HIR Mobile Technical Working Group

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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 (It is out of date as soon as the consumer buys it).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
Penetration rate: 68% in 2022, 73% in 2030, 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
Penetration rate: 55% in 2022, 64% in 2030, CAGR 2022-2030: 4.5%

Operator revenues and investment
2022: $1.07tn
2030: $1.20tn

Operator capex
2022: $1.5tn
92% on 5G

SIM connections (excluding licensed cellular IoT)
2022: 8.4bn
2030: 9.8bn
Penetration rate: 105% in 2022, 114% in 2030

4G Percentage of connections (excluding licensed cellular IoT)
2022: 60%
2030: 36%

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 phone shipments by standard

Over 64% of phones sold in 2027 will be 5G
# Apple iPhone Evolution

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<th>Proximity/Light</th>
<th>Compass</th>
<th>Gyroscope</th>
<th>Fingerprint</th>
<th>Barometer</th>
<th>NFC</th>
<th>3D Touch</th>
<th>FaceID</th>
<th>UWB</th>
<th>Lidar</th>
<th>Satellite “SOS”</th>
<th>Periscope Cam.</th>
<th>Front Camera</th>
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Note: Specs for main model - not larger display or lower priced versions

Courtesy Prismark Partners
Apple iPhone 14/15 pro max comparison
Apple iPhone 14/15 pro Front board comparison

Note: Front board is 10L any-layer HDI

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

iPhone 15 Pro adds 1.75cm² front board area previously cut out for SIM card slot on rear board. Moves Flash memory to there

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

Photos source: Prismark/Binghamton University
Apple iPhone 14/15 pro Rear board comparison

iPhone 14 Pro

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

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 Manager (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

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

iPhone 15 Pro gains use of 1.75cm² 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)
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: Prizmark/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: Prizmark/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
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

<table>
<thead>
<tr>
<th></th>
<th>Snapdragon 8 Gen 3</th>
<th>Exynos 2400</th>
<th>Dimensity 9300</th>
<th>A17 Pro</th>
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<tr>
<td><strong>CPU</strong></td>
<td>1x 3.3 GHz – Cortex-X4</td>
<td>1x 3.1 GHz – Cortex-X4</td>
<td>1x 3.25 GHz – Cortex-X4</td>
<td>2x 3.78 GHz – P-Core</td>
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<td>3x 3.15 GHz – Cortex-A720</td>
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<td>3x 2.85 GHz – Cortex-X4</td>
<td>4x 2.11 GHz E-Core</td>
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<td>2x 2.96 GHz – Cortex-A720</td>
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<td>3x 2.85 GHz – Cortex-X4</td>
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<tr>
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<td>2x 2.27 GHz – Cortex-A520</td>
<td>4x 1.8 GHz – Cortex-A720</td>
<td>4x 2 GHz – Cortex-A720</td>
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<td><strong>GPU</strong></td>
<td>0.77GHz Adreno 750</td>
<td>1.2GHz Xclipse 940</td>
<td>Mali G720</td>
<td>1.4GHz Apple</td>
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<td><strong>Memory</strong></td>
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<td>Early 2024</td>
<td>November 2024</td>
<td>Sep 2023</td>
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Some uncertainty for future releases. Geekbench scores may change as processors/phones are optimized prior to commercial release.

Source: Prismark Partners
Foldable Devices

Back of Display

Protective Cover Films

Glass

OLED

Carbon-Fiber Stiffener

Digitizer

Metal

OLED Polyimide Folds Over to Back of Display

Front of Display

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
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