Ubiquitous Location:

challenges and opportunities of enabling all-day, everywhere location for all mobile platforms

Stanford PNT
October 29, 2014
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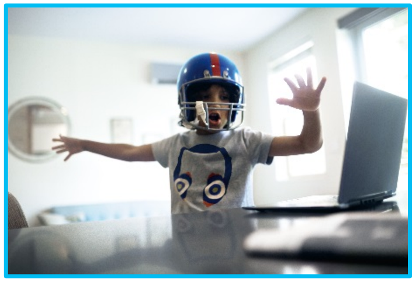
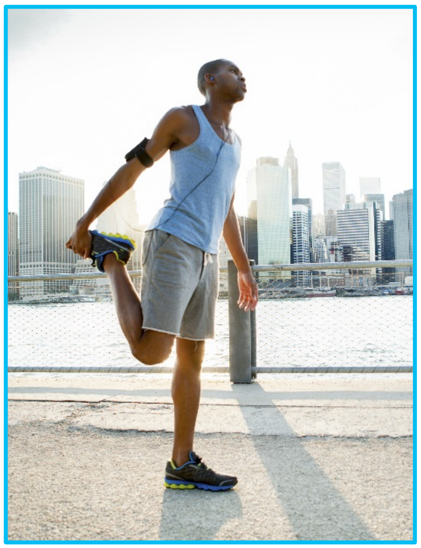
Agenda

- Intel is in mobile?
- GNSS market trends for consumers
- Impact of indoor location
    - GNSS system architecture
- Silicon trend impacts

Intel's Mission

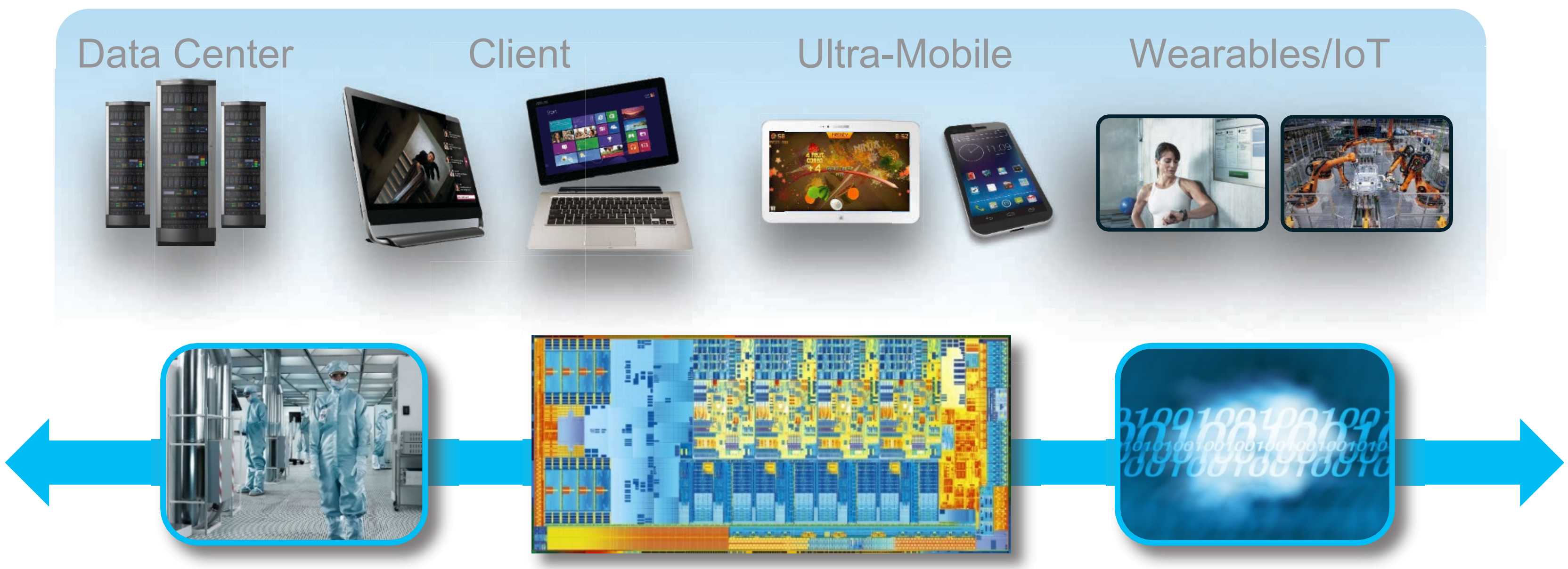


Utilize the power of Moore's Law to bring smart, connected devices to every person on earth.



Intel’s Vision
If it is smart and connected, it is best with Intel.



Growing Variety of Intel-based LTE Devices

Samsung
Galaxy Alpha

Samsung
Galaxy Tab S 10.5

Samsung
Galaxy Note 4

Samsung
Galaxy Tab S 8.4

ASUS
Transformer Pad
TF303CL

ASUS
Fonepad 7
ME372CL

Dell
Venue 7

Dell
Venue 8

ASUS
MeMo Pad 8

ASUS
PadFone X Mini

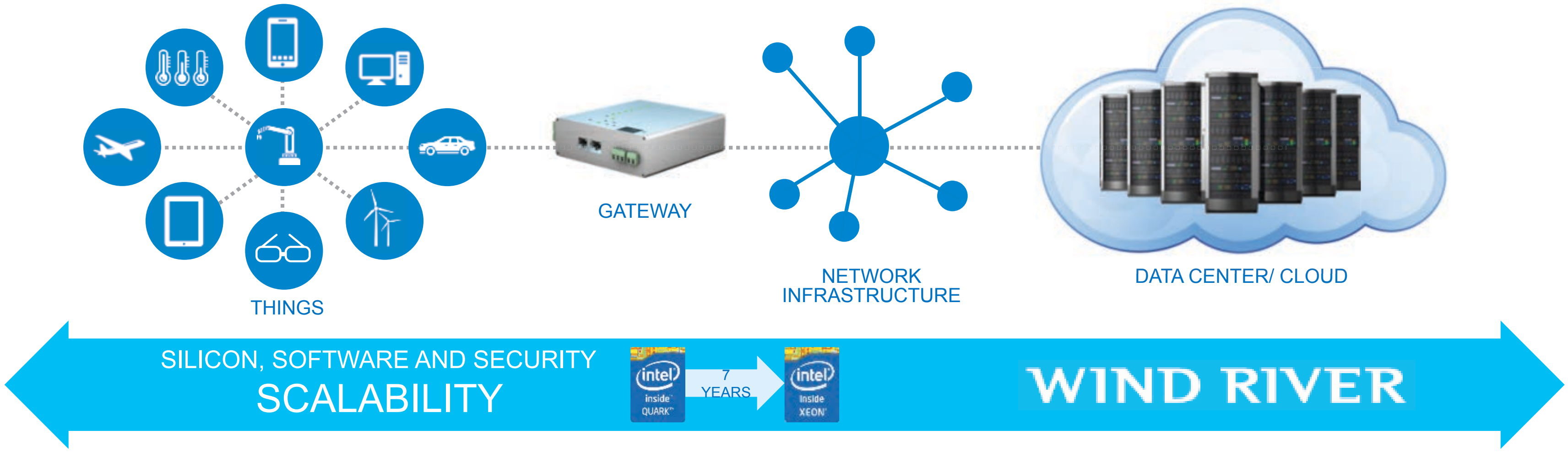
Lenovo
Tab S8

...more smartphones & tablets on the way !

*Other names and brands may be claimed as the property of others

Internet of Things Group

Lead the industry in transforming businesses and the way we live by making it simple to create exciting, new IoT solutions



THE INTERNET OF THINGS:

Devices that connect to the Internet

integrating greater compute capabilities

using data analytics to extract information

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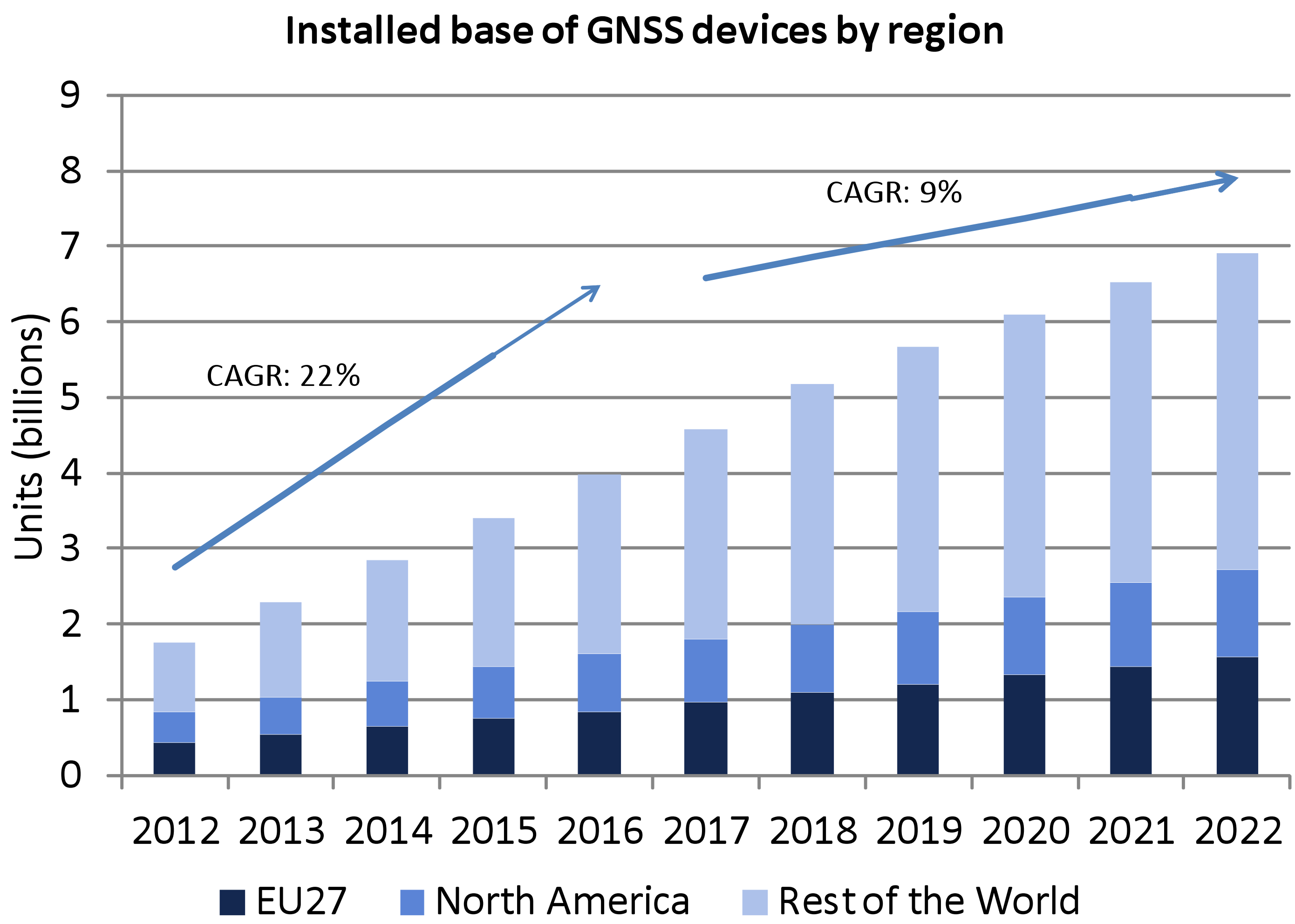
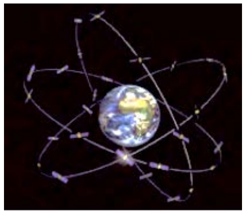
GNSS Mass-Market

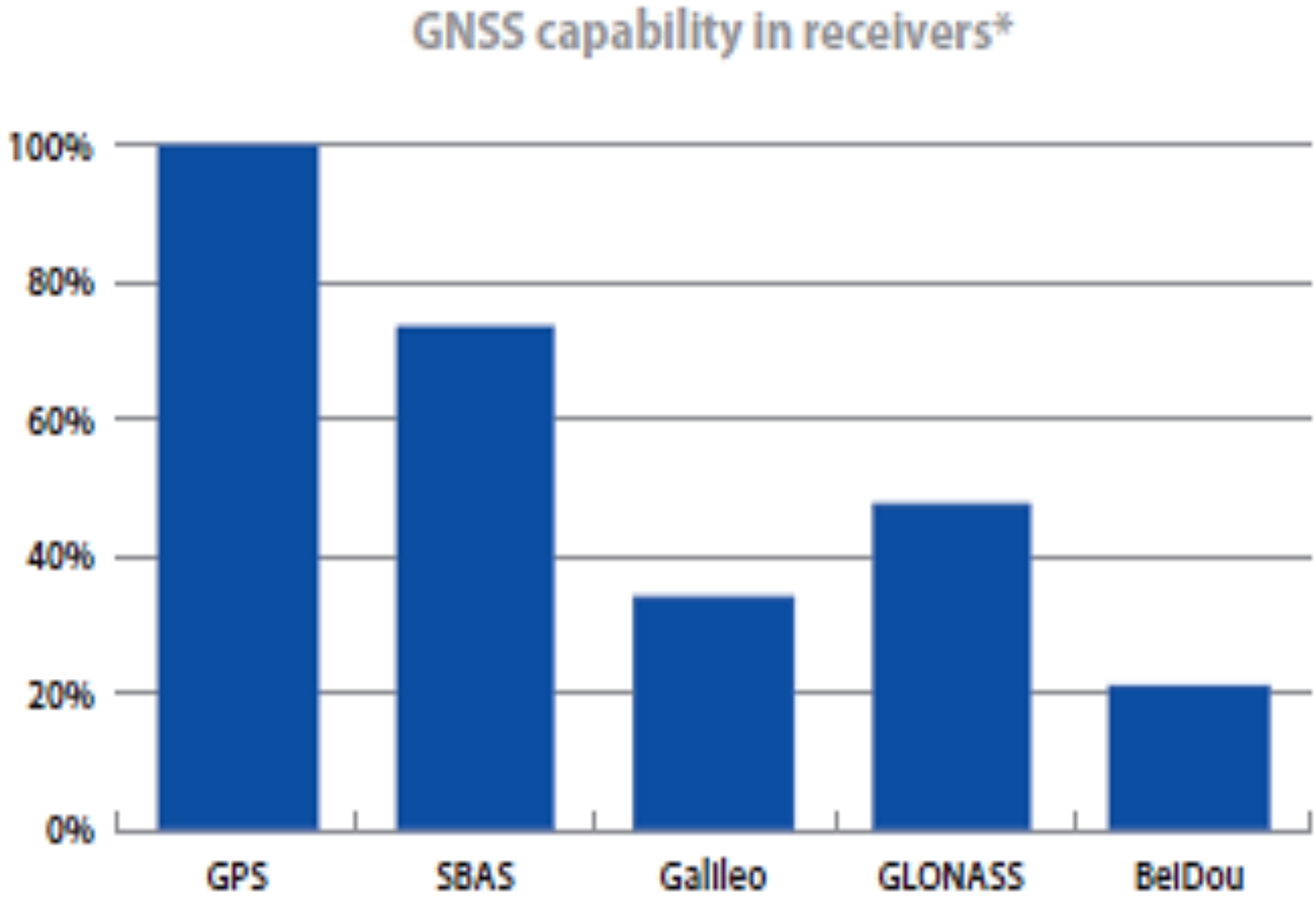
GNSS market continues to grow at a rapid pace



Source: GSA GNSS Market Report

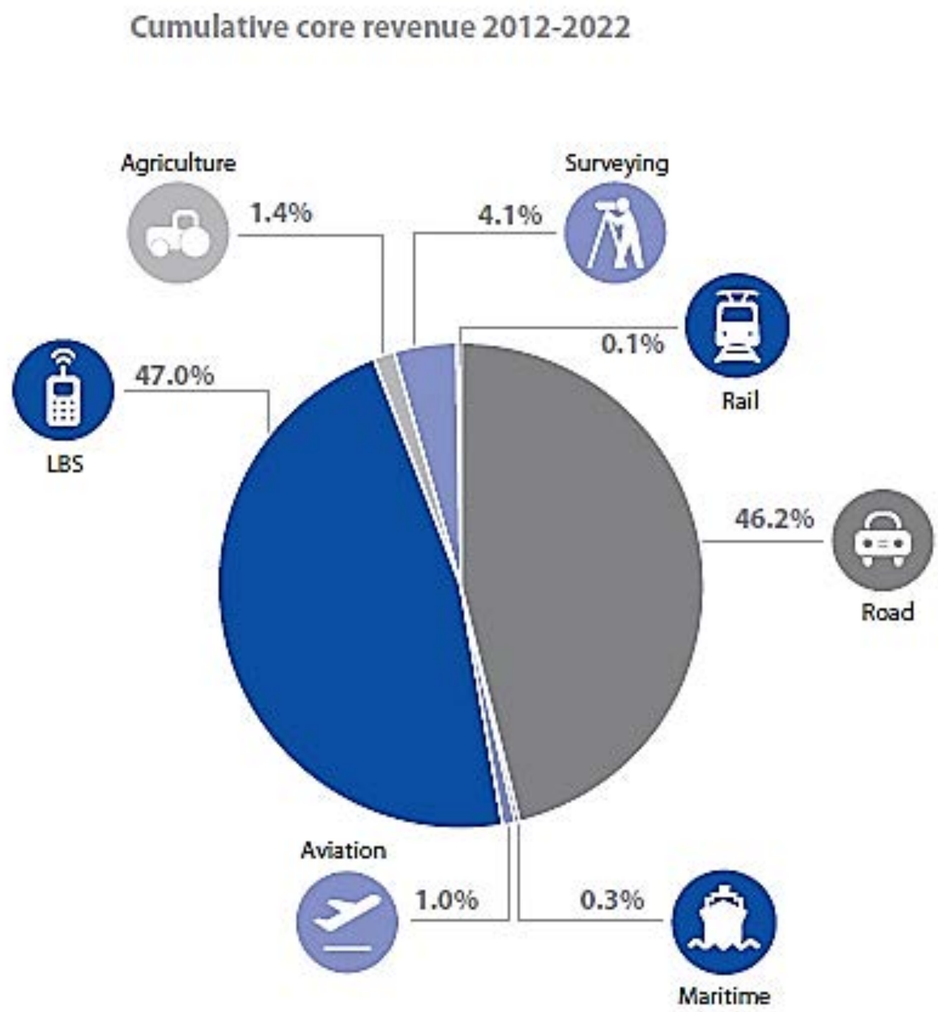
GNSS – Multi Constellation Trends





Source: GSA GNSS Market Report

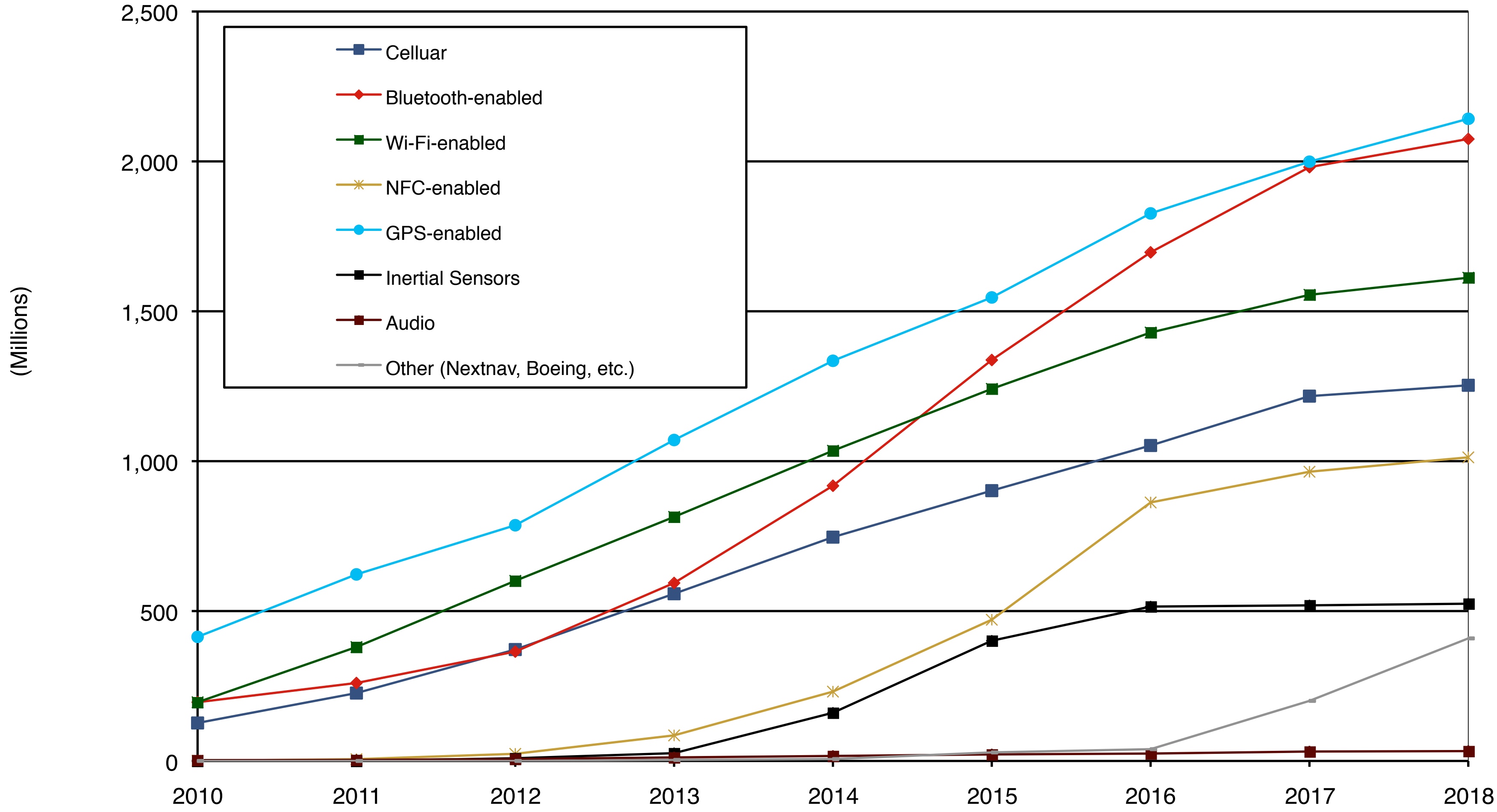
GNSS Market Segment - By Revenue



Source: GSA GNSS Market Report

Alternative Location Technology Shipments

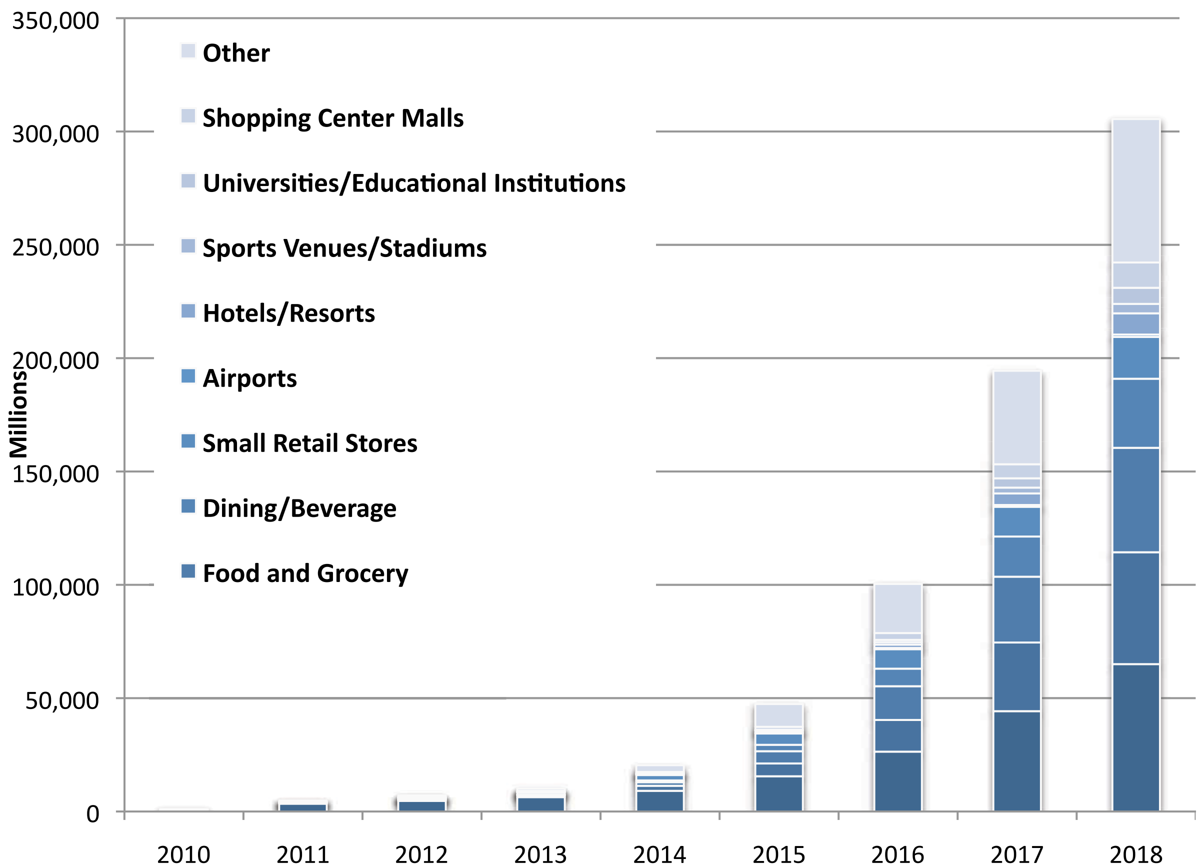
World Market, Forecast: 2010 to 2018



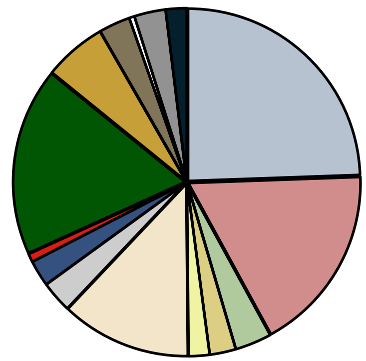
Source: ABI Location Technologies Market Data

Indoor Location Technology Installations, Split by Vertical Market

World Market, Forecast: 2010 to 2018



Highly fragmented supplier base



Source: ABI Location Technologies Market Data

LBS Value Chain

Highly complex ecosystem with each segment looking to differentiate and monetize indoor location

- **Venue Owners**
- **Application Developers**
- **Service and Content Providers**
- **Device Vendors**
- **Operating System providers**
- **Chipset Manufacturers**

Source: GSA GNSS Market Report

Opportunity summary

- The market opportunity for location is clearly huge and still growing
  - It has expanded from GPS to GNSS and now to Location
  - Indoor location is the next big opportunity
    - Not as a standalone opportunity, but rather because it enables "always located" capability
- Always located is a requirement for devices that are always with us and always need context
  - Phones, tablets, wearables and internet of things are good examples of known needs

Major shifts in underlying platforms

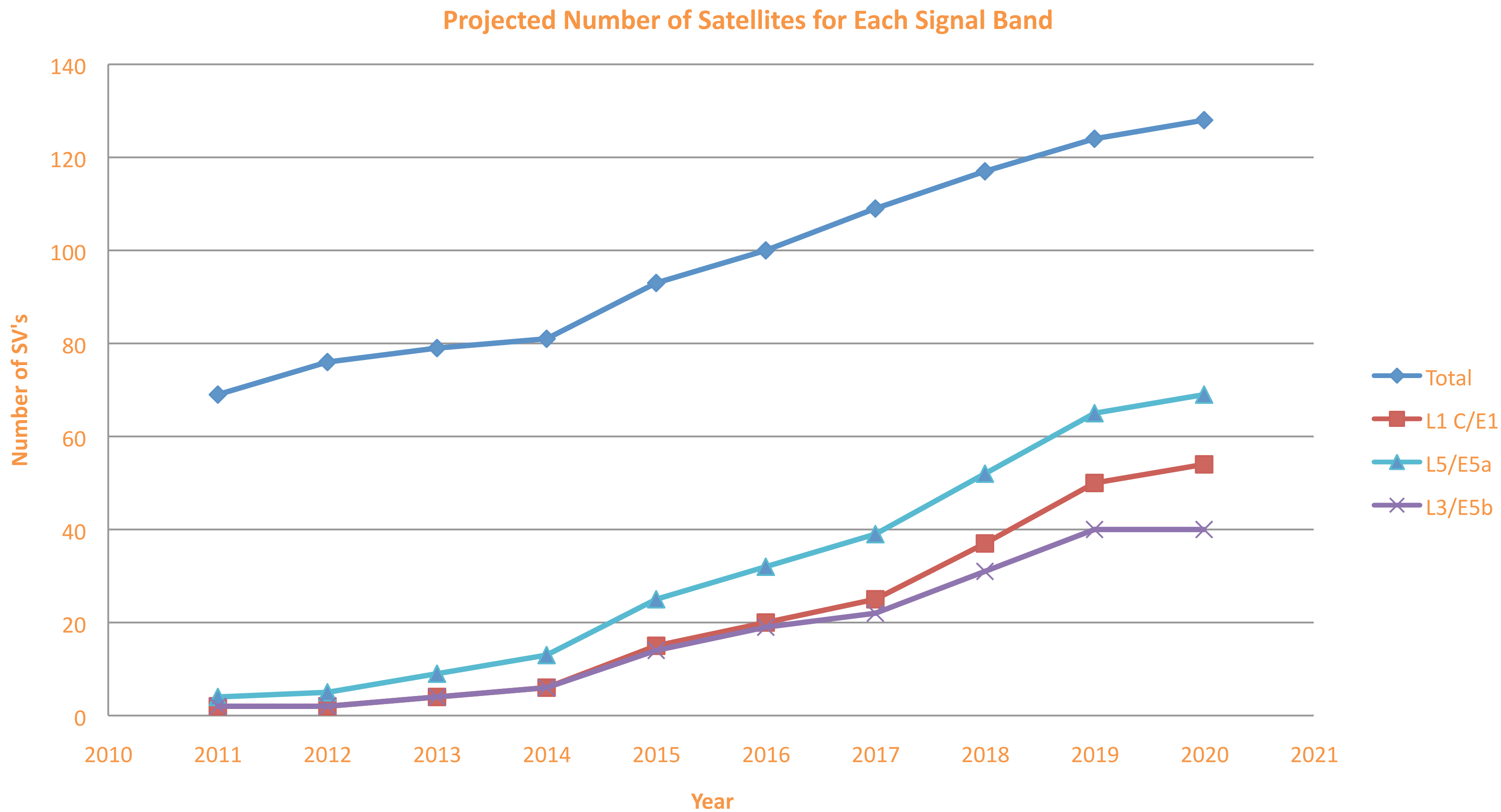
Time	Main Volume Platform	Key Use Case	Featured Specification	Secondary Specification
Early 2000s	PND	Urban Canyon	Sensitivity	TTFF
Mid 2000s	Feature Phone	E911	TTFF	Sensitivity
2010 - today	Smart Phone	LBS	Active Power	Availability (MultiGNSS)
Coming Soon	Wearables/IOT	Continuous Location	Energy/Day	Availability (Hybrid)

Requirements Summary

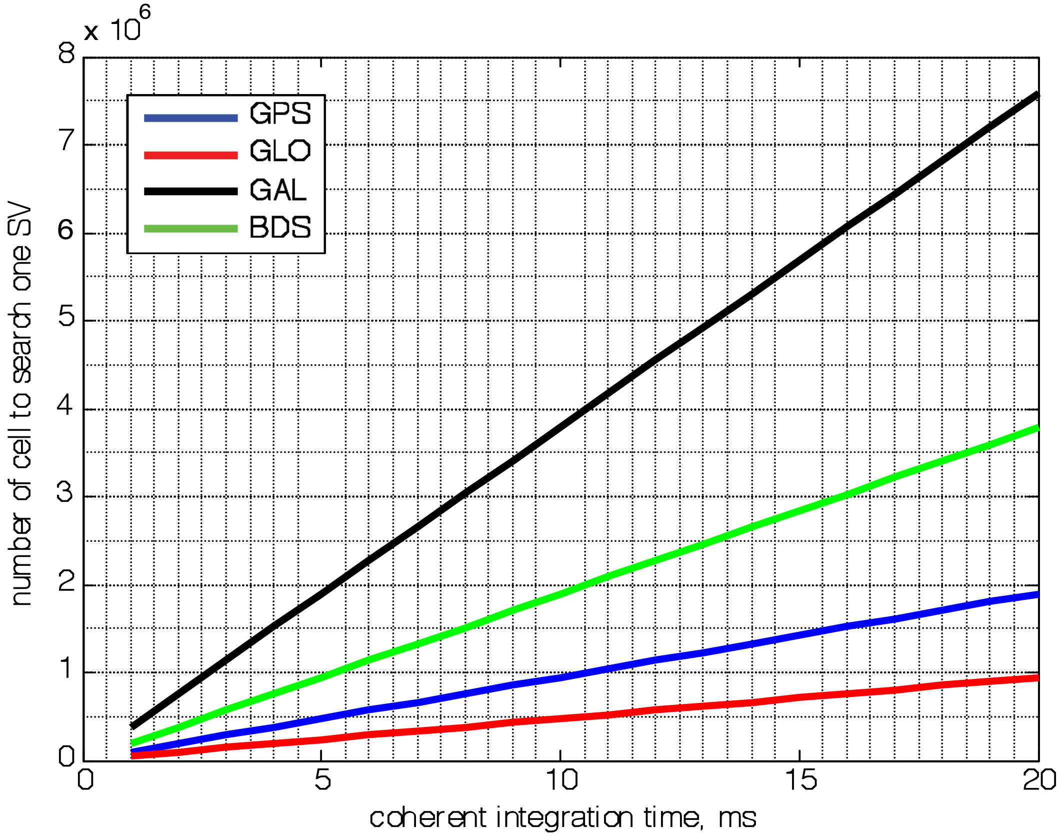
- Always located creates new requirements for devices
  - Availability at 100%
    - Multi-technology fusion since no single technology can achieve this in a reasonable infrastructure cost
  - Power consumption that allows a minimum of 16 hours of usage (full day) between charges
    - Standby power is MORE important than active power
  - Accuracy that can vary to support multiple applications
  - Size constraints driven by wearables

GNSS Architecture Impact

Projected Number of Satellites



Relationship between the Coherent Period & Number of correlators required to search for 1 satellite in each constellation



±1ppm local oscillator frequency uncertainty

±10 kHz Doppler shift range

50% Doppler bin overlap

1/4-chip correlator spacing

Test Scenarios – Cold Start Test

-130dBm Cold Start Test with an initial Frequency uncertainty of ±1ppm

	GPS	GLONASS	Beidou	Galileo
Correlator spacing	¼ chip	¼ chip	¼ chip	¼ chip
Number of chips in PRN code	1023	511	2046	4092
Number of correlator required to search 1 PRN	4092	2044	8184	16368
Code Length	1ms	1ms	1ms	4ms
Number of Doppler Windows (50% overlap)	7	7	7	26
Number of Satellites in Constellation	32	24	37	30
Number of correlators required	916,608	171,696	2,119,656	12,767,040

75x Difference!

Test Scenarios – Hot Start Test

-140dBm Hot Start Test with an initial Frequency uncertainty of ±0.2ppm & a 160ms search time

	GPS	GLONASS	Beidou	Galileo
Correlator spacing	¼ chip	¼ chip	¼ chip	¼ chip
Number of chips in PRN code	1023	511	2046	4092
Number of correlator required to search 1 PRN	4092	2044	8184	16368
Coherent Period	8ms	8ms	1ms	4ms
Number of Incoherent dwells	20	20	160	40
Number of Doppler Windows (50% overlap)	10	10	2	6
Number of Visible Satellites	10	10	10	10
Number of correlators required	409,200	204,400	163,680	982,080

6X

Typical GPS Spec Sheet

General Receiver Characteristics

Channels	50
Frequency	L1 band
Codes	GPS C/A, Galileo BOC, Glonass FDMA1

Time-To-First-Fix

~~Cold Start (unaided)~~	~~27s~~
~~Warm Start (unaided)~~	~~27s~~
Hot Start (unaided)	1s
Aided Starts	1s

Signal Sensitivity

Tracking & Navigation	-162 dBm
Reacquisition	-160dBm
~~Cold Start~~	~~-147dBm~~

Navigation

~~Max update rate~~	~~5 Hz~~
Horizontal accuracy	5m
~~Time sync~~	~~30ns~~
~~Velocity accuracy~~	~~0.1 m/s~~
~~Heading accuracy~~	~~0.5 degrees~~
~~Maximum Dynamics~~	~~4g~~

Power Consumption

Supply	3V
~~Continuous~~	~~18.5mA~~
1Hz Power Save	4mA

Silicon Design Impact

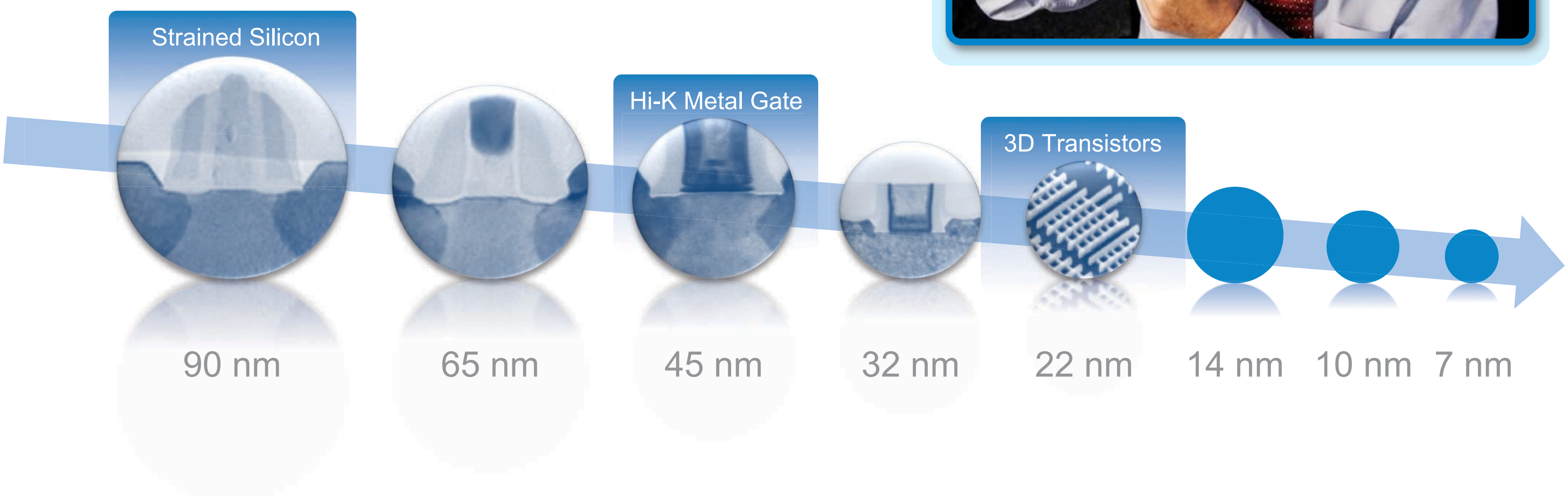
Impacts of new requirements on silicon design

- Standby power reduction impacts
  - SRAM is the leakiest component of typical design
    - Needs to be reduced or ideally eliminated
  - Non-continuous fix methods
    - Ability to quickly save and restore state information
- Hybrid location solutions
  - Support measurements from multiple radios
    - Need to share radios, not duplicate chains
  - Increased integration of of multiple radios on single die
    - Need more interference rejection capability
    - Ability to support concurrent radio operation on single die

Predictable Silicon Track Record

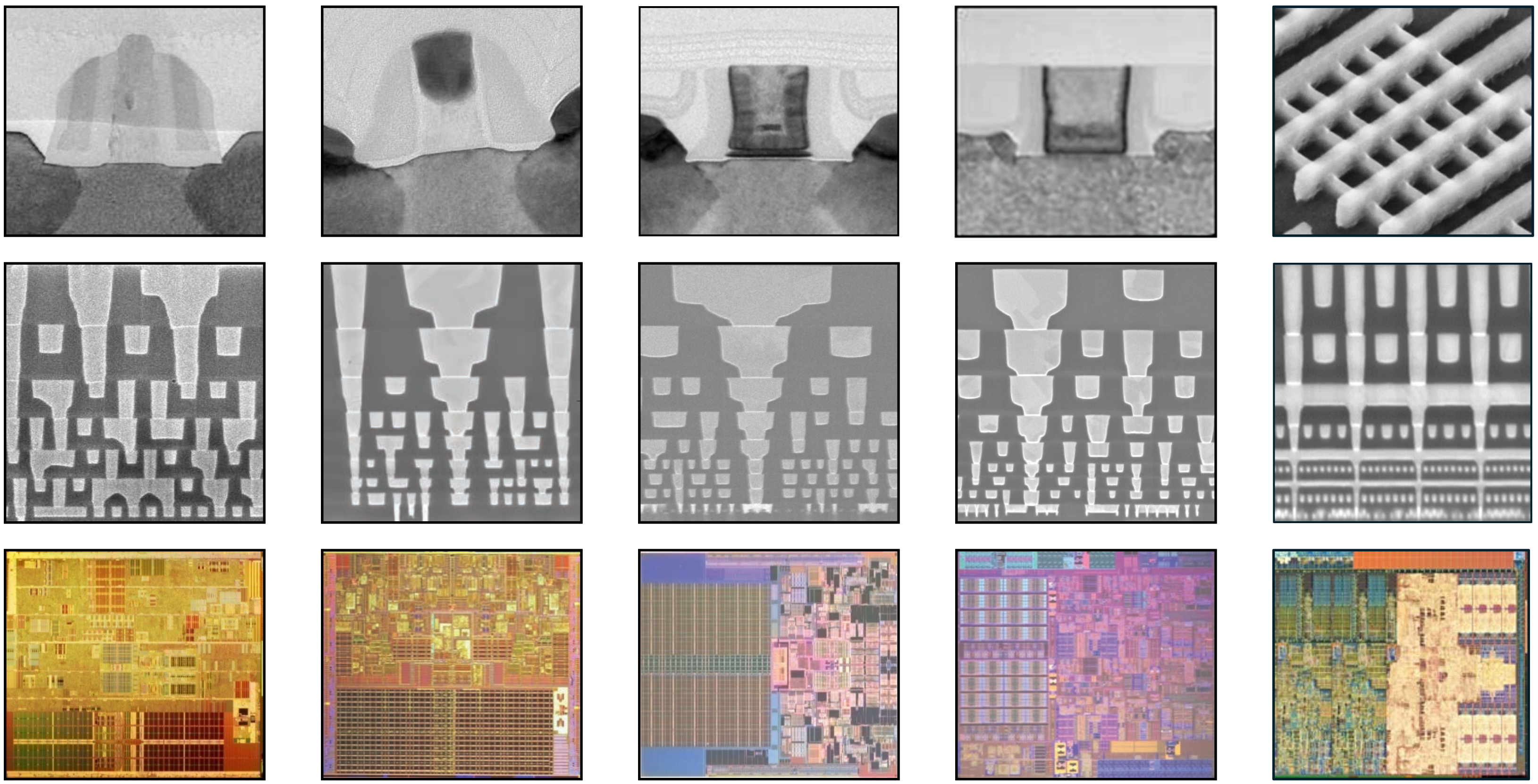
Executing to Moore's Law

Enabling new devices with higher functionality and complexity while controlling power, cost, and size

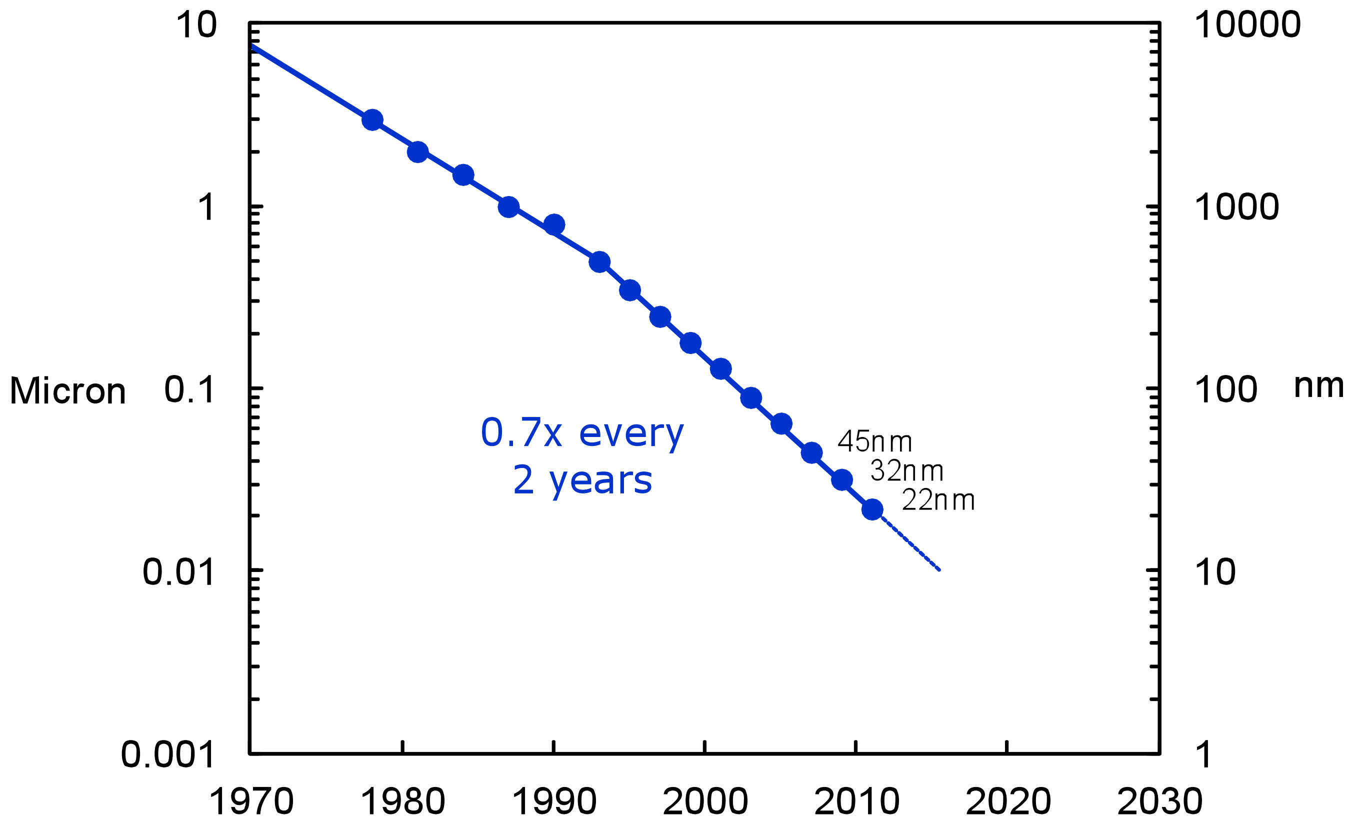


2 Year Technology Cycles

90 nm	65 nm	45 nm	32 nm	22 nm
2003	2005	2007	2009	2011

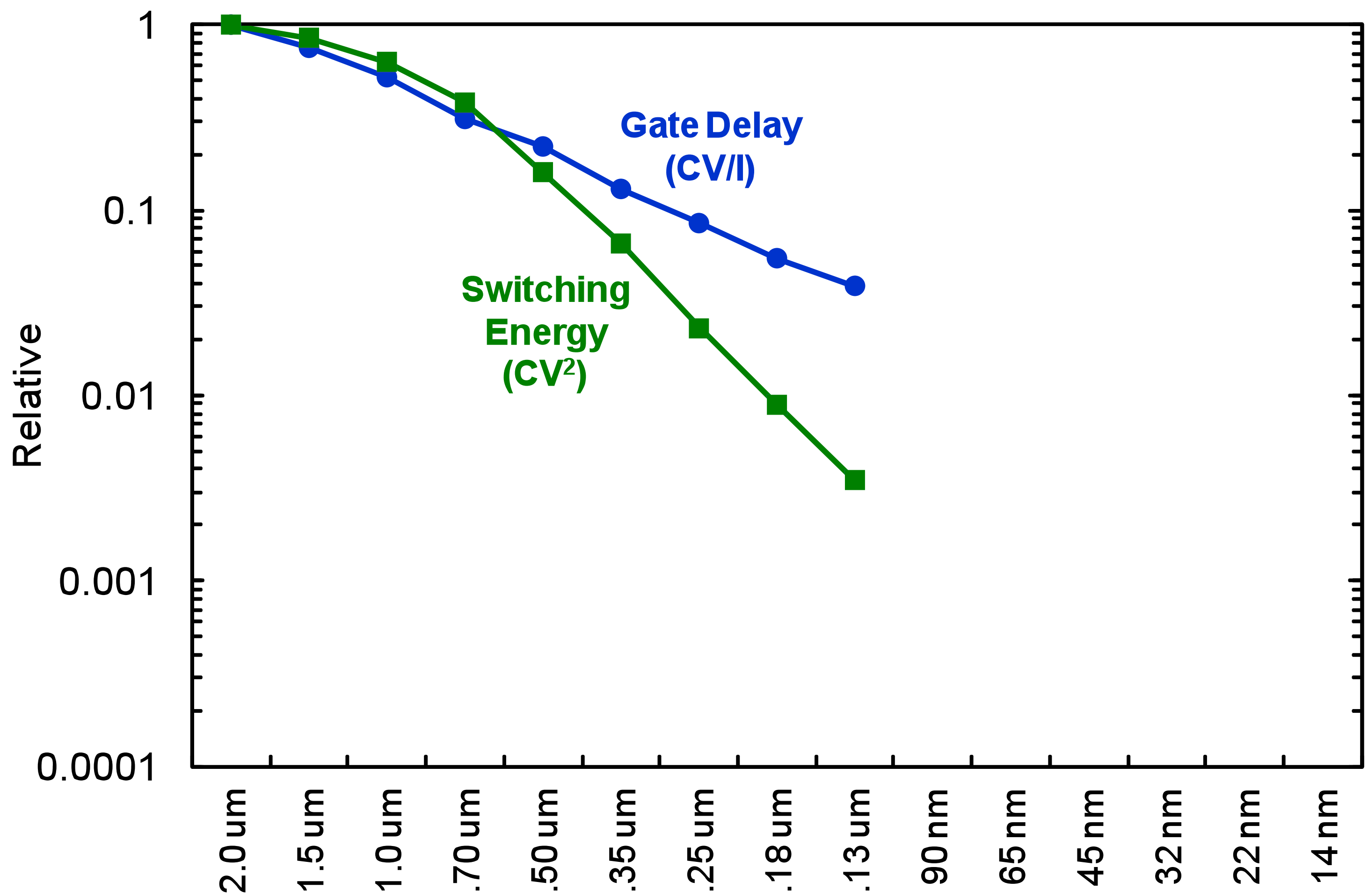


Transistor Scaling improve performance



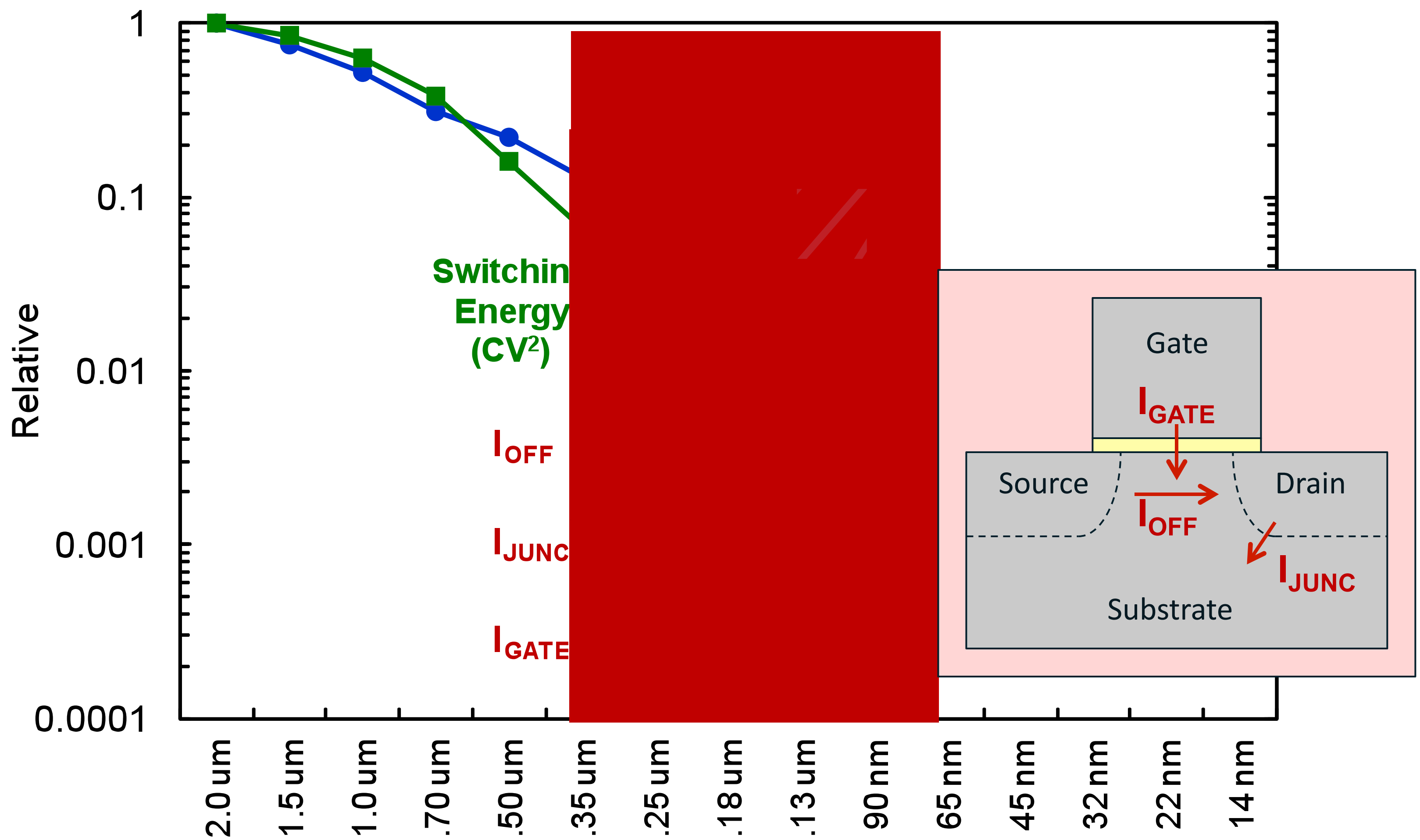
In GNSS, this means more gates and more memory for less cost.
Improves TTFF and sensitivity by allowing more search capability

Scaling also increases speed and reduces power



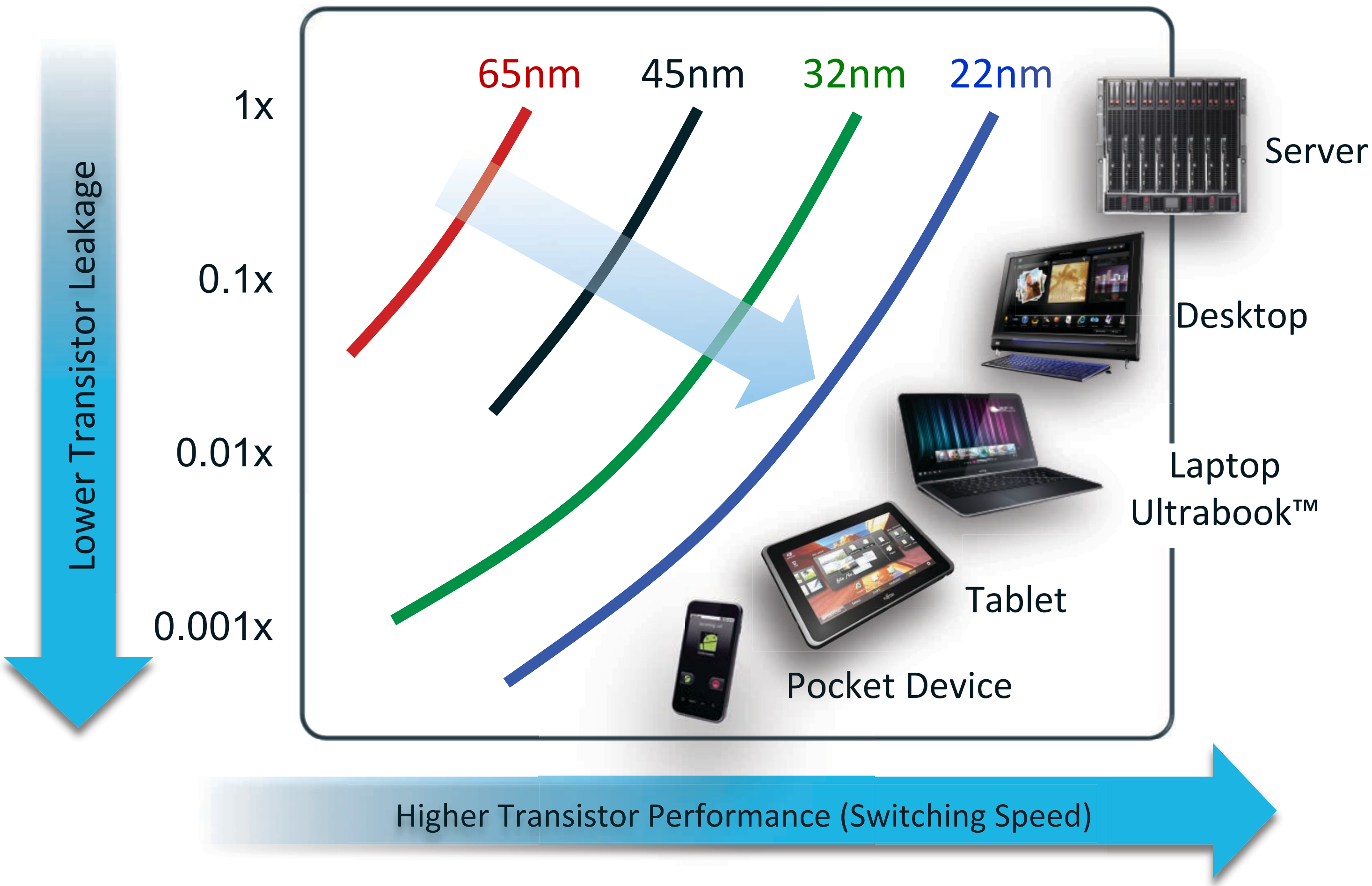
Higher clock speed provide better search and more complex navigation algorithms
Lower energy improves power consumption in full power tracking modes

But at the expense of increased leakage



This hurts standby power and the ability to save state for lower fix rates and fast restarts

Transistor Performance vs. Leakage



Wider range of transistors to support a wider range of products

Design Challenges for GNSS

- Take advantage of benefits of smaller geometries
  - Higher clock speeds, more memory, lower active power, smaller size
- While greatly reducing standby power from leakage
  - New methodologies at chip and system design level
- Integrate multiple radios on single die to reduce cost and size
  - Without creating interference to a very sensitive GNSS radio
- Integrate multiple radio sources into a single location solution
  - Bring together a disparate value chain

Intel's plan

- Bring our advanced silicon process technology to location
  - Provide GNSS and Location silicon with best in class performance
- Bring our platform level integration capability to merge multiple location technologies
  - Intel CPU cores provide ideal platform to integrate hardware and software for GNSS, BT, WiFi and cellular
- Bring this capability to multiple products from tablets and phone to wearables
- Ubiquitous location capability will improve the experience of every mobile product

Questions?

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PEG-Wireless Connectivity Solutions

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