



***United States Cellular Telecommunication:
Cellular Analog to Digital Evolution***

***IEEE ICC 2013
Wireless History Session:
From AMPS to Digital
Cellular Mobile***

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United States Cellular Telecommunication: **Cellular Analog to Digital Evolution**

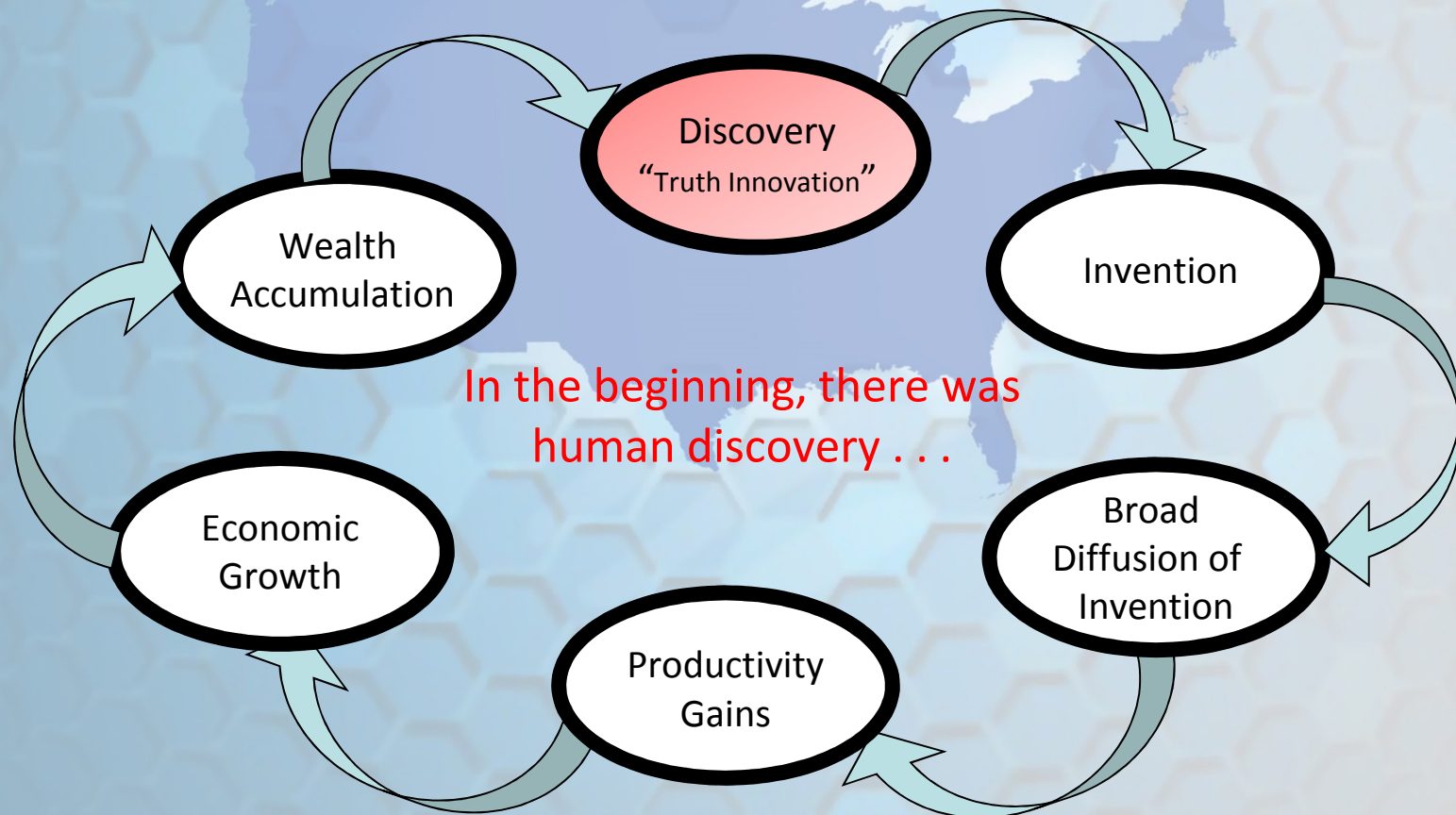
- ***A Perspective on the American Dynamic Innovation Ecosystem***
- ***The Evolution from Analog to Digital Cellular Communications***
- ***The “Next Big Thing” Enterprise Cellular Networks (ECNs)- “1 Gigabit Digital Cellular Channels”***



United States Cellular Telecommunication: Cellular Analog to Digital Evolution

A Perspective on the American Dynamic Innovation Ecosystem

The Discovery-Economic Growth Continuum

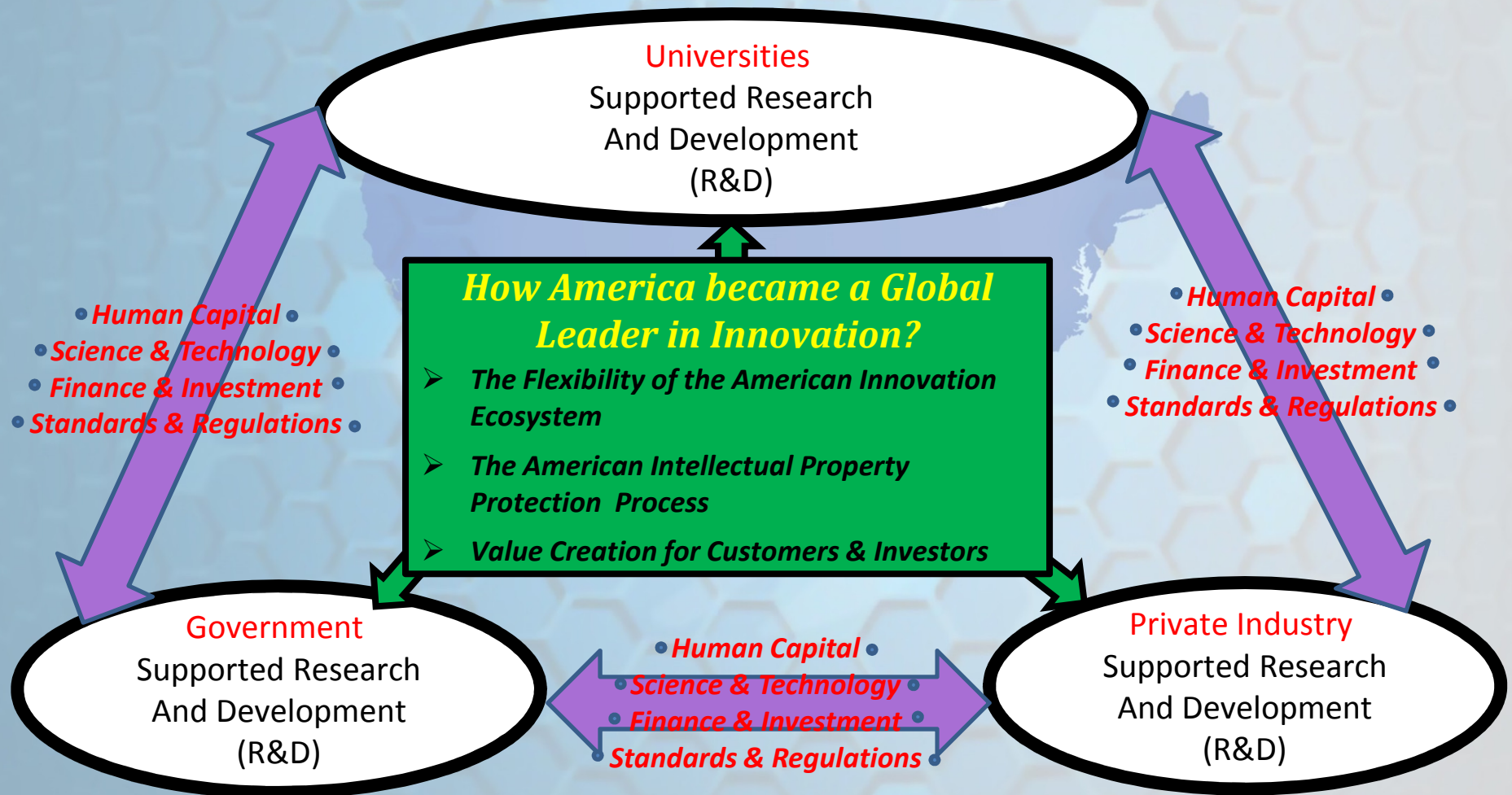


How...? "Discovering the Need before the Masses have the Need"



United States Cellular Telecommunication: Cellular Analog to Digital Evolution

A Perspective on the American Dynamic Innovation Ecosystem



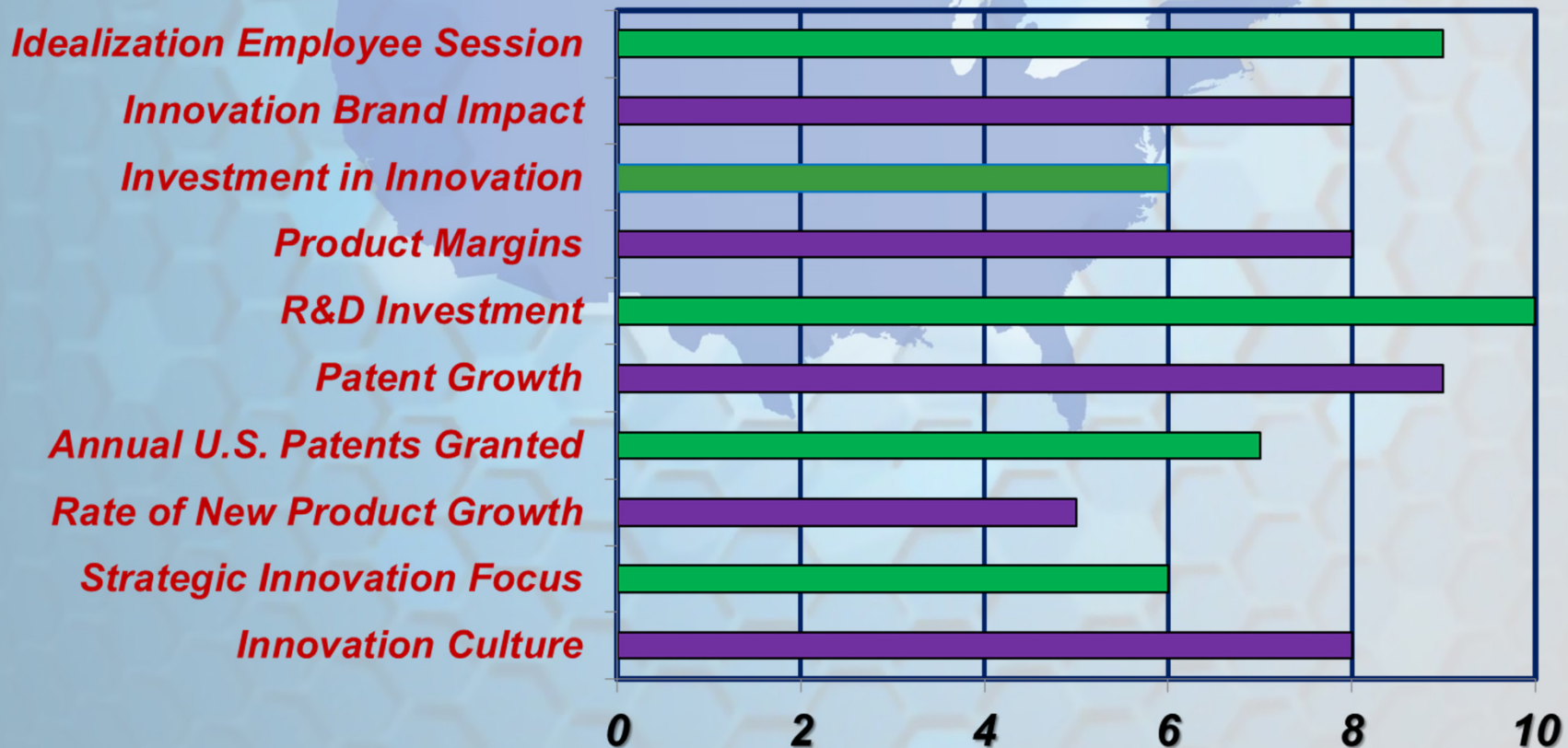
How...? "The American Innovation Ecosystem and Human Capital"



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A Perspective on the American Dynamic Innovation Ecosystem

INNOVATION SUCCESS FACTORS



Measurement...? "The American Innovation Ecosystem is a Team Sport"

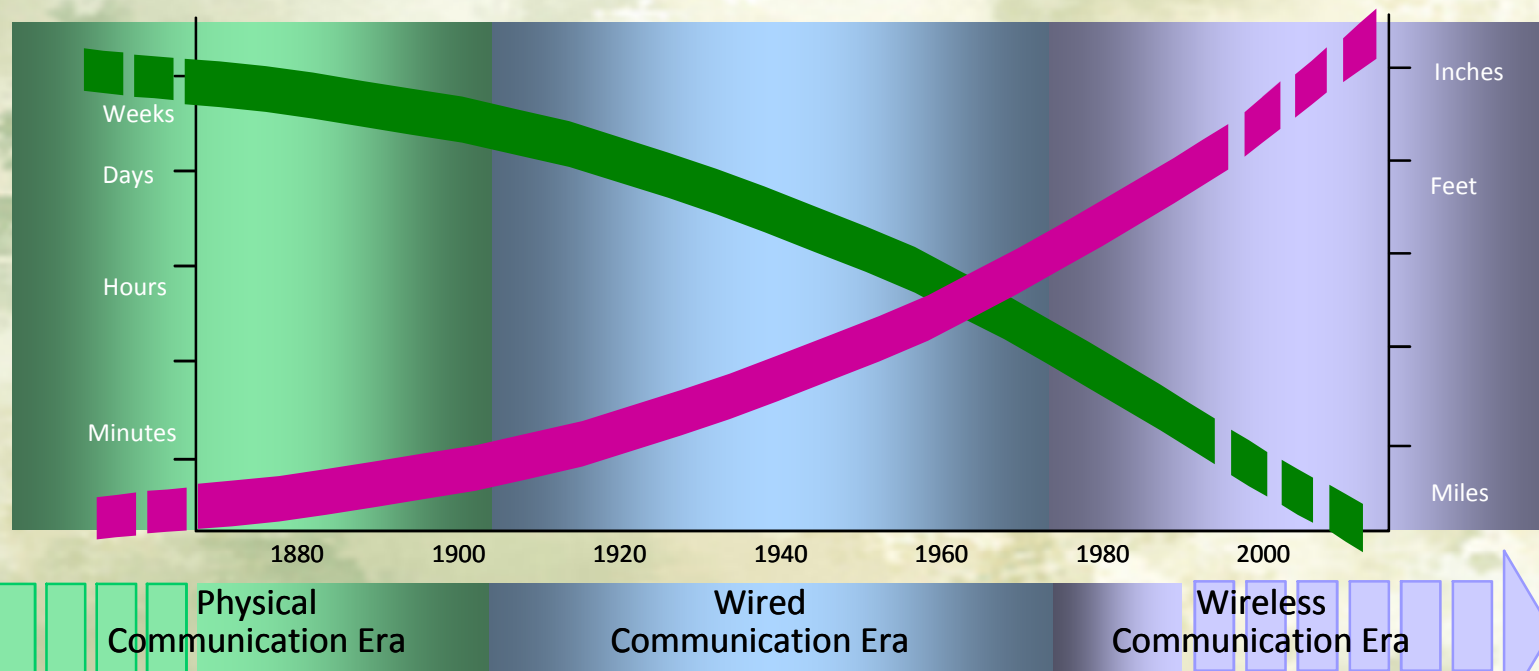


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A Perspective on the American Dynamic Innovation Ecosystem

“Half-Life” of
Perceived Personal
Information Value

“Inconvenience Threshold”
Travel Distance to Obtain
Valuable Information



“Each Technology Transition Discovery has resulted in
Economic Growth and Wealth Accumulation”



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United States Cellular Telecommunication: Cellular Analog to Digital Evolution

United States AMPs to Digital Cellular Chronology: From Concept to Realization

1946: First Mobile Telephone Call (Car Phone) -150MHz

1947: D.H. Ring at Bell Labs: Cellular Concept of hexagonal grid, with automatic call handoff

1960s: Richard Frenkiel and Joel Engel of Bell Labs using computers and electronics made the Cellular Concept work



1946: First Mobile Telephone Call

1971 (Dec): AT&T makes Proposal to the FCC for a Cellular System



1976: Cellular Phone AMPS Evaluation System

1978: AT&T conducted FCC-authorized field trials in Chicago and Newark, N.J.



1960s: Dick Frenkiel and Joel Engel of Bell Labs



United States Cellular Telecommunication: Cellular Analog to Digital Evolution

United States AMPs to Digital Cellular Chronology: From Concept to Realization

1982: FCC grants commercial licenses to an AT&T subsidiary, Advanced Mobile Phone Service Inc (AMPS). AMPS was later divided among the local companies as part of the planning for divestiture



1982 (January 8): AT&T Bell System Breakup was mandated to create 7 Independent RBOCs & the Breakup of Bell Labs (Bell Labs & BELLcore (Bell Communications Research))



AT&T retained Long Distance Business, Western Electric and Bell Labs



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United States AMPs to Digital Cellular Chronology: From Concept to Realization

1983 (Oct 13) : First Commercial Cell Phone Call made by Ameritech



The call was from Chicago to the Great Grandson of Alexander Graham Bell in Germany

Marty Copper, Motorola, Inventor of the Cell Phone used in the 1st Cellular Call the DynaTAC 10" long weight. 2.5 pounds, Cost ~ \$4,000



1984: The US Digital Cellular Communication Concept -800 MHz

1984: Jesse Russell and Digital Cellular Team at AT&T Bell Labs Develops the US Digital Cellular Concept: Digital Cellular Concept was based Dual Mode Phones "Analog-Digital" and Digital Cellular Base Stations Utilizing Low Bit Rate Speech Encoders, Digital Modulation, Linear High Power Amplifiers for RF Channel Combining, and Digital Cellular Switching with Automatic Analog-Digital handoff





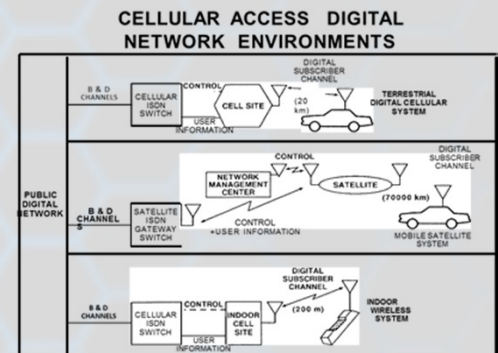
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United States Cellular AMPs to Digital Chronology: From Concept to Realization

1986: The US Cellular Access Digital Network (CADN) (IS54/IS136) Concept

1986: (2nd Nordic Seminar on Digital Land Mobile Radio Communications, Stockholm, Sweden) Cellular Access Digital Network (CADN) supporting ISDN-AT&T Bell Labs

1987: In-door Digital Wireless Communication for Personal Communication Services (PCS)--AT&T Bell Labs



1988 (March): 1st Digital Cellular Call in Chicago Demonstrating AMPs to Digital Cellular Handoff



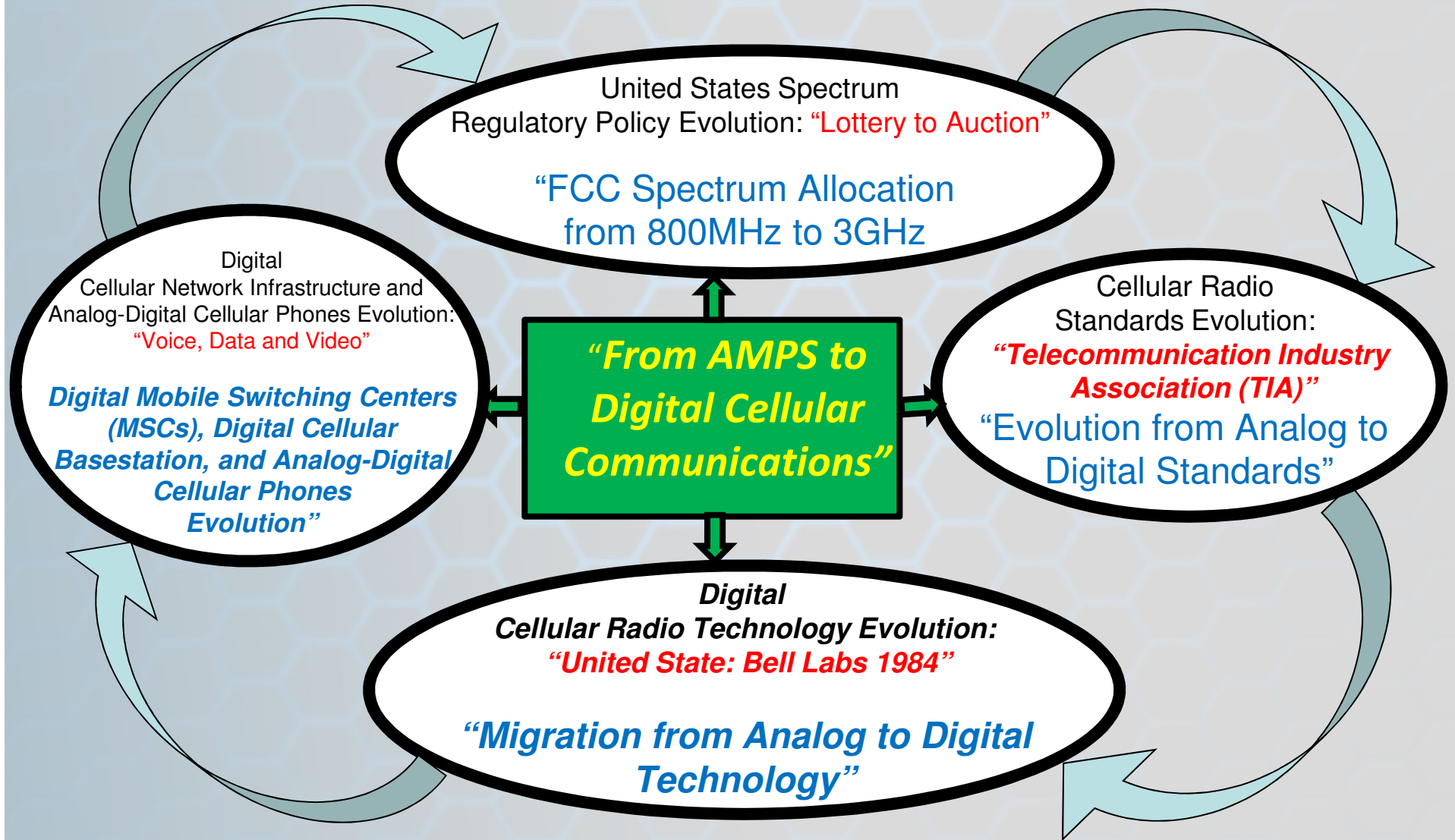
AT&T Bell Labs

The call was within Chicago between Richard Notebaert, President of Ameritech Mobile and Jesse Russell, Director AT&T Bell Labs- Cellular Telecommunications Laboratory





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Base Station Design Evolution

1990: 1st All Digital Cellular Base Station System utilizing linear high Power RF Amplifiers Supporting AMPS, TDMA & CDMA Common Air Interfaces (CAI)-**AT&T Bell Labs**



AMPS: System Access Monitor



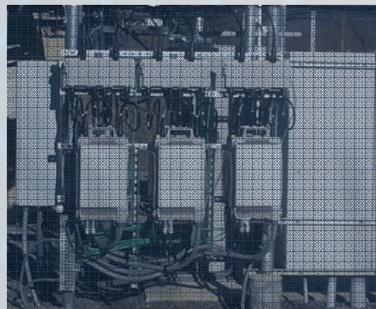
Dual band IS-136 RBS 884 Base Station (Ericsson)



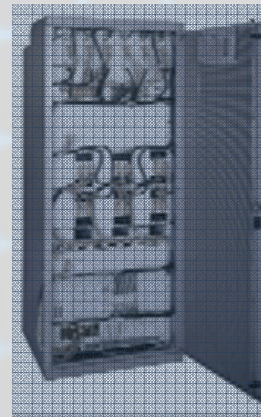
Multi-standard Base Station GSM/GPRS/EDGE/UMTS (ALU)



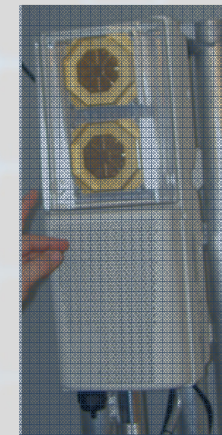
1998: 1st Small Cell based on The US Digital Cellular Standard IS-136 – **AT&T Bell Labs**



LTE Rooftop BS (ALU)



3G CDMA2000 Base Station



6 cm Radio Cube with RF Amplifiers, & Passive Cooling for **Next Gen** Radios



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2007 (Jan 27): 1st iPhone in the USA -- Smart Phone (2G)

*Smart Phone
Revolution*

3G and LTE
iPhone



4G LTE
iPhone



Mobile Phone Operating Systems: iOS, Android, Microsoft, BlackBerry 10



BlackBerry
z10



Nokia -
Microsoft



Samsung -
Android



Apple -
iOS



OKI -1976



OKI -1976



DynaTAC



1989 (April 25):
MicroTAC



1994:
Intellicom
GSM



1996: Clamshell / Flip
Mobile Phone –
Motorola Star Track



1999, Nokia
TDMA Phone



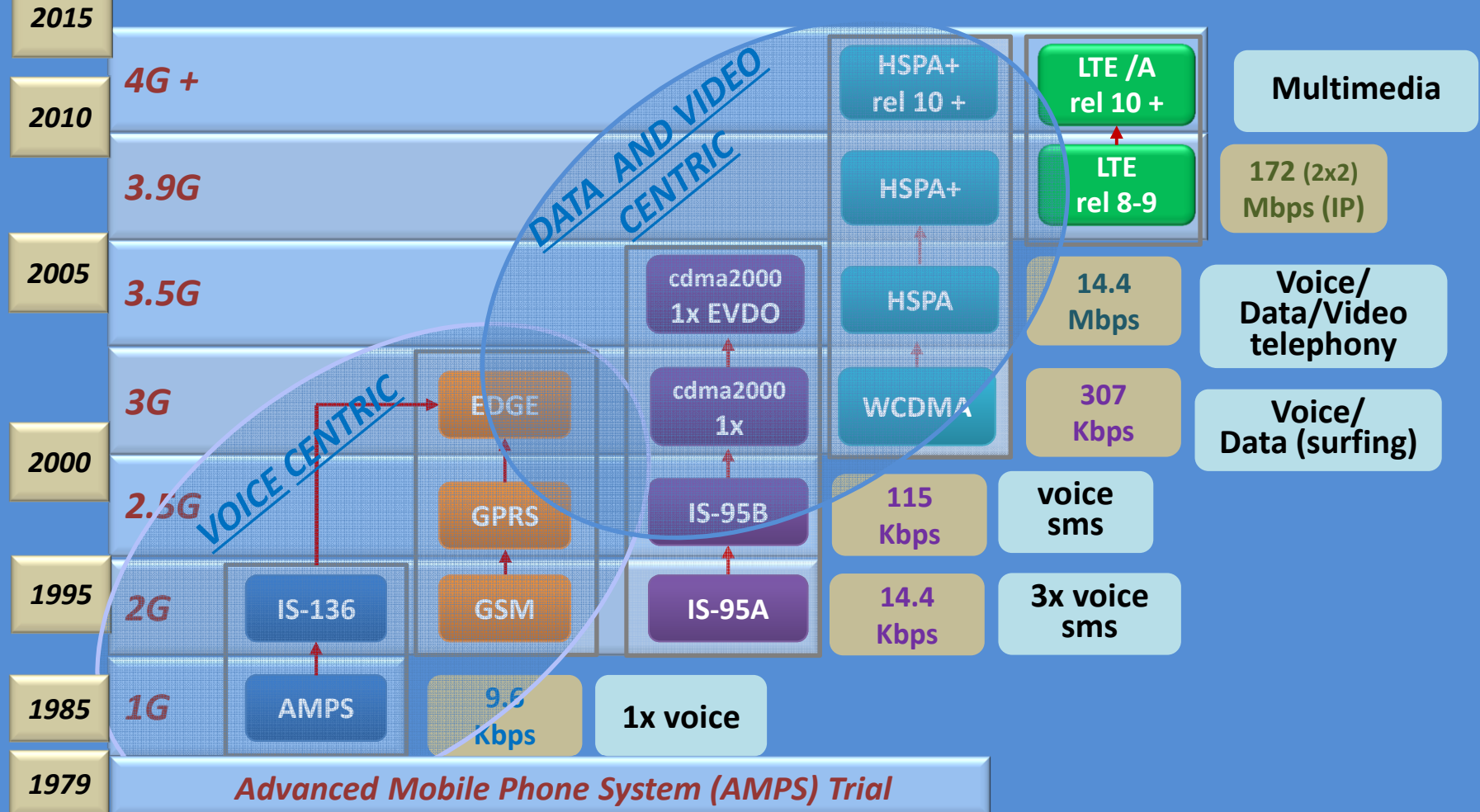
1999, RIM 1st
BlackBerry-email



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Mobile Standards Generations and Services Evolution



Each Higher Generation provides Higher Data Throughput



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The evolution of mobile standards

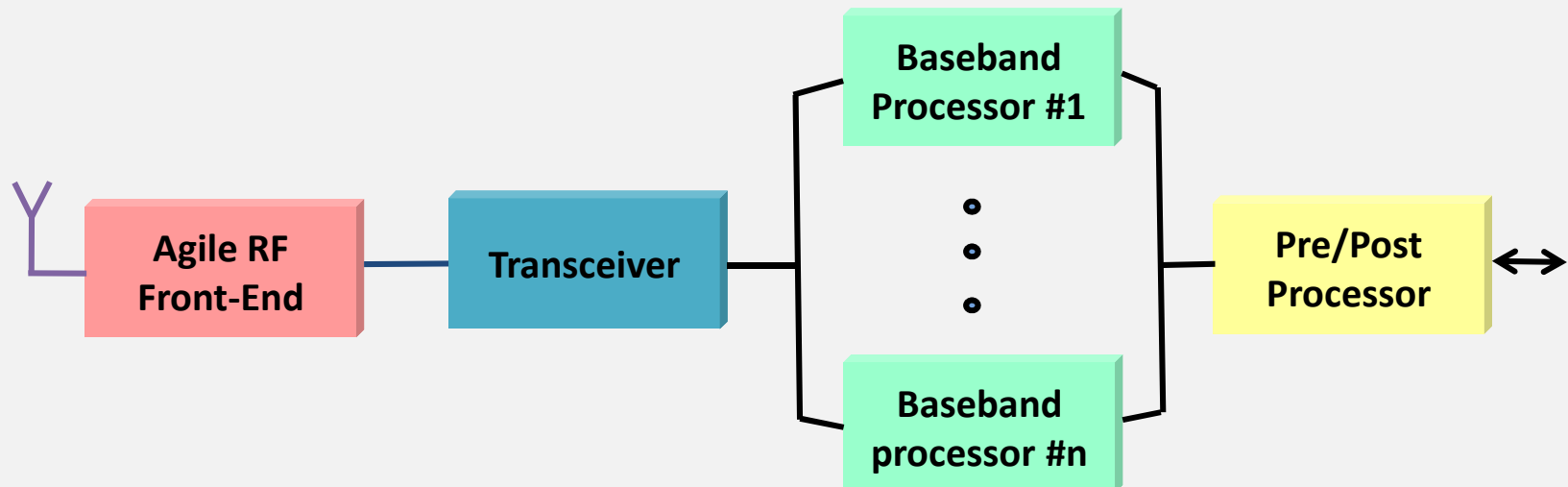
| Mobile standards | 3GPP | | Qualcomm | China | IEEE |
|--------------------------------------------------------------------------------------------|---------------------------------------------------|-----------------------------|---------------------------------------------------------------------------------------------------------|------------------------|--------------------------------------------|
| Carriers using: | AT&T and T-Mobile US, majority of global carriers | | Sprint, Verizon Wireless | China Mobile | Sprint |
| 2G: digital + data services | GSM: 2G | | CDMAOne | | |
| | GPRS: 2.5G | | | | |
| | EDGE: 2.75G | | | | |
| 3G: at least 200 kbps iPhone 4 currently delivers up to 7.2Mbps down, 5.8Mbps up | Release 4 | UMTS 3G | CDMA2000 EVDO rev 0 | TD-SCDMA (up to 2Mbps) | Mobile WiMAX 3.9G (4 Mbps cap on EVO "4G") |
| | Release 5 | HSDPA 3.5G (to 21Mbps down) | CDMA2000 EVDO rev A (up to 3.1Mbps down, 1.8 up) | | |
| | Release 6 | HSUPA 3.5G (to 5.8Mbps up) | EVDO Rev C / Ultra Mobile Broadband Canceled: Sprint moving to WiMAX, Verizon moving to 3GPP LTE | | |
| | Release 7 | HSPA+ 3.5G | | | |
| | Release 8/9 | LTE 3.9G | | | |
| 4G: at least 100 Mbps, IP-based | Release 10 | LTE Advanced | | TD-LTE | WiMAX 4G |

The "Next Big Thing" Enterprise Cellular Networks (ECNs):
"1 Gigabit Digital Cellular Channels"



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Enterprise Cellular Networks (ECNs): “1 Gigabit Digital Cellular Channels”



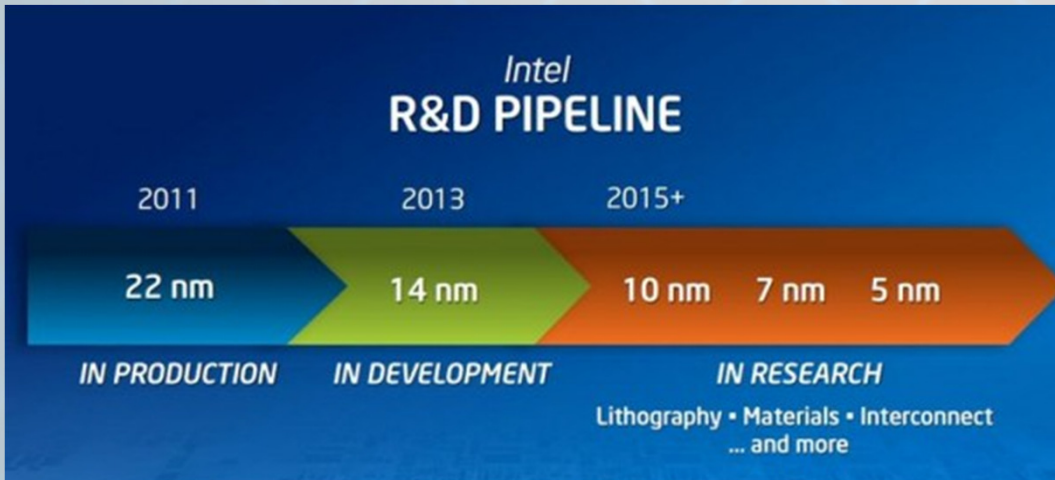
- **Agile RF Front-End Band Selection Process:** “Dynamic RF Band Selection “Active Filter Technology”
- **Transceiver Processes Selected Band:** “RF Wide-Band Channel Processing Technology”
- **Programmable Baseband Processing:** “Concurrent Baseband Channels Processing Technology”
- **Channel Data Aggregation:** “Pre/Post Processing to Align and Aggregate Data from Different Spectrum Bands”



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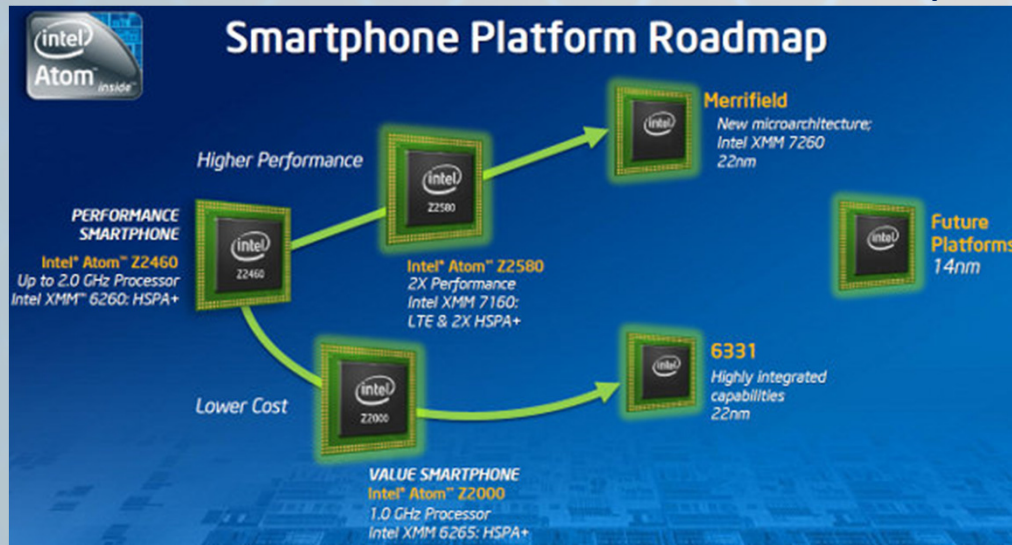
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Semiconductor Manufacturing Processes- INTEL's View of the Shrinking Die



Intel view of Shrinking Die

Decreases Power Consumption and Cost
More Head Room for clock speed



Semiconductor Manufacturing

Processes -Time Line Wikipedia:

| | |
|------------------------|-------------|
| 10 μm | — 1971 |
| 3 μm | — 1975 |
| 1.5 μm | — 1982 |
| 1 μm | — 1985 |
| 800 nm | — 1989 |
| 600 nm | — 1994 |
| 350 nm | — 1995 |
| 250 nm | — 1997 |
| 180 nm | — 1999 |
| 130 nm | — 2002 |
| 90 nm | — 2004 |
| 65 nm | — 2006 |
| 45 nm | — 2008 |
| 32 nm | — 2010 |
| 22 nm | — 2012 |
| 14 nm | — est. 2014 |
| 10 nm | — est. 2015 |
| 7 nm | — est. 2020 |
| 5 nm | — est. 2022 |