Dejia/DJ Kong
Advantest

IoT/IoE/M2M/IoTS

Internet of Things (IoT)
Internet of Everything (IoE)
Machine to Machine (M2M)
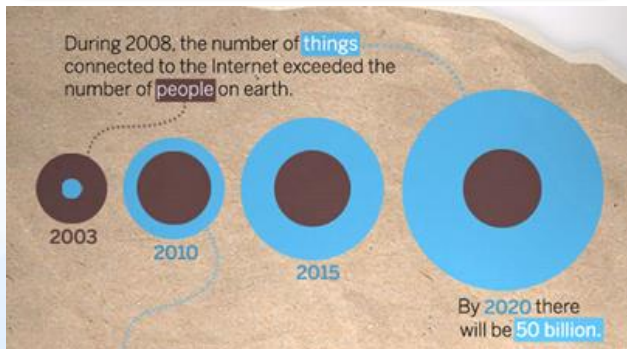**Internet of Things & Services (IoTS)**
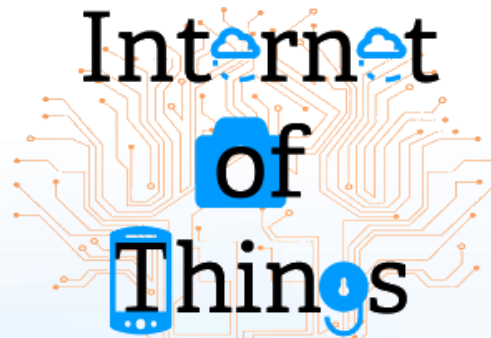
IoT Concept

- A new wide range of applications enabled by the combination of :
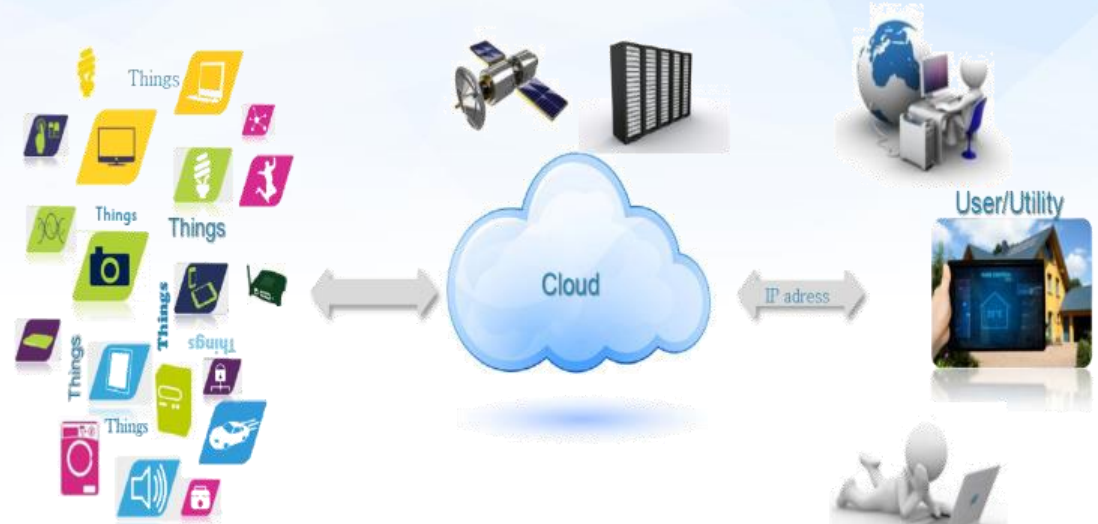 - Sensors / Actuators
  - Computing (+ Software)
  - Connectivity (Wireless, Wired)

- Largest Growth Market in the coming years
  - 50B Installed units in 2020

During 2008, the number of things connected to the Internet exceeded the number of people on earth.

2003   2010   2015   By 2020 there will be 50 billion.

Cloud   IP adress   User/Utility

Connectivity	Sensing	Processing
Wireless/Wired Narrow/Broad	Motion Environment	Ultra Low Power High Performance
RFSubGHz –WiFi-BT BTLE–PLC–RFID-NFC	MEMS - Accel. – Gyro Pressure – Humidity Temp – Microphone	Cortex M0+/M3/M4
Powering	Security	...others
Efficiency Harvesting	Identification Authentication	Certification Cost Effective
PV & TEG harvesting Battery Charger, Regulator	ISO 14443 ISO 15963 CRYPTO	ASIC, RTC, OPAmp. Protection, Balun, etc...

Smart City
Smart Grid

Smart Car
Tracking System

Smart Home
Smart Me

Fitness & Wellness
e-Healthcare

Smart Agriculture
Smart Farms

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Building Blocks→ Sensors / Actuators

- Established and emerging technologies:
  - Motion Mems:
    » Accelerometers, Gyroscopes, Compasses
  - Environmental:
    » Barometric Pressure, Temperature, Humidity, UV, CO, CO2, Air Quality, Gas Flow sensing
  - Health:
    » Blood Pressure, Glucose Monitor, Heart Rate, ECG Monitor
  - Optical Sensors:
    » Proximity, Ambient Light, RGB Color Image Sensors
  - Touch Sensors:
    » Multi-Touch, Touch less Hover, Pressure Touch
  - RF Sensors:
    » GPS / A-GPS, Wi-Fi , BT Low Energy, NFC
  - Other Sensors:
    » MEMS Microphones, Biometric Sensors, Fingerprint, Bio Sensors
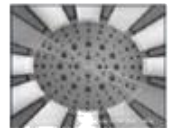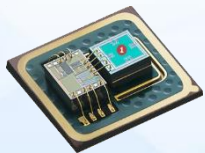
Accelerometers
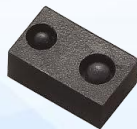
Fingerprint

Optical MEMS

Others

RF MEMS

Gyroscopes

Magnetometers (Digital Compass)

Microfluidics

Pressure Sensor

Proximity
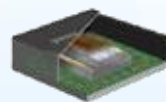
Inertial Combos

Si Microphones

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Building Blocks➔ Computing

- Many requirements depending on target application
  - Low Power is the Key
  - Medium Flash size 32KB-256KB

- ARM Microcontroller is mostly used but not only
  - STM ➔ STM32F2 Cortex™ M0 , STM32LO Cortex™ M4
  - ADI ➔ ADUCRF101 Cortex™ M3, ADUC702632 ® MCU
  - TI ➔ 66K2Hx I multicore DSP+ Cortex™-A15
  - QUALCOMM➔ SnapDragon™

Source: Texas Instruments

STM32L0:
MCU Cortex M0+

STM32F2
Cortex M4 - High Performance MCU

Qualcomm snapdragon

Source: Arm

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Building Blocks→ Connectivity

- Many different solutions
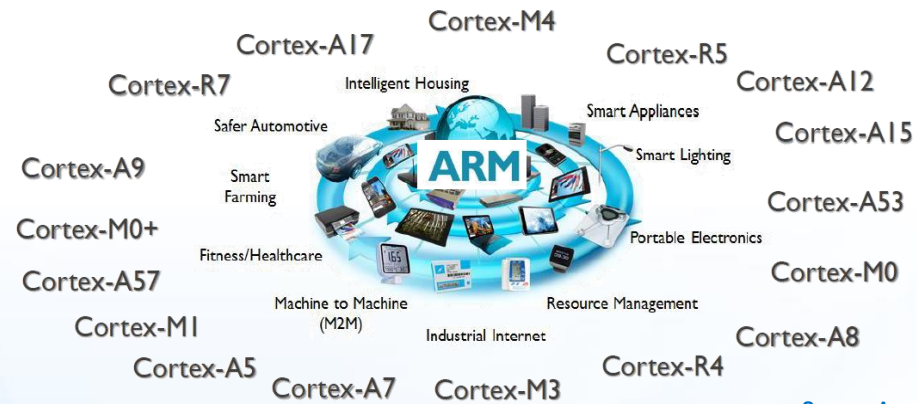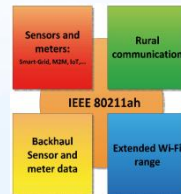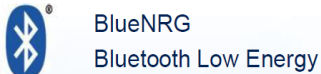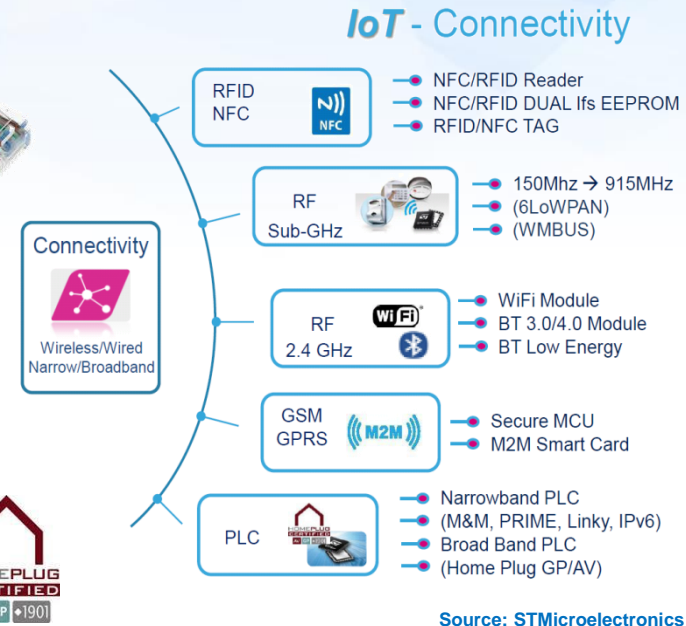 - Low Power is the Key (Low Data Rate)
  - Medium Range 90% of the Market < 100m

- Standard and proprietary Wireless protocols
  - 2.4 Gz : BluethootNRG, WiFi
  - Sub Ghz : NFC, RFID, Z-Wave, Zigbee, Spirit-1

- Standard and proprietary Wired protocols
  - Ethernet, Mbus
  - LonWorks, KNX

IoT - Connectivity

RFID NFC	NFC/RFID Reader / NFC/RFID DUAL Ifs EEPROM / RFID/NFC TAG
RF Sub-GHz	150Mhz → 915MHz / (6LoWPAN) / (WMBUS)
RF 2.4 GHz	WiFi Module / BT 3.0/4.0 Module / BT Low Energy
GSM GPRS	Secure MCU / M2M Smart Card
PLC	Narrowband PLC (M&M, PRIME, Linky, IPv6) / Broad Band PLC (Home Plug GP/AV)

Connectivity
Wireless/Wired
Narrow/Broadband

HOMEPLUG CERTIFIED
AV GP ◆1901

Source: STMicroelectronics

ZigBee	• Low power mesh network • Smart metering & lighting • Moving into home automation	**Sub-1GHz**	• Low power & long range • Proprietary & open protocols • Metering, security systems
Wi-Fi	• Fast – 10Mbps++ • Direct Internet connection • Home & enterprise apps	**Bluetooth** SMART	• Lowest power • Connect to tablet/phone • Moving to industrial, automotive
PRIME ALLIANCE **G3-PLC** Alliance	• Data over power lines (OFDM) • Developed for smart grid • Lighting, solar, appliances	**EtherCAT.**	• Fast, low latency Ethernet • Real-time industrial control • Information technology

NFC   RFid   Bluetooth   IEEE P1901.2   ANT+   RF4CE
GPS   2.4GHz   LoWPAN   EtherNet/IP   PurePath Wireless Audio   IEEE 802.15.4

Source: Texas Instruments

LonWorks

BlueNRG
Bluetooth Low Energy

EIB
KNX

Z-wave

IEEE 802.11

IEEE 802.15

ISA 100Wireless

WirelessHART

Sensors and meters: Smart-Grid, M2M, IoT...
Rural communication
IEEE 80211ah
Backhaul Sensor and meter data
Extended Wi-Fi range

RF Connectivity Pro & cons

- Power/Range/Cost are the 3 axis
- Security adding additional constraints
- Application success will drive Standards

RF STANDARD	NFC	RFID	Bluetooth	Bluetooth 4.0 Low Energy	ANT+	Proprietery Sub-GHz & 2.4 GHz	WiFi	ZigBee	Z-wave	EI3 KNX	WirelessHART	6LoWPAN IPv6-based Low-power Wireless Personal Area Networks	Wimax	3G
Network	PAN	PAN	PAN	PAN	PAN	LAN	LAN	LAN	LAN	LAN	LAN	LAN	MAN	WAN
Topology	P2P	P2P	Star	Star	P2P, Star, Tree Mesh	Star, Mesh	Star	Mesh, Star, Tree	Mesh	Mesh, Star, Tree	Mesh, Star	Mesh, Star	Mesh	Mesh
Power	Very Low	Very Low	Low	Very Low	Very Low	Very Low to Low	Low-High	Very Low	Very Low	Very Low	Very Low	Very Low	High	High
Speed	400 Kbs	400 Kbs	700 kbs	1 Mbs	1 Mbs	250 kbs	<100 Mbs	250 kbs	40 Kbs	1.2 Kbps	250 kbs	250 Kbs	<100 Mbs	<7.2 Mbs
Range	<10 cm	<3 m	<30 m	5-10 m	1-30 m	10-70 m	4-20 m	10-300 m	30 m	800 m	200	800 m SubGHz	50 km	Cellular network
Applications	Pay, get access, share, initiate service, easy setup	Item tracking	Network for data exchange, headset	Health and fitness	Sports and fitness	Point to point connectivity	Internet, multimedia	Sensor networks, building and industrial automation	Residential lighting and automation	Building automation	Industrial sensing networks	Senor networks, building and industrial automation	Metro area broadband Internet connectivity	Cellular phones and telemetry
Cost Adder	Low	Low	Low	Low	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	High	High

Different Integration opportunities

- Module (System on board)
  - Short time to market
  - Low risks
  - High costs

- SIP (System in Package)
  - Enabling HVM
  - Medium risks
  - Medium costs

- SOC (System on Chip)
  - Enabling Profit
  - Highest risks
  - Lowest costs
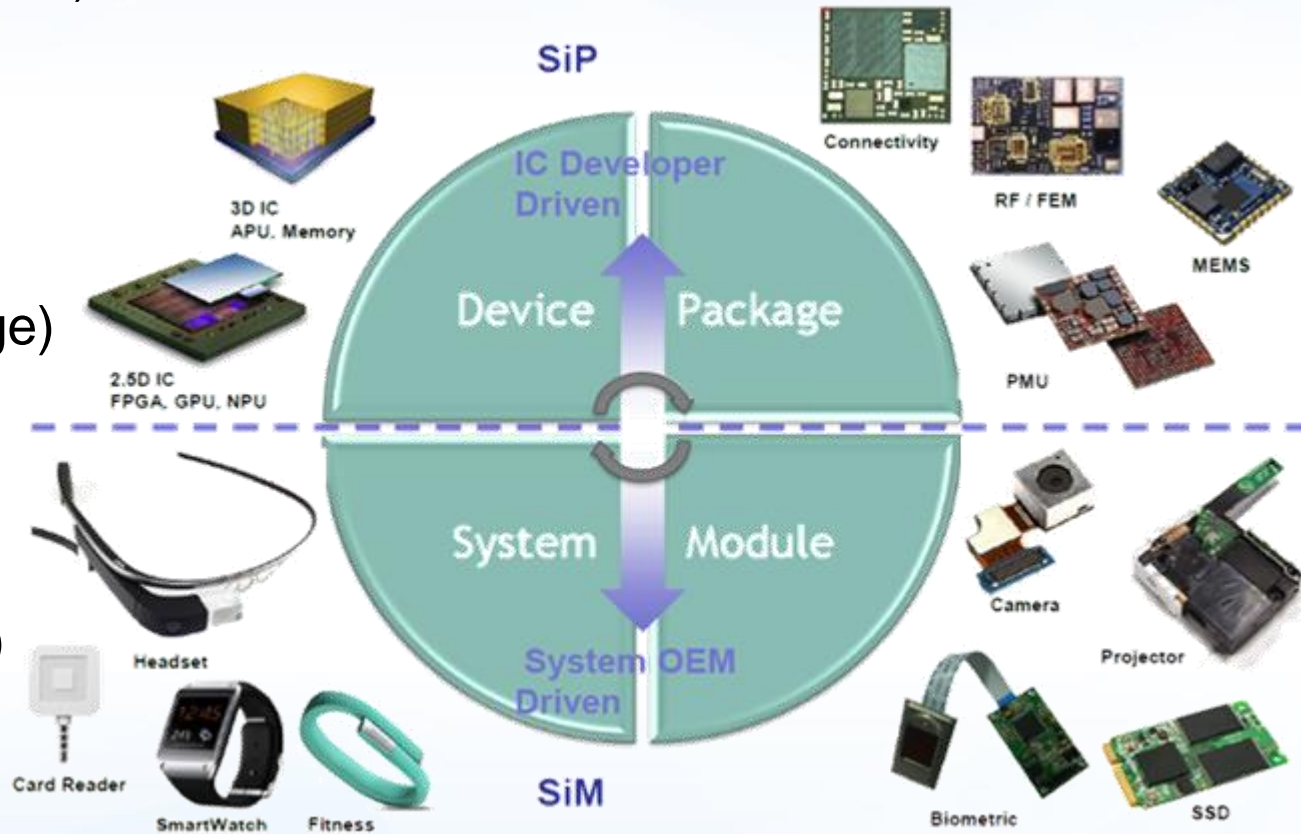
Source: IC ASE Group

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IoT
Expected Growth
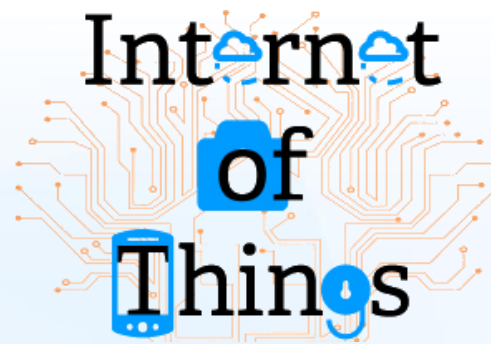
Roadmap for 50 Billion connected devices

THE INTERNET OF THINGS

AN EXPLOSION OF CONNECTED POSSIBILITY
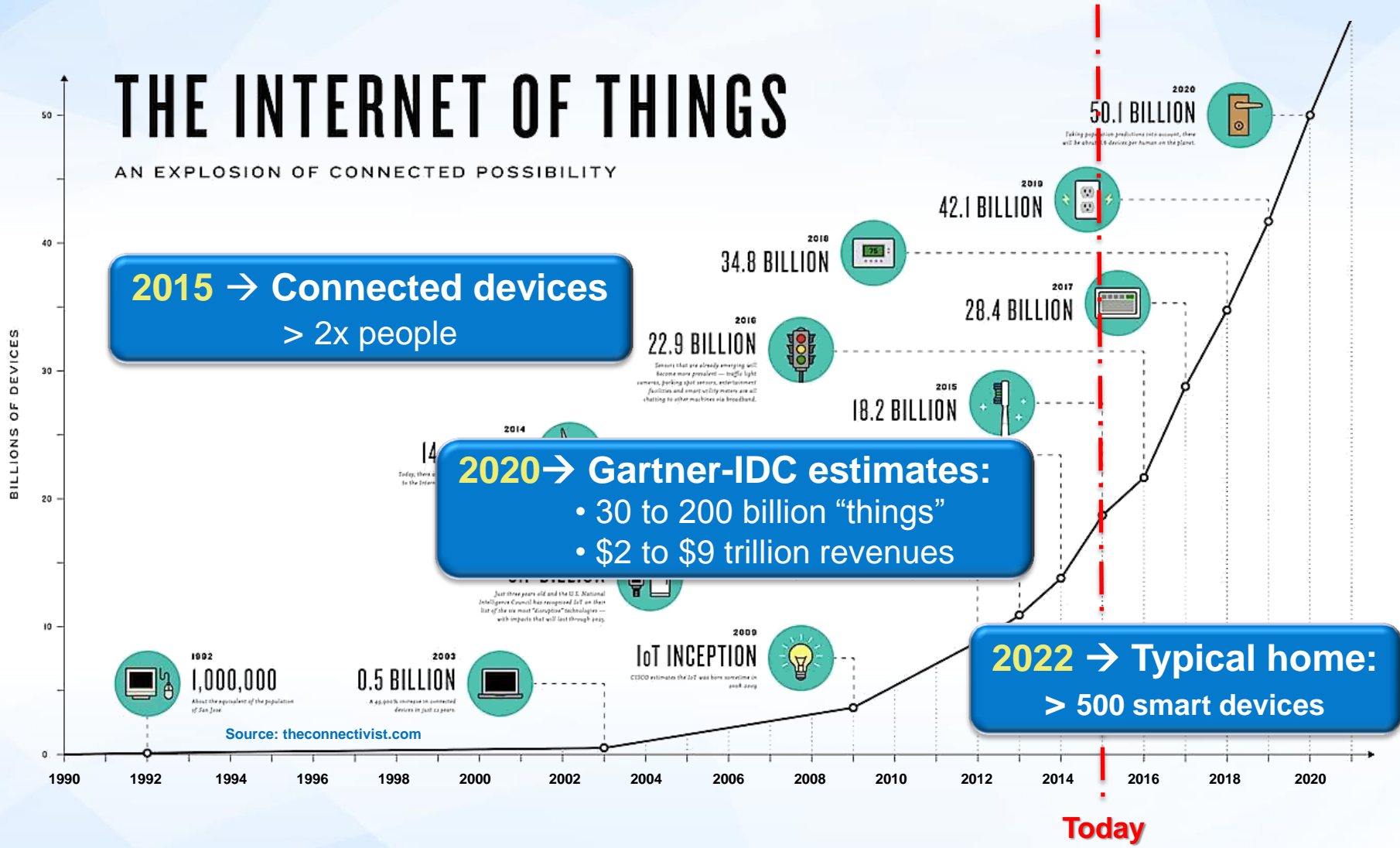
2015 → Connected devices
> 2x people

2020 → Gartner-IDC estimates:
- 30 to 200 billion "things"
- $2 to $9 trillion revenues

2022 → Typical home:
> 500 smart devices

2020 50.1 BILLION
Taking population predictions into account, there will be about 6.6 devices per human on the planet.

2019 42.1 BILLION

2018 34.8 BILLION

2017 28.4 BILLION

2016 22.9 BILLION
Sensors that are already emerging will become more prevalent — traffic light cameras, parking spot sensors, entertainment facilities and smart utility meters are all chatting to other machines via broadband.

2015 18.2 BILLION

2014 14 BILLION
Today, there are more devices tied to the Internet...

Just three years old and the U.S. National Intelligence Council has recognized IoT on their list of the six most "disruptive" technologies — with impacts that will last through 2025.

2009 IoT INCEPTION
CISCO estimates the IoT was born sometime in 2008-2009.

1992 1,000,000
About the equivalent of the population of San Jose.

2003 0.5 BILLION
A 49,900% increase in connected devices in just 11 years.

Source: theconnectivist.com

BILLIONS OF DEVICES

Today

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IoT Expected Growth

Market Value Repartition in IoT Structure ($M)

Hardware (incl. Sensors)
→ Will top at $70B in 2018

Then will Lower
→ because of price pressure!

$400B

Source: Yole

Today

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	CAGR
Hardware	9,458	17,895	34,426	58,295	69,995	67,200	54,555	54,785	47,005	43,172	46,338	17%
Cloud	431	970	2,113	4,097	5,867	10,060	14,895	26,984	36,003	46,931	58,851	63%
Data	2,156	4,848	10,631	21,004	31,338	56,914	82,743	144,400	187,763	240,330	296,149	64%
Total	12,045	23,713	47,170	83,396	107,200	134,174	152,193	226,169	270,770	330,433	401,337	42%

An explosion of Market Players

Smartphone/Tablet Market Wave
- Few application Types
- 5 billions Devices
- Few Players to covers 80% of Revenues

IoT Market Wave
- A wide variety of applications
- 50 billions Devices
- Top Players will address less than 40%

10 x Volumes
100 x Applications
1000 x Players

- 100 x applications to drive 10x device volumes:
  - Few High Volume Runners
  - Many Medium Volume Runners

- Testing Flexibility to be a key requirement to support applications variety
  - Same Test Cell to support many type of devices

- Hundreds of Tier-2 players forced to implement Fabless model
  - Cannot invest in Test equipment to Match ASP
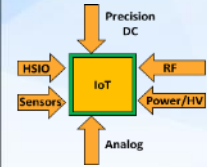 - A step of flexibility increase required at OSAT

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IoT
Test Challenges
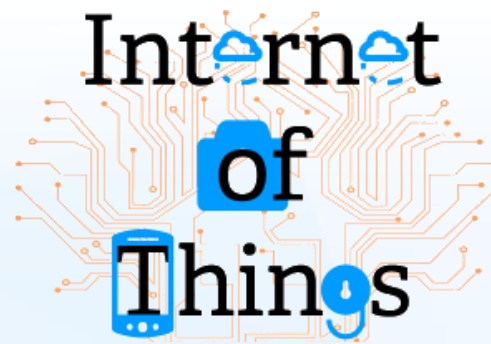
IoT Test Challenges

Integration creates new device class
- Compute/Security, Communication,
  Smart Power, Sensors & Actuators

Low power devices
- Smaller voltage swings
- Low leakage

Cost pressure
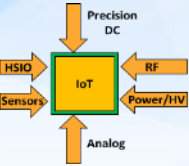- High volume, falling ASP

Unpredictability of emerging market
- Low volume/High mix (High runners?)
- In-house vs Outsource

Technical & economic trends are breaking installed tester base

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IoT Test System Requirements

Integration creates new device class → ATE system covering all domains
- Compute/Security, Communication, (Dig/HS/DC/MX/RF/Memory)
  Smart Power, Sensors & Actuators → Universal Pins

Low power devices → DC accuracy
- Smaller voltage swings
- Low leakage

Cost pressure → High throughput (test-time & MSE)
- High volume, falling ASP → COT optimized test solutions

Unpredictability of emerging market → Fast Time to Quality
- Low volume/High mix (High runners?) → Expandability of ATE system
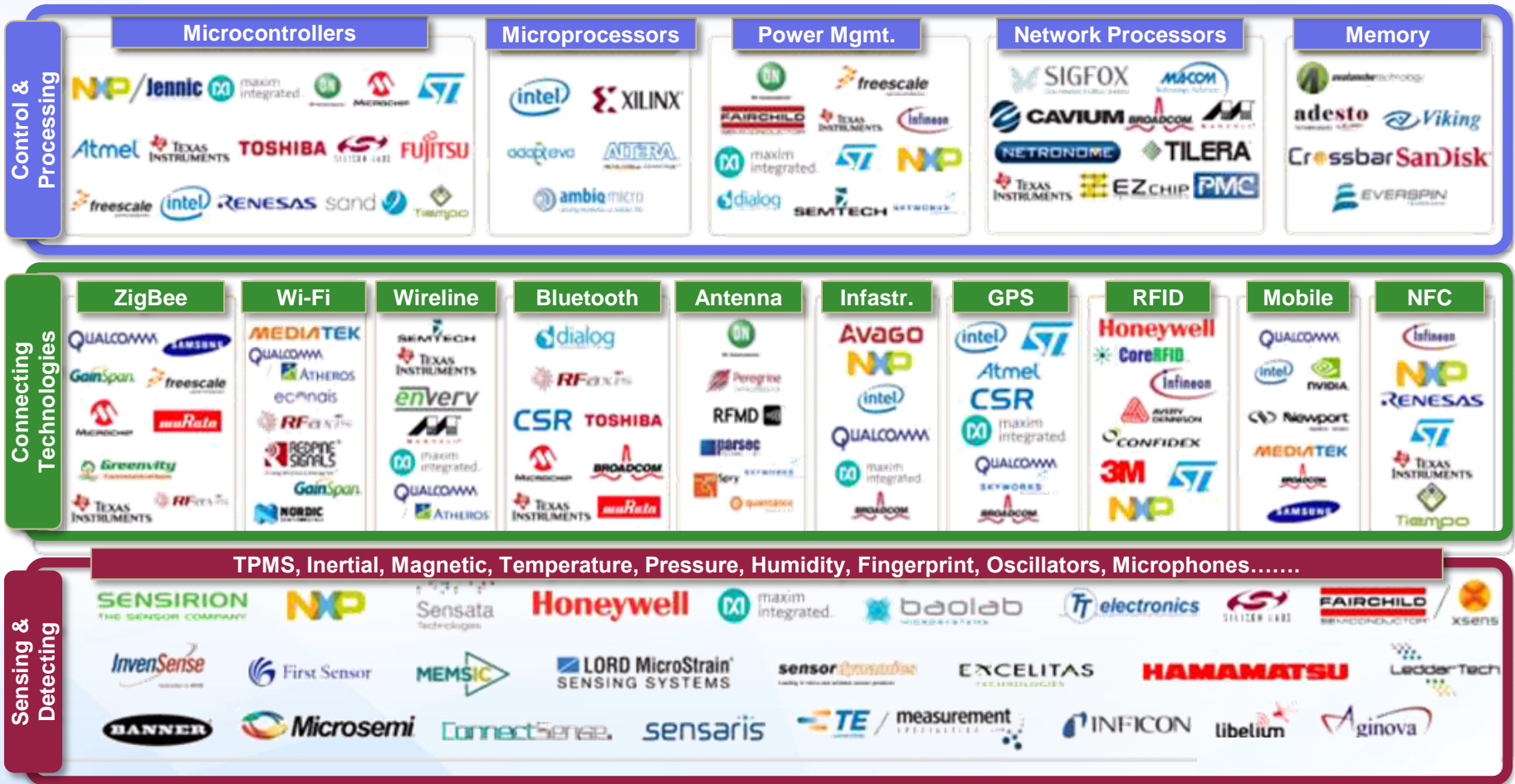- In-house vs Outsource → Availability at OSATs

Technical & economic trends are breaking installed tester base
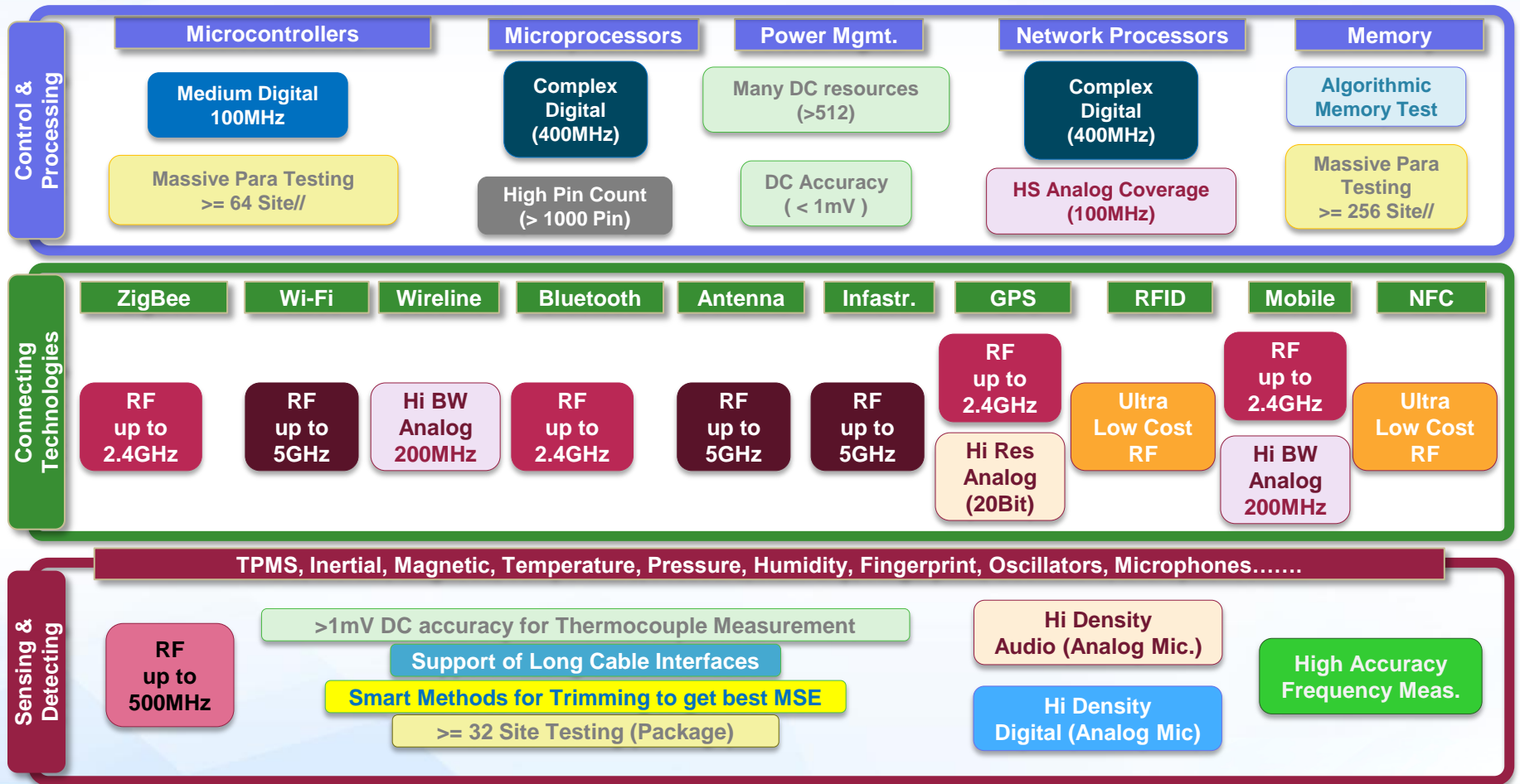
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IoT Market Map

- Processing & Control still will dominate IOT Scenario
- Connecting Technologies to play significant role
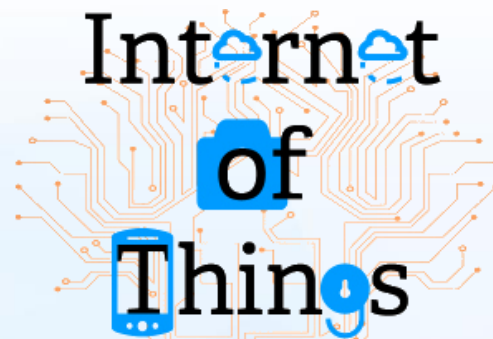- Sensor & Actuators will follow

IoT Market needs

- Best Flexibility
- High Parallelism and High Multi-Site Efficiency (MSE)
- High Accuracy

Control & Processing

Microcontrollers	Microprocessors	Power Mgmt.	Network Processors	Memory
Medium Digital 100MHz	Complex Digital (400MHz)	Many DC resources (>512)	Complex Digital (400MHz)	Algorithmic Memory Test
Massive Para Testing >= 64 Site//	High Pin Count (> 1000 Pin)	DC Accuracy (< 1mV)	HS Analog Coverage (100MHz)	Massive Para Testing >= 256 Site//

Connecting Technologies

ZigBee	Wi-Fi	Wireline	Bluetooth	Antenna	Infastr.	GPS	RFID	Mobile	NFC
RF up to 2.4GHz	RF up to 5GHz	Hi BW Analog 200MHz	RF up to 2.4GHz	RF up to 5GHz	RF up to 5GHz	RF up to 2.4GHz / Hi Res Analog (20Bit)	Ultra Low Cost RF	RF up to 2.4GHz / Hi BW Analog 200MHz	Ultra Low Cost RF

Sensing & Detecting

TPMS, Inertial, Magnetic, Temperature, Pressure, Humidity, Fingerprint, Oscillators, Microphones.......

RF up to 500MHz

>1mV DC accuracy for Thermocouple Measurement

Support of Long Cable Interfaces

Smart Methods for Trimming to get best MSE

>= 32 Site Testing (Package)

Hi Density Audio (Analog Mic.)

Hi Density Digital (Analog Mic)

High Accuracy Frequency Meas.

IOT
Tester Architecture
Requirements

Universal Pin Concept for IoT

Digital
- Excellent signal fidelity (from kHz to 1.6Gbps)
- Voltage range - 2.0 .. 6.5 V
- SCAN: narrow, wide and SerDes
- All protocols (I2C, SPI, DSI3, SPI5, …)
- OTP / eFlash programming / testing
- Driving large capacitance loads

RF
- RF Spectrum Analyzer up to 800MHz

DC / VI
- Sequencer/pattern controlled
- Precise voltage/current measurements (1mV, 10nA)
- Device trimming/calibration in parallel

DPS
- PPMU as low current power supply
- Up to 40mA (60mA /16 pins per module),slew control
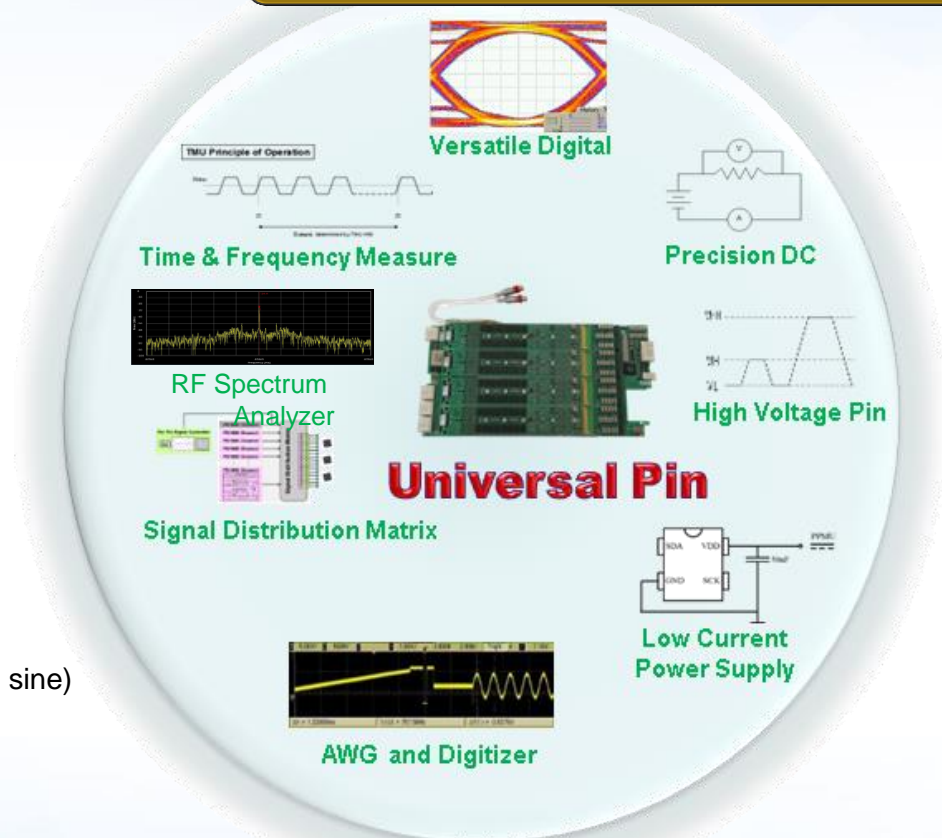- Idd (quiescent (10nA), operating, standby)

Analog
- AWG per pin: for static & dynamic test (>86dB @ 20KHz sine)
- Digitizer per pin: 54 Ksps static, 250 Ksps dynamic

Frequency & Time Measurement Unit
- Fast and accurate time measurements
  (frequency, jitter) (50Msps, 35ps accuracy)

128 … 1024 "Universal Pins" in V93000 A-Class Test Head!

Versatile Digital

Time & Frequency Measure

Precision DC

RF Spectrum Analyzer

High Voltage Pin

Universal Pin

Signal Distribution Matrix

Low Current Power Supply

AWG and Digitizer

Tester resources for all device functions behind each pin

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Higher Performance Tester Requirements for IoT

Higher performance Digital IO
- Higher speed Serial and/or Parallel interfaces (eg SERDES, Memory Interfaces, …)

Higher performance DPS / DC / VI
- Higher Power voltage/current measurements

Higher performance Analog
- Higher performance AWG and Digitizer for static & dynamic test

Higher performance RF
- RF Source and Measure

Optional

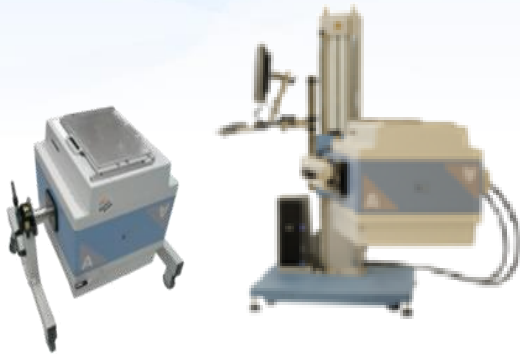|	
DPS128 128ch 15V	**PS9G** 64ch >8G
VI32 32ch 25V	**Port Scale RF** 6Ghz
AV8+ 4 AWG, 4 DIG Hi-Res/Hi-Freq.	**PVI8** 8ch Power

Higher Performance Tester resources available as options if needed

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Scalable Test Platform for IOT
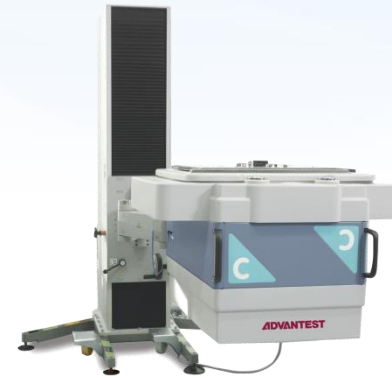
- Smaller, low pin-count configurations
  - Lowest capex
  - Smaller devices
  - Engineering, "Lower" Volumes

- Larger, high pin-count configurations
  - Larger devices
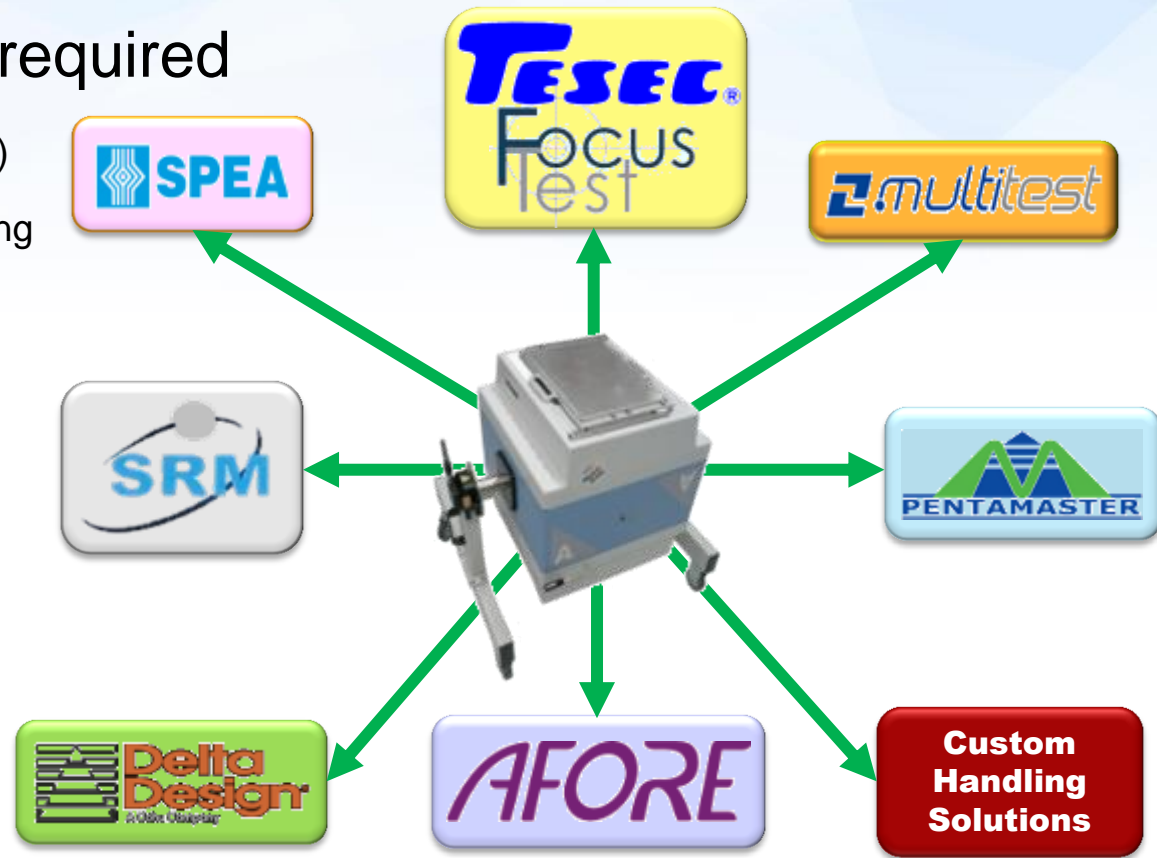 - Higher levels of multi-site
  - "Higher" Volumes

Same Performance, Same SW, Same DUT board, Same Wafer Prober/Handler I/F

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IoT Sensors Handling & Stimulus

- Test Cell Solution is required

    - Tester (~25% of test Cell cost)

    - Handler for HVM & Engineering

    - Sensor Stimulus

        - Inertial
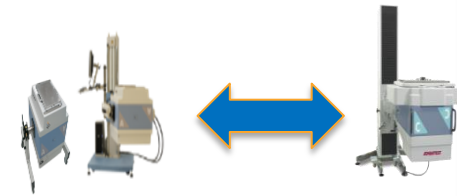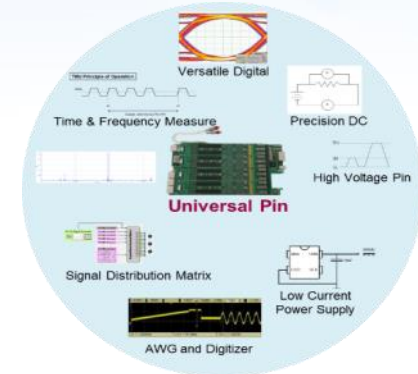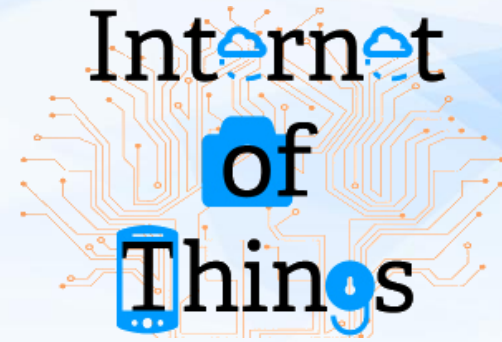
        - Temp/Hum

        - Pressure

        - Magnetic

- Partnership with Sensors Handler Manufacturers

    - Propose 'turnkey' solutions for new players

    - Unique interface with customer for problems solving

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IoT Test Platform

- **Integrates** Digital, DPS, Analog, Mixed Signal, RF and Memory Test in one scalable platform

- **Universal Pins** for maximum flexibility & slim configuration

- **Scalable** from small, low pin count configurations (for lowest capex), to larger, high pin count configurations (for highest levels of multi-site) with the same performance and HW/SW compatibility

- **Broad availability** in market and in OSATs

Thanks you for your attention!