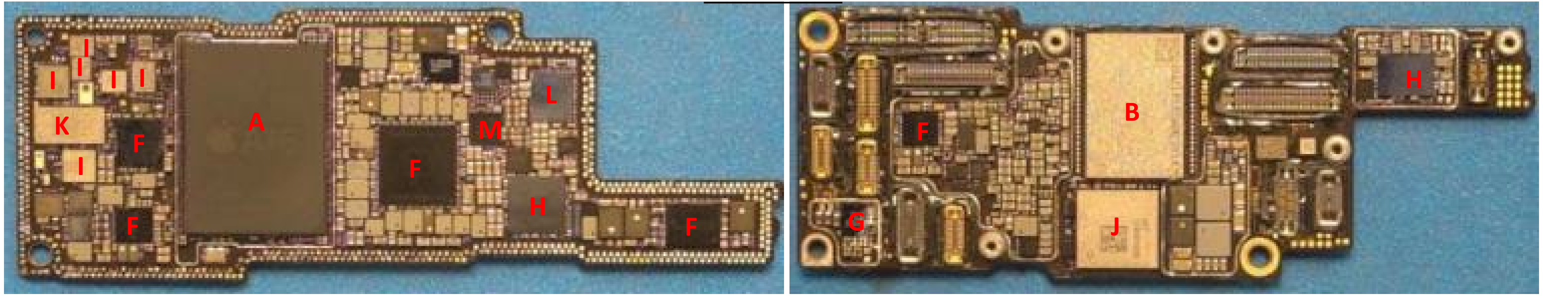
iPhone 15 Pro



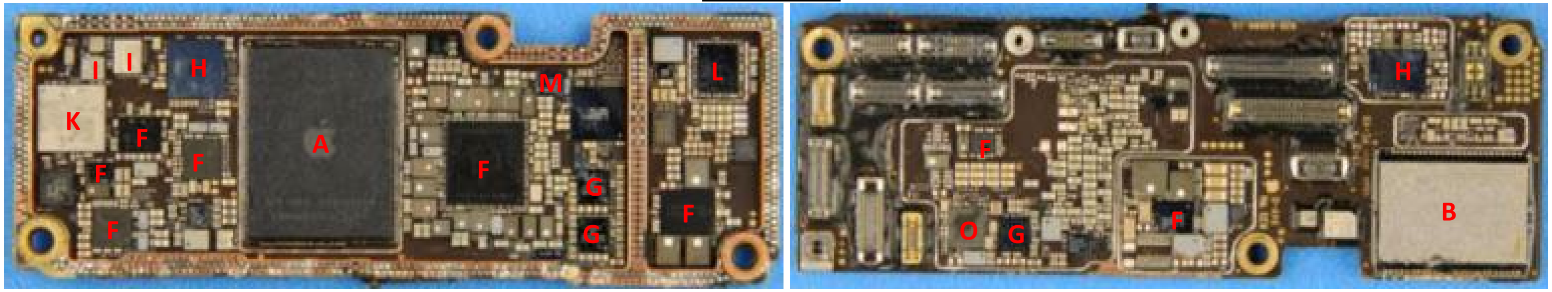
Source: Prismark / Binghamton University

Apple iPhone 14/15 pro Front board comparison

iPhone 14 Pro



iPhone 15 Pro



Important: US model where 15 Pro no longer has SIM card slot is shown

A.	Apple A16/A17 Pro Applications Processor
B.	Flash Memory
C.	Qualcomm SDX65M 2G-5G Baseband
D.	Qualcomm SDR735 2G-5G TRx (sub-6GHz), 2x
E.	Qualcomm SMR546 5G IF TRx (mmWave)
F.	Power Manger (Apple, Qualcomm, etc)
G.	Apple/Cirrus Logic Audio Amplifier
H.	Apple/Cirrus Logic Audio Codec
I.	FEM (Broadcom, Skyworks, etc.)
J.	Wi-Fi/Bluetooth Module
K.	USI UWB Module
L.	Broadcom Wireless Charging
M.	NXP Display Manager
N.	5G mmWave Module
O.	NXP NFC Controller

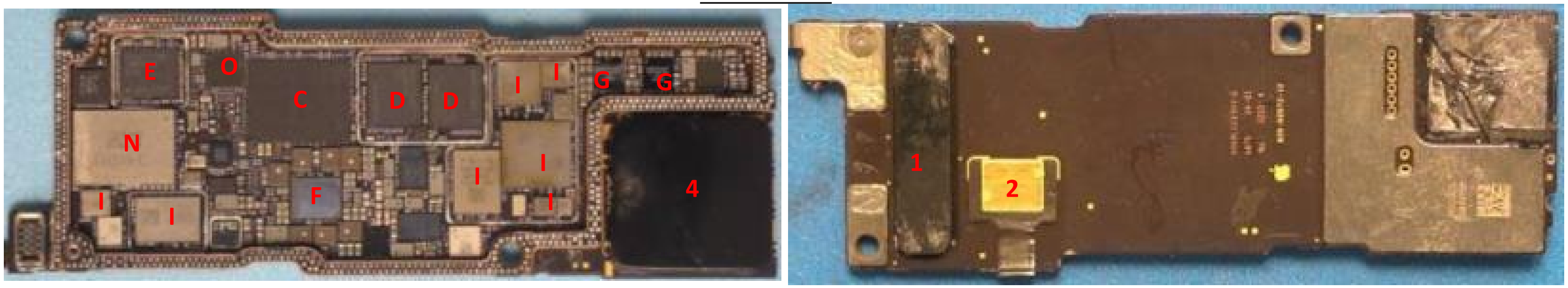
iPhone 15 Pro adds 1.75cm^2 front board area previously cut out for SIM card slot on rear board. Moves Flash memory to there

Note: Front board is 10L any-layer HDI

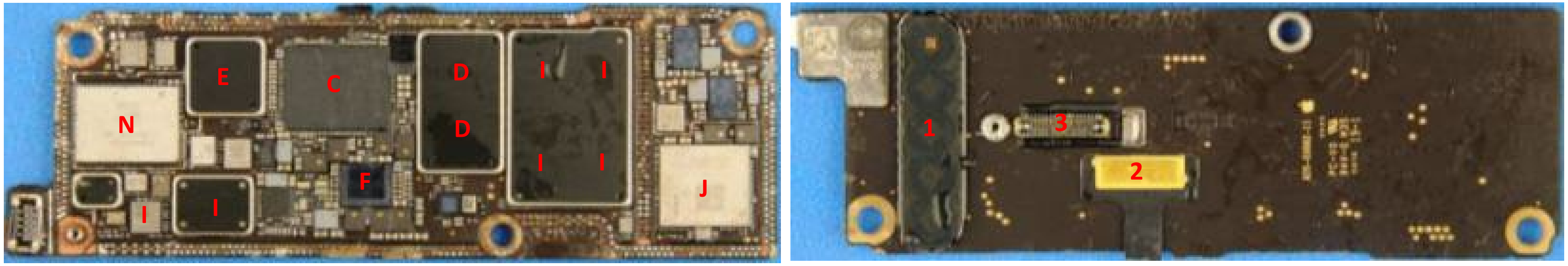
Photos source: Prismark/Binghamton University

Apple iPhone 14/15 pro Rear board comparison

iPhone 14 Pro



iPhone 15 Pro



Important: US model where 15 Pro no longer has SIM card slot is shown

A. Apple A16/A17 Pro Applications Processor
B. Flash Memory
C. Qualcomm SDX65M/SDX70M 2G-5G Baseband
D. Qualcomm SDR735 2G-5G TRx (sub-6GHz), 2x
E. Qualcomm SMR546 5G IF TRx (mmWave)
F. Power Manger (Apple, Qualcomm, etc)
G. Apple/Cirrus Logic Audio Amplifier
H. Apple/Cirrus Logic Audio Codec
I. FEM (Broadcom, Skyworks, etc.)
J. Wi-Fi/Bluetooth Module
K. USI UWB Module
L. Broadcom Wireless Charging
M. NXP Display Manager
N. 5G mmWave Module
O. NXP NFC Controller

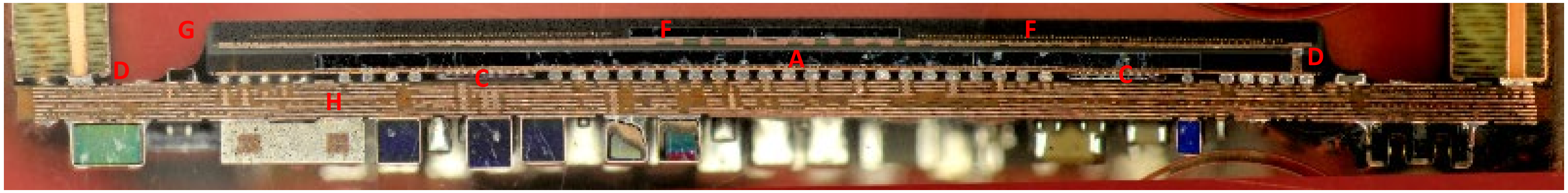
1. **Rear-Facing 5x1 5G mmWave Passive Antenna**
2. **Soldered flex feedline to side-facing 5x1 5G mmWave AiP**
3. **Connector for Wireless Charging/Flash/Mic Flex**
4. **Space for SIM Card Slot on Rear Board**

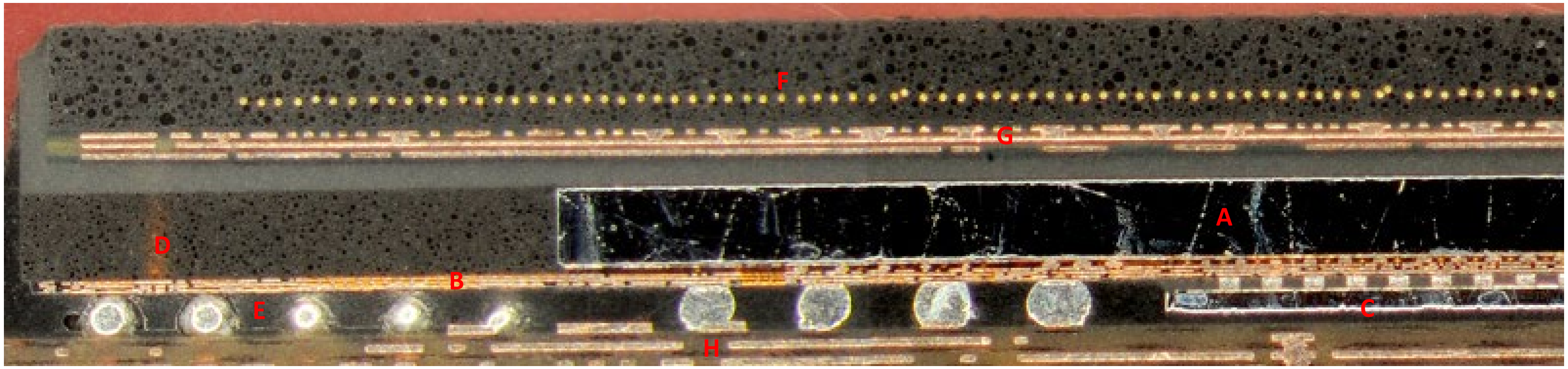
iPhone 15 Pro gains use of 1.75cm^2 rear board area previously used by SIM card slot. Moves WiFi module from front board to here

Note: Rear board is 8L any-layer HDI on iPhone 14 Pro, but 10L any-layer on iPhone 15 Pro

Photos source: Prismark/Binghamton University

Apple A17 Pro processor





- A17 Pro in 16.5x13mm FO-WLP (A) as bottom package
  - 4 RDL layers (B) plus die contacts, 11/9µm lines/spaces
  - Capacitor die (C) on underside of FO-WLP
  - Peripheral TMV (D) for top package interconnect
  - 0.3mm minimum ball pitch (E)
  - Nominal 54x42 array, estimated 1800 balls
  - 0.4mm collapsed height
- Memory (F) in top package
  - Wire bonded memory die
  - 3L HDI (G)
  - 0.3mm ball pitch (not shown)
  - 0.5mm collapsed height
- 0.9mm total collapsed height of stacked packages
- 10L Any-layer front main board (H)

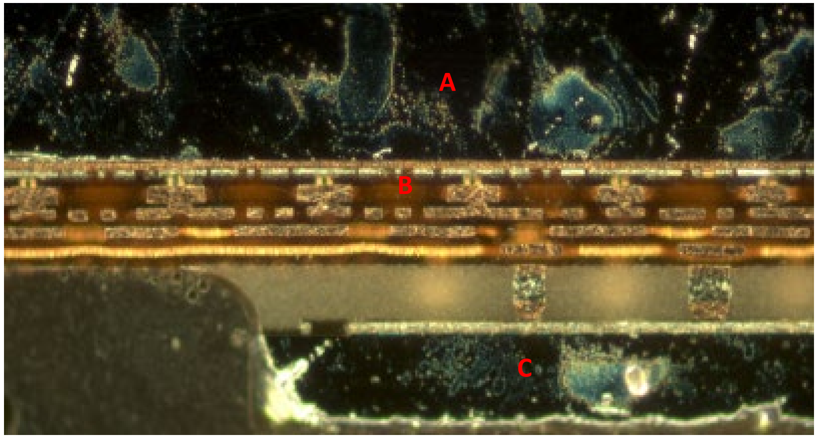


Photo source: Prismark/Binghamton University

Apple iphone 14/15 pro Rear board comparison

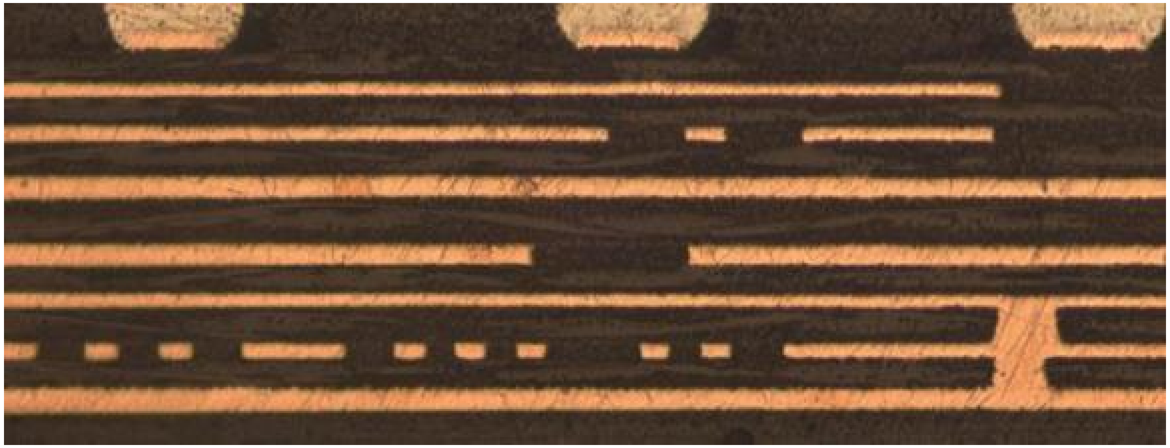
iPhone 14 Pro

8L Any-Layer HDI

~ 33/28µm L/S

~ 420µm thick

~ 7x2.5cm, with SIM slot



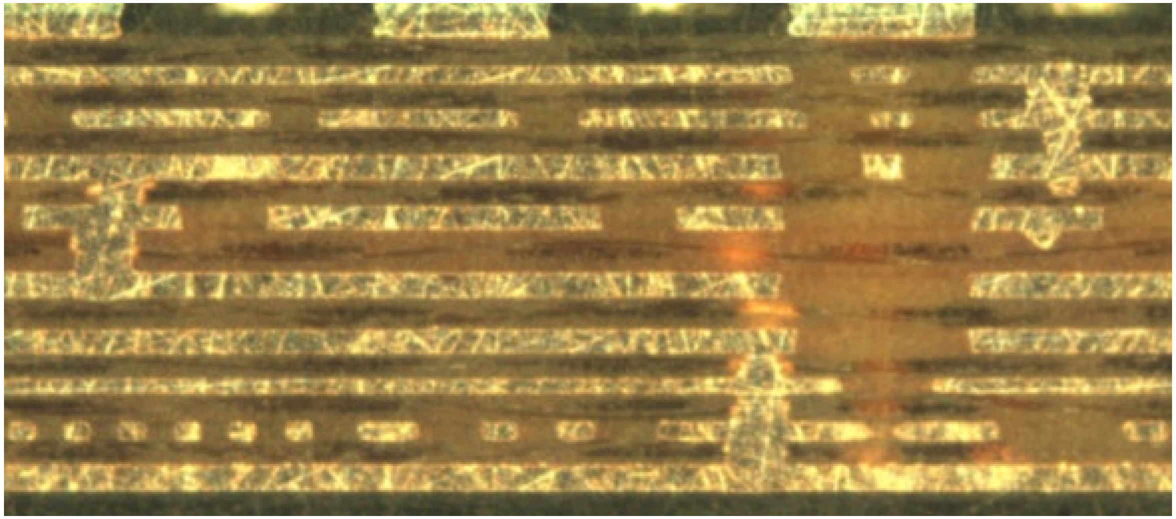
iPhone 15 Pro

10L Any-Layer HDI

~ 32/32µm L/S

~ 560µm thick

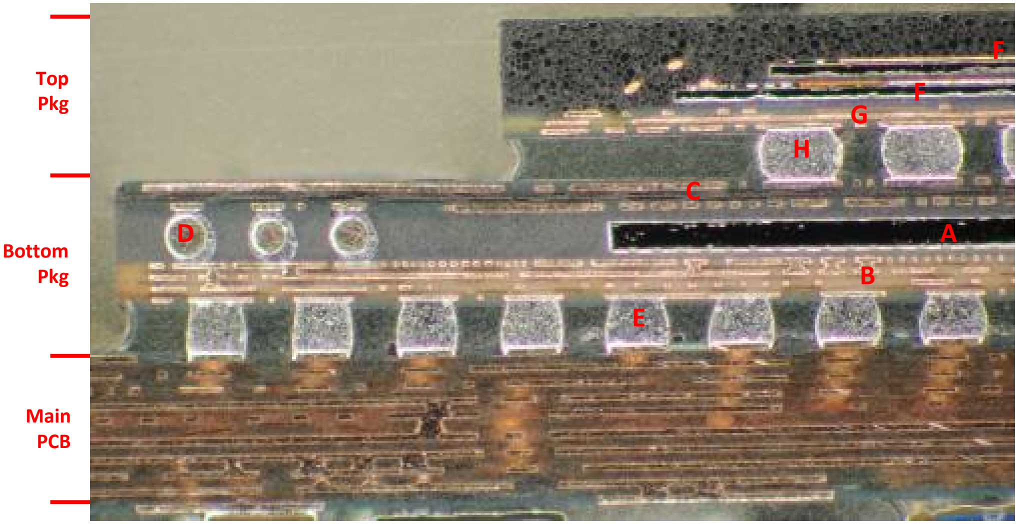
~ 7x2.5cm, no SIM slot

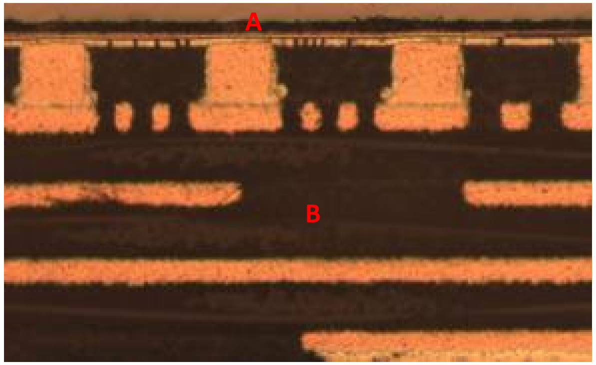


Photos source: Prismark/Binghamton University

Samsung galaxy s22 ultra – snapdragon 8

- Snapdragon 8 CPU in 15x14mm Bottom Package
  - A. Flip chip die, 90µm pitch bumps
  - B. 4L substrate
    - 120µm thick, 12µm/30µm L/S
  - C. L substrate
    - 90µm thick, 25µm L/S
  - D. Copper balls, 120µm diameter
  - E. 0.35mm ball pitch, 42x39 ball array
- Memory in Top Package
  - F. 2 stacked wire bonded die
  - G. 3L substrate
    - 65µm thick, 25µm/35µm L/S
  - A. 0.4mm ball pitch
- 950µm total collapsed package stack height





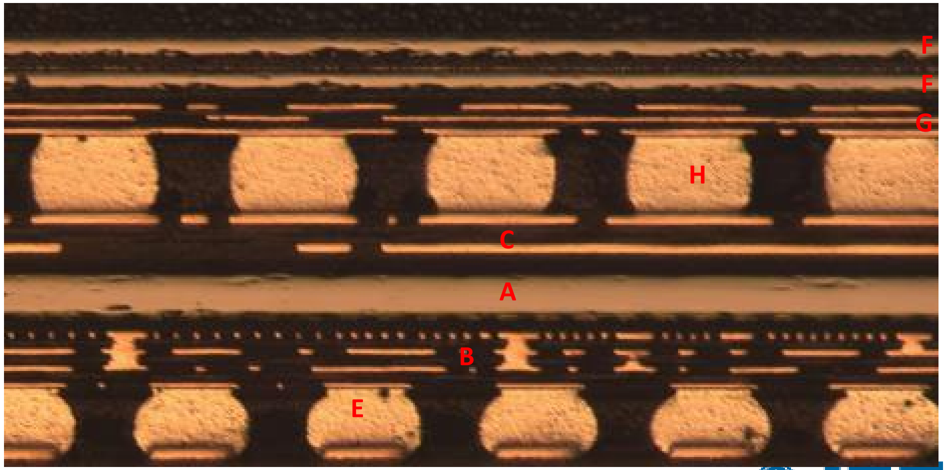
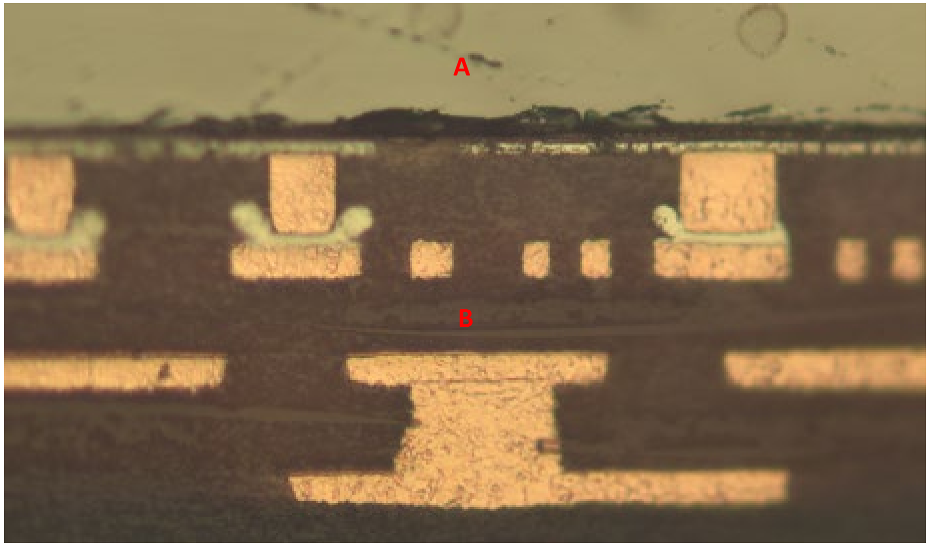


Photo source: Prismark/Binghamton University

Samsung galaxy s23 ultra – snapdragon 8 gen 2

- Snapdragon CPU in 17x15mm Bottom Package
  - A. Flip chip die, 90µm pitch bumps
  - B. 3L substrate
    - 90µm thick, 18µm/25µm L/S
  - C. 2L substrate
    - 80µm thick, 14/14µm L/S
  - D. Copper balls, 180µm diameter
  - E. 0.35mm ball pitch, 44x39 ball array
- Memory in Top Package
  - F. 4 stacked wire bonded die
  - G. 3L substrate, 90µm thick
  - H. 0.4mm ball pitch
- 1.1mm total collapsed package stack height



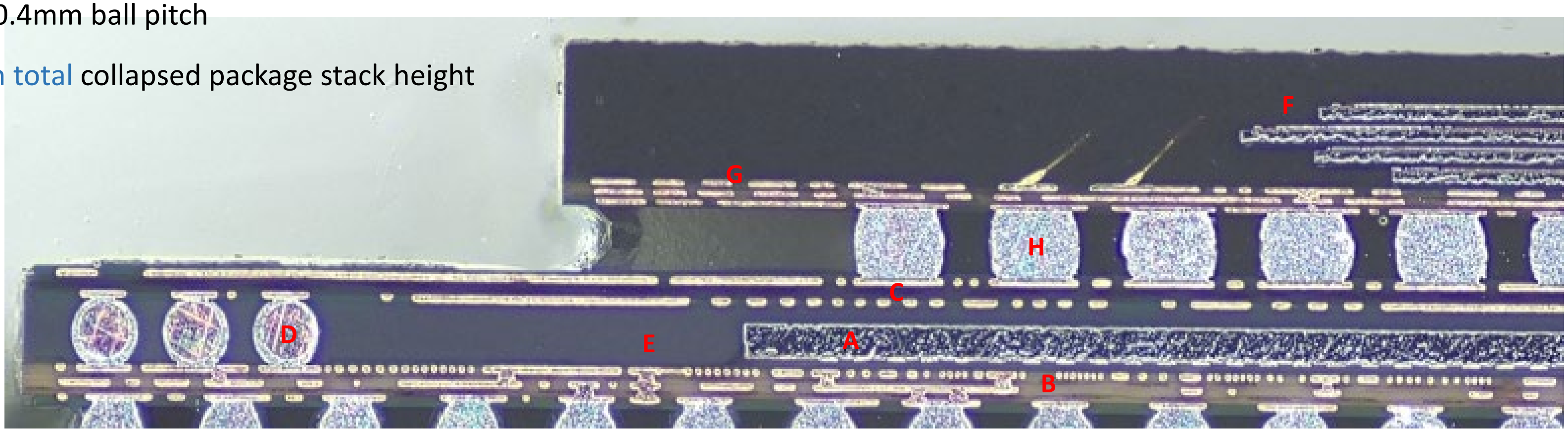
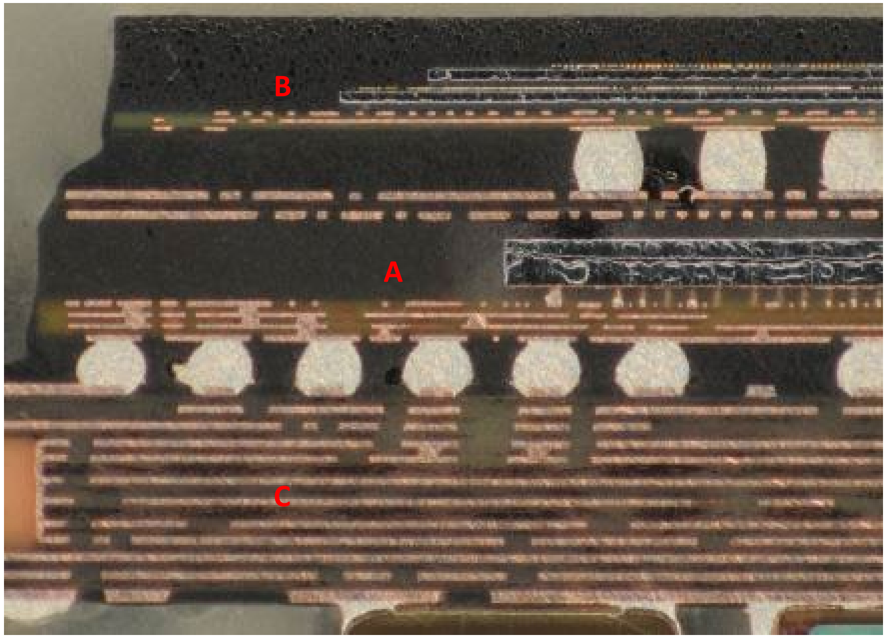
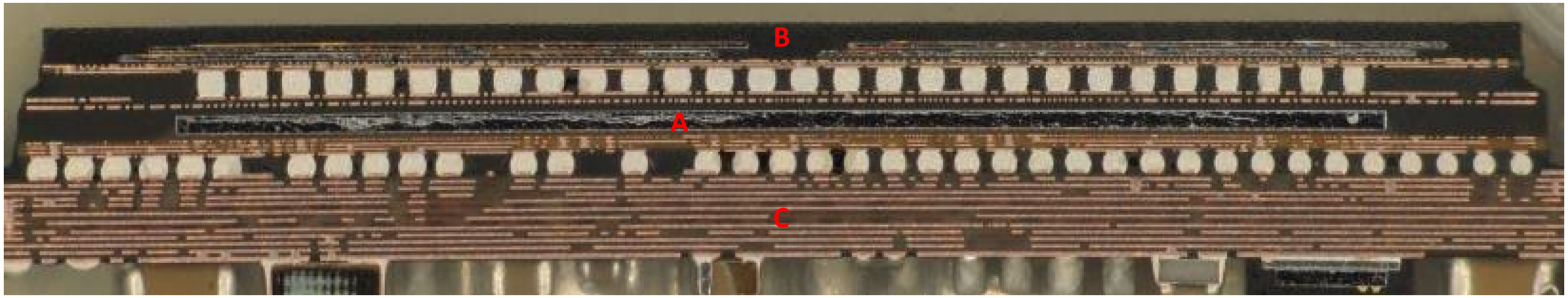


Photo source: Prismark/Binghamton University

Mediatek Dimensity 9200 Processor

- 15x15mm Processor/Memory PoP
- Processor in Bottom Package (A)
  - Flip chip die, min 80µm pitch
  - 4L substrate, min 7/11µm L/S
  - TMV and 2L substrate for Top Package
  - 39x38 ball array, 0.35mm pitch
- Memory in Top Package (B)
  - 4 wire bonded die in 2 side-by-side stacks
  - 3L substrate, 70 µm thick
  - 0.4mm pitch balls to Bottom Package
- 12L Any-layer HDI Main Board (C), 0.7mm thick
  - Vivo X90 smartphone

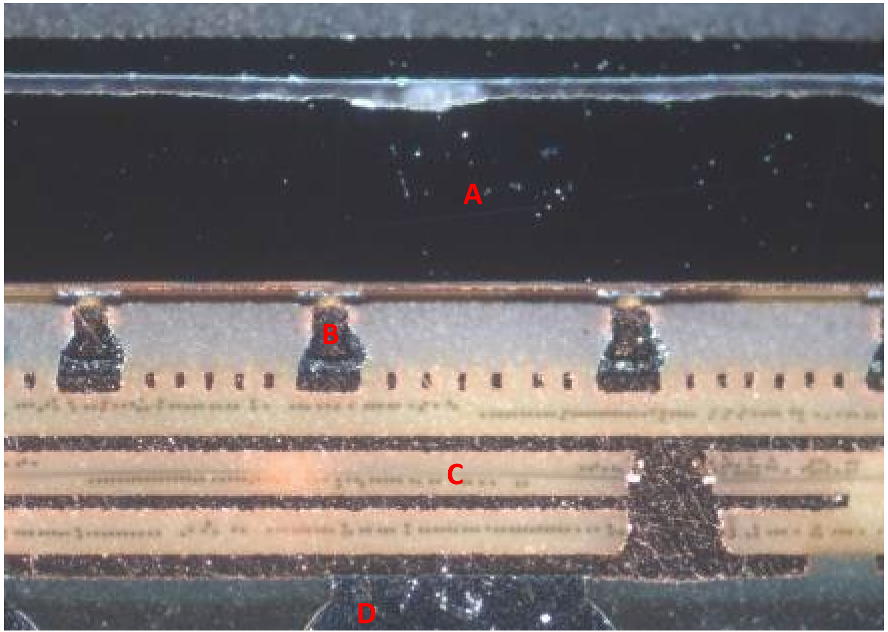


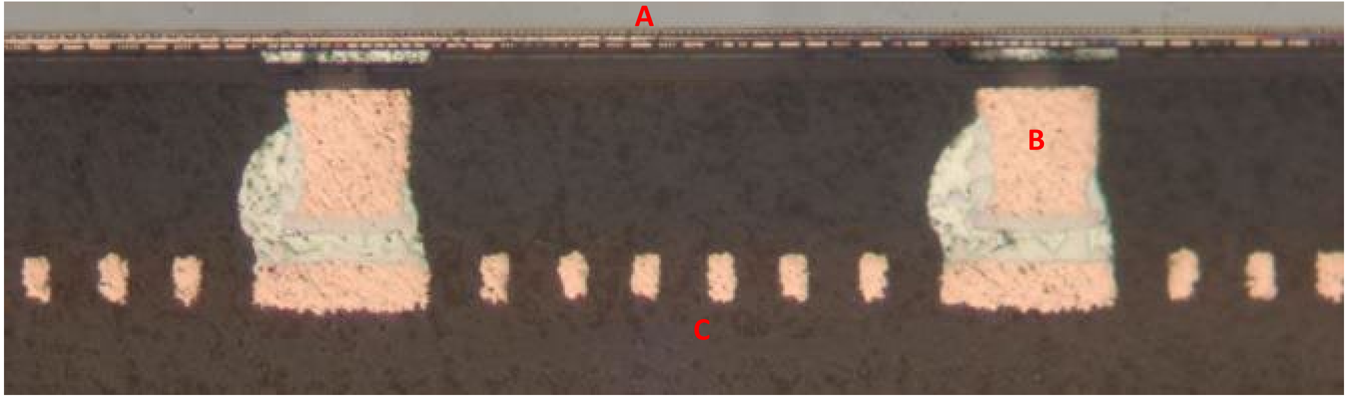


Photos source: Prismark/Binghamton University

Mediatek Dimensity 9200 Processor

- Processor in 15x15mm Bottom Package of PoP
    - Flip chip die (A) with Cu bumps (B)
        - Varying bump pitch, min 80µm
        - 40µm bump width
        - 40µm final stand-off height
    - 4L substrate (C), min 7/11µm L/S
        - 130µm thick, min 7/11µm L/S
    - TMV and 2L substrate for Top Package
    - 39x38 ball array, 0.35mm pitch (D)



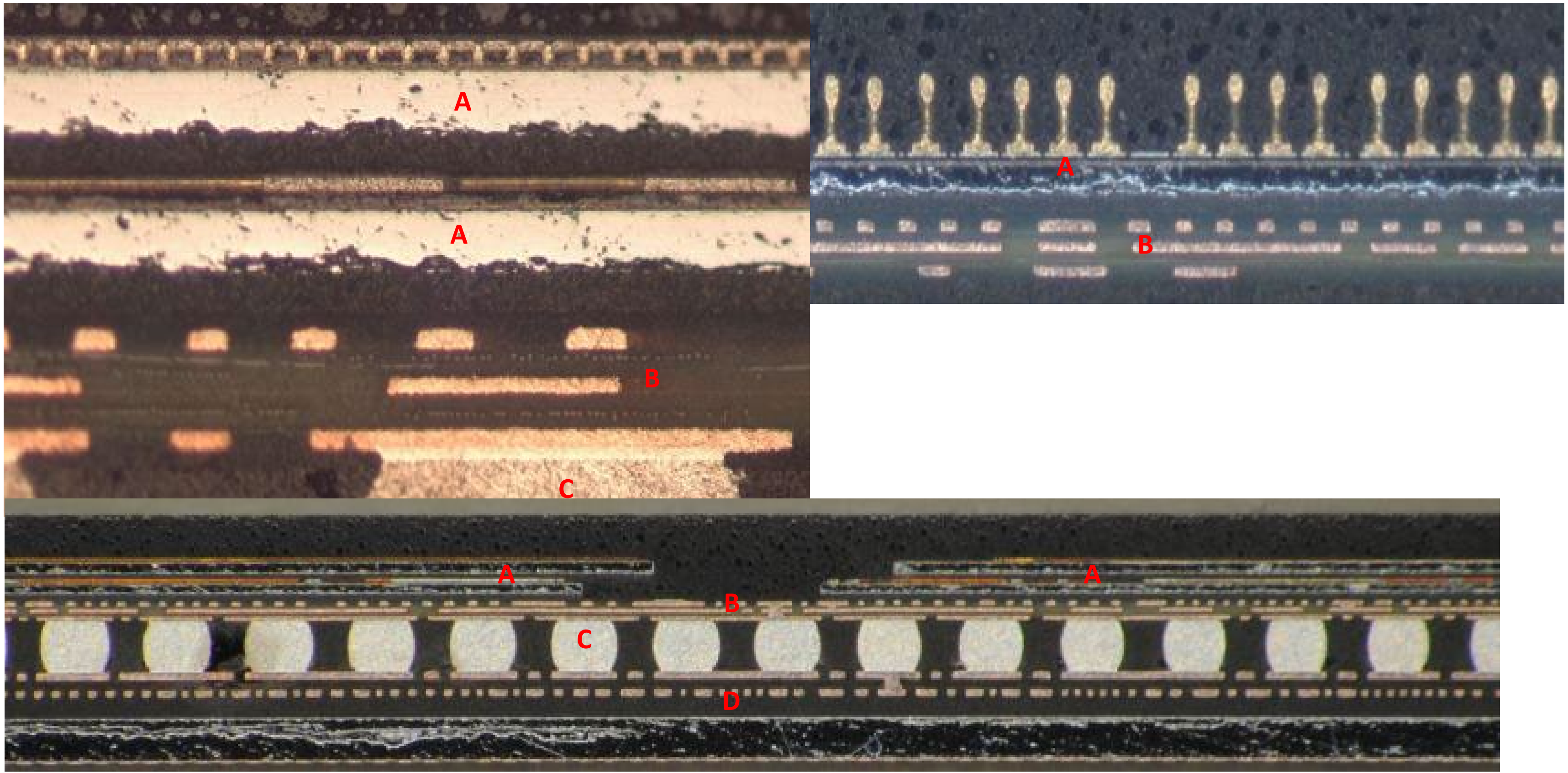


Photos source: Prismark/Binghamton University

0223.193mvc

Mediatek Dimensity 9200 Processor

- Memory in 14x13mm Top Package of PoP
  - 4 wire bonded die (A) in 2 side-by-side stacks
  - 3L substrate (B), 70µm thick
  - 0.4mm pitch balls (C) to Bottom Package (D)



Photos source: Prismark/Binghamton University

Mobile Processor Comparison

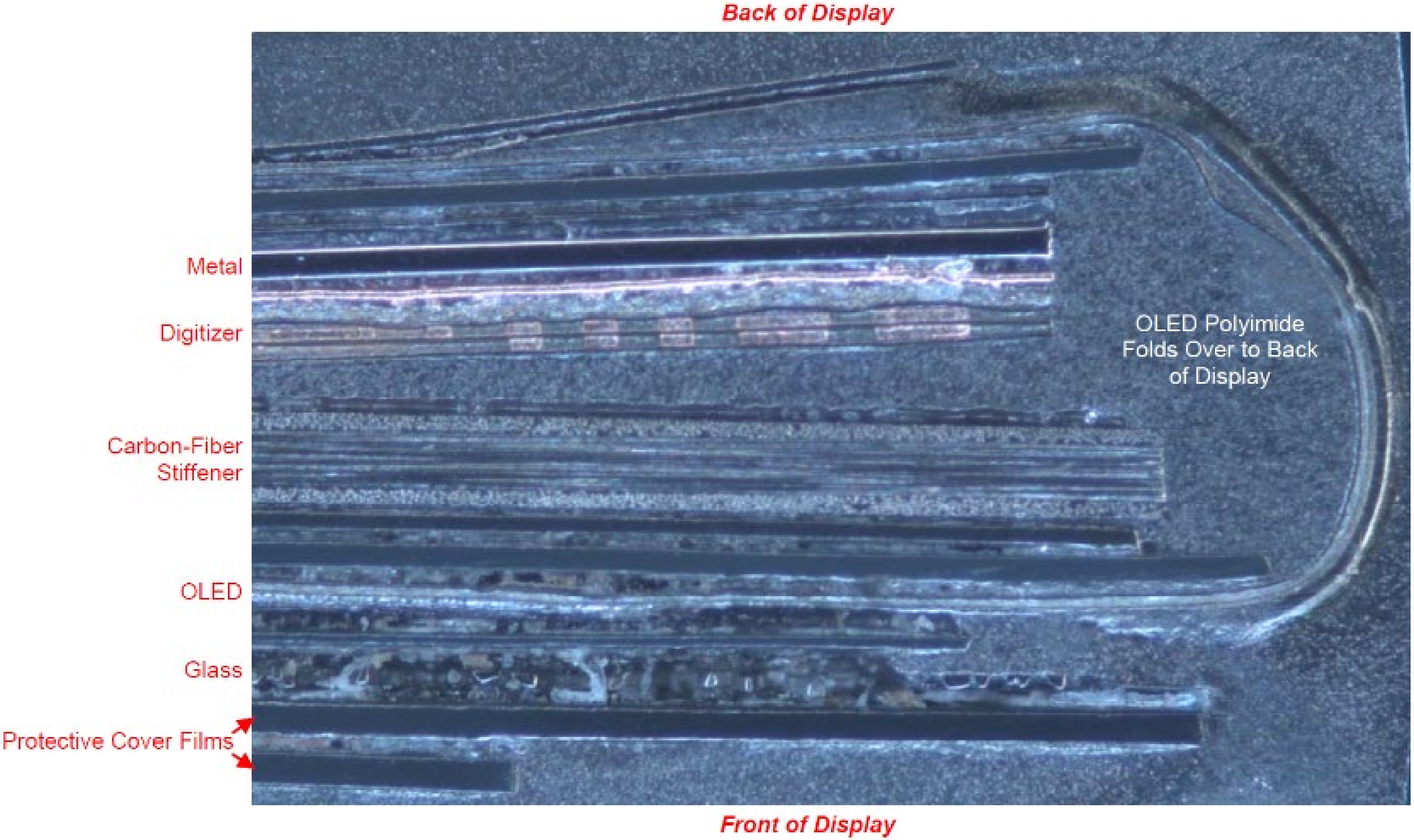
		Snapdragon 8 Gen 3	Exynos 2400	Dimensity 9300	A17 Pro
CPU		1x 3.3 GHz – Cortex-X4 3x 3.15 GHz – Cortex-A720 2x 2.96 GHz – Cortex-A720 2x 2.27 GHz – Cortex-A520	1x 3.1 GHz – Cortex-X4 2x 2.9 GHz – Cortex-A720 3x 2.6 GHz – Cortex-A720 4x 1.8 GHz – Cortex-A520	1x 3.25 GHz – Cortex-X4 3x 2.85 GHz – Cortex-X4 4x 2 GHz – Cortex-A720	2x 3.78 GHz – P-Core 4x 2.11 GHz E-Core
GPU		0.77GHz Adreno 750	1.2GHz Xclipse 940	Mali G720	1.4GHz Apple
Memory		LPDDR5X, 4200MHz	LPDDR5X, 4200MHz	LPDDR5X, 4266MHz	LPDDR5, 3200MHz
Node		TSMC 3nm	Samsung 4nm	TSMC 4nm	TSMC 3nm
Geekbench 6	**Single-Core**	2224	2080	2211	2977
	Multi-Core	7078	6562	7153	7476
Smartphone Shipment		November 2024	Early 2024	November 2024	Sep 2023

Some uncertainty for future releases. Geekbench scores may change as processors/phones are optimized prior to commercial release

Source: Prismark Partners


17:28
12:30
THU, JAN 1
2020
SLASHGEAR

Foldable Devices

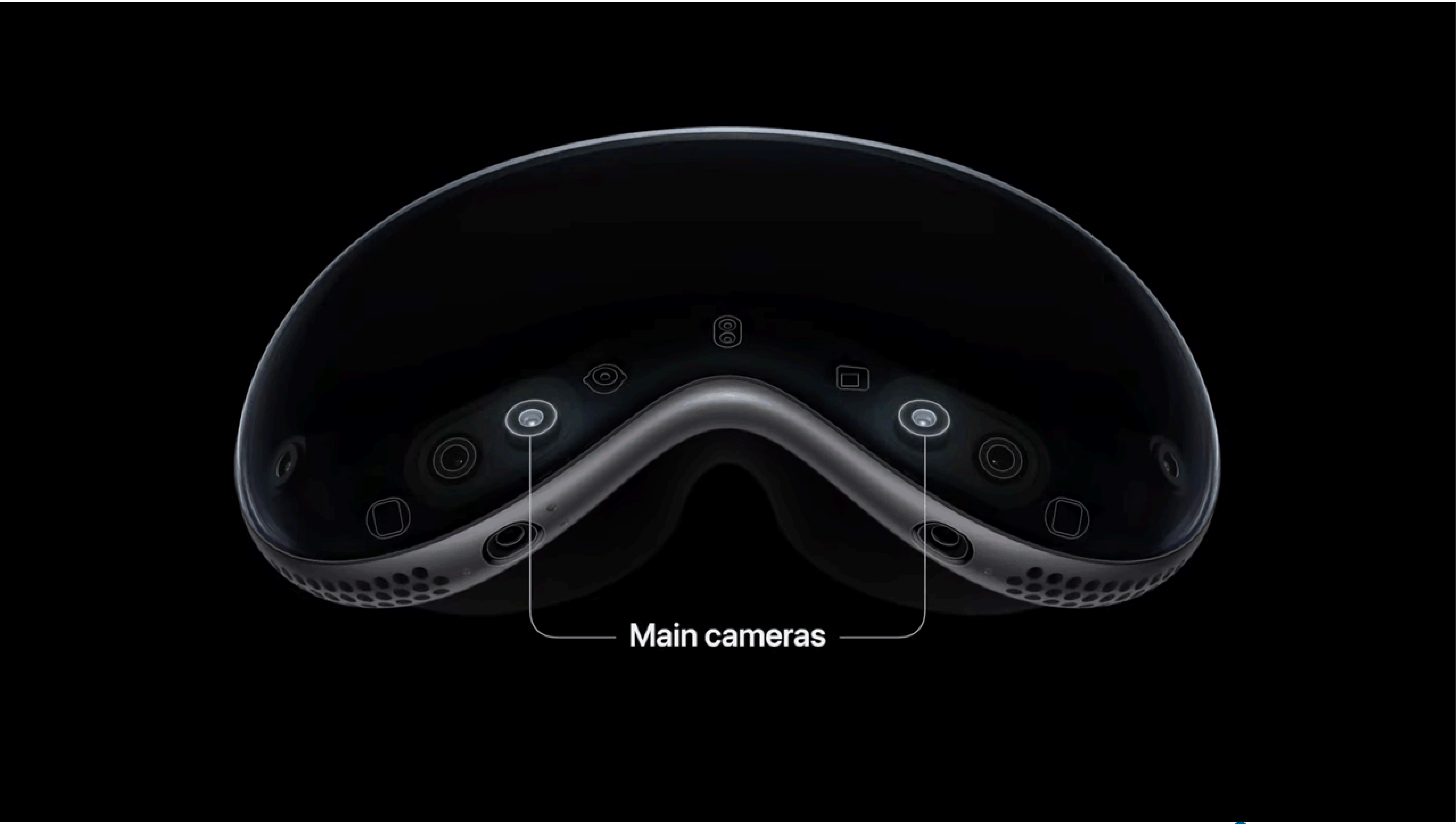


Photos source: Prismark/Binghamton University

AR/VR/MR Challenges

- Billions Spent on AR/VR/MR Already
  - Realization that this could be the next big thing
  - Apple, Meta, Google, Microsoft, Magic Leap, Xiaomi and many startups around the world
- Further Hardware Improvements Needed:
  - Processor performance vs battery life
  - Display resolution, FoV, refresh rate, brightness
  - Eye tracking to enhance immersion
  - Weight reductions and weight balancing
  - Size reductions, aesthetic designs
  - Improved controllers (haptics)
  - Faster wireless connectivity
  - Hardware/software integration just as important

- Especially Difficult Challenges of AR Glasses:
  - Optics for AR image as well as actual view
    - Floating AR image must not interfere with actual view, nor be visible to others
    - FoV, brightness, transmissivity, depth focus, ”glowing eyes”
  - Ruggedness versus aesthetics and portability
  - Inputs/controls via voice, gestures, touch

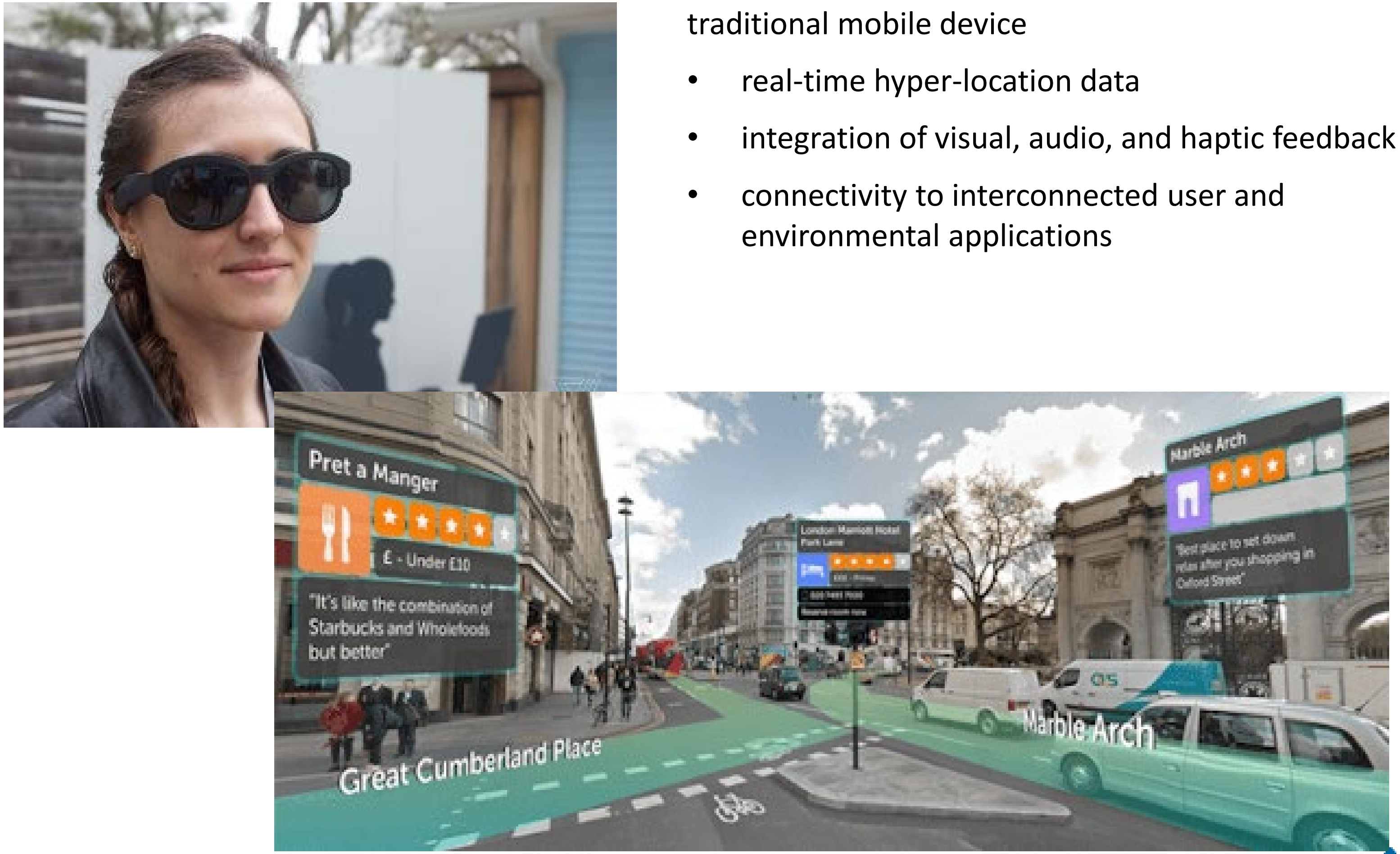


Main cameras

A spatial personal virtual ecosystem

Delivering existing and additional functionality of a traditional mobile device

- real-time hyper-location data
- integration of visual, audio, and haptic feedback
- connectivity to interconnected user and environmental applications



Cross TWG Collaborations

5G/6G, mmWave

Single / Multichip

Reliability

MEMS and Sensors

Thank You

We need YOU to join the Mobile TWG