

2014 CPMT Seminar

Latest Advances in Organic Interposers

# Future packaging and required interposer technologies for cognitive computing devices



**Yasumitsu Orii,**  
**Senior Manager of Science & Technology,**  
**IBM Research Tokyo**



## Agenda / Outline / Overview

- *Computer System for the Era of Big Data*
- *What is “Cognitive Computer” ?*
- *Requirement for Cognitive Computing Devices*
  - *Interposer Technologies*
  - *Packaging Technologies*

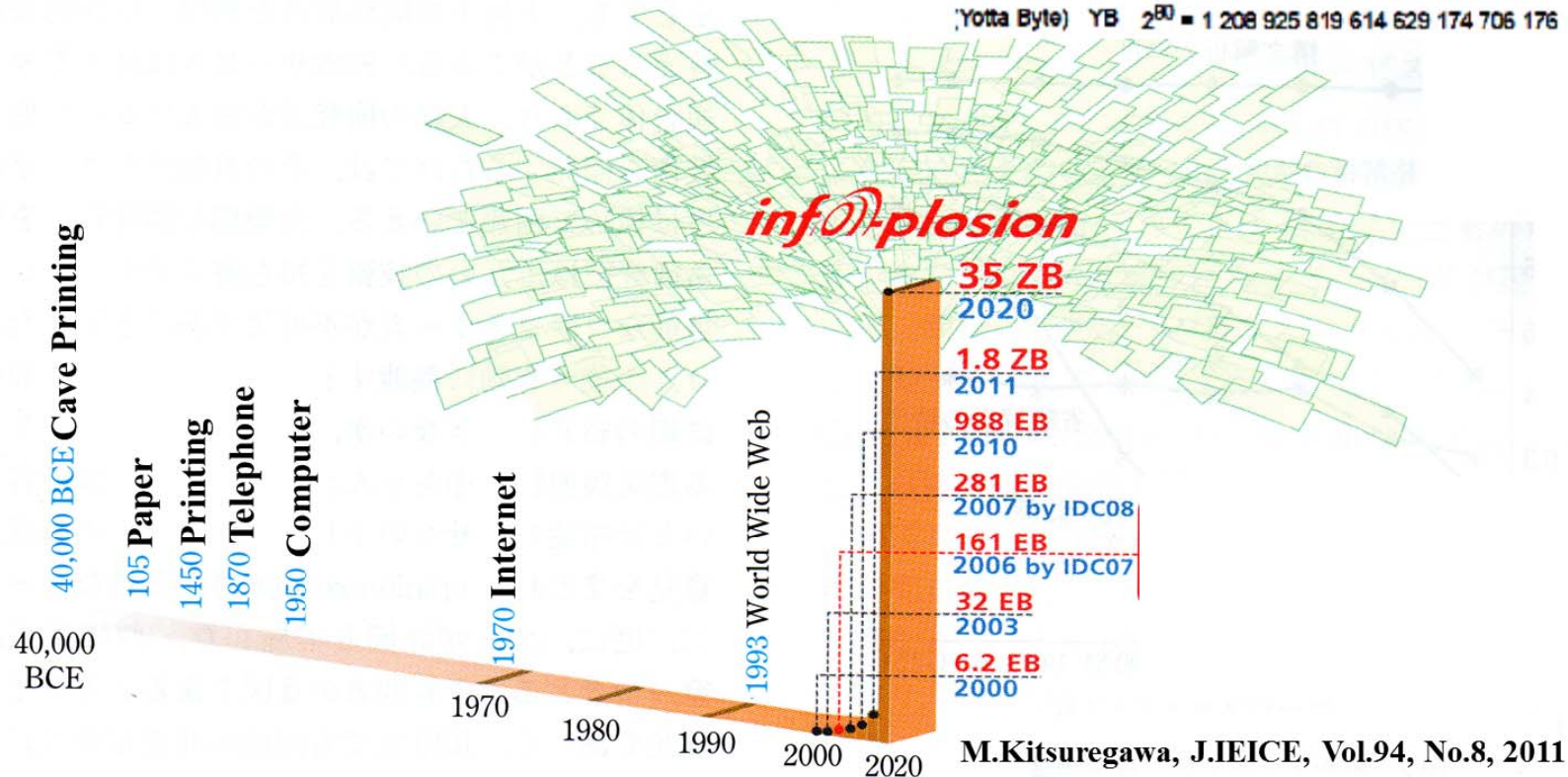
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# Info-Plosion

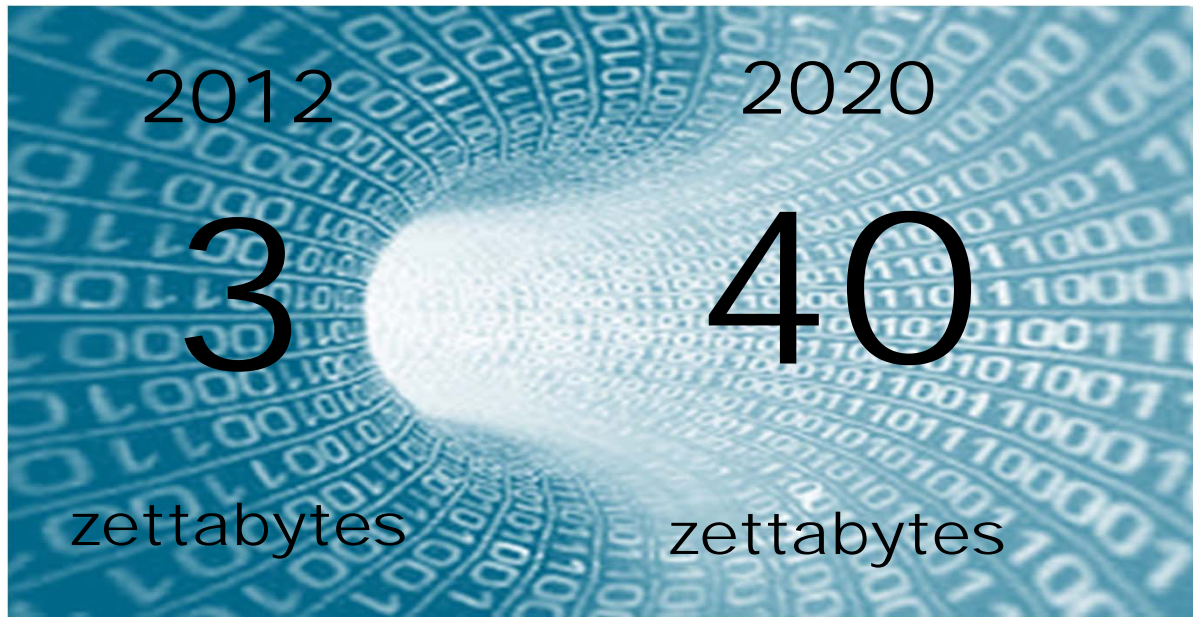
The oceans of data to be produced in the world  
 The size of data generated per Day in 2010 is “1ZB”,  
 which is equal to 3.7 trillion years News Paper Data.

- (Kilo Byte) KB  $2^{10} = 1\,024$
- (Mega Byte) MB  $2^{20} = 1\,048\,576$
- (Giga Byte) GB  $2^{30} = 1\,073\,741\,824$
- (Tera Byte) TB  $2^{40} = 1\,099\,511\,627\,776$
- (Peta Byte) PB  $2^{50} = 1\,125\,899\,906\,842\,624$
- (Exa Byte) EB  $2^{60} = 1\,152\,921\,504\,606\,846\,976$
- (Zetta Byte) ZB  $2^{70} = 1\,180\,591\,620\,717\,411\,303\,424$
- (Yotta Byte) YB  $2^{80} = 1\,208\,925\,819\,614\,629\,174\,706\,176$



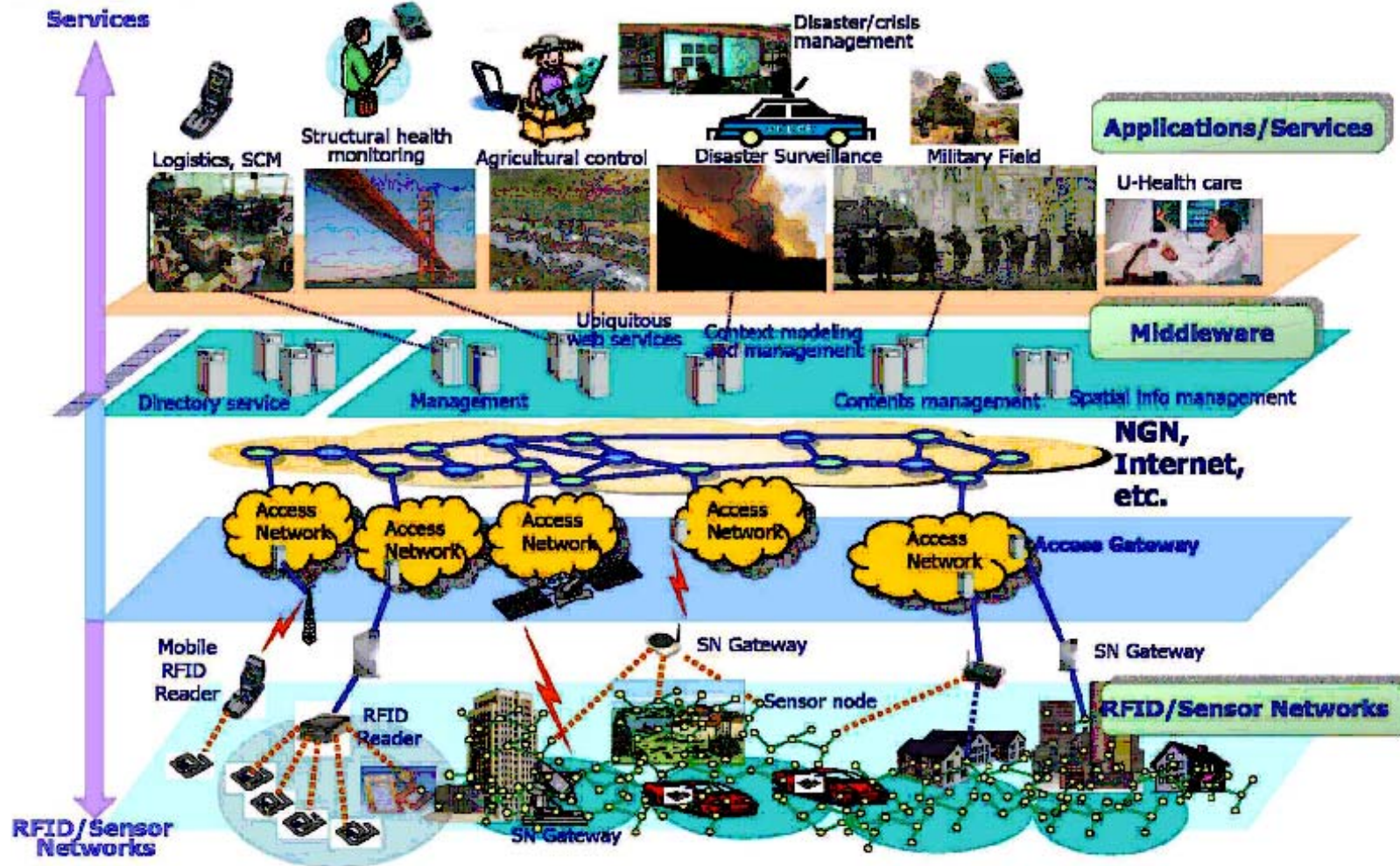


# *Data volume is increasing !*



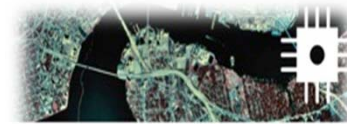
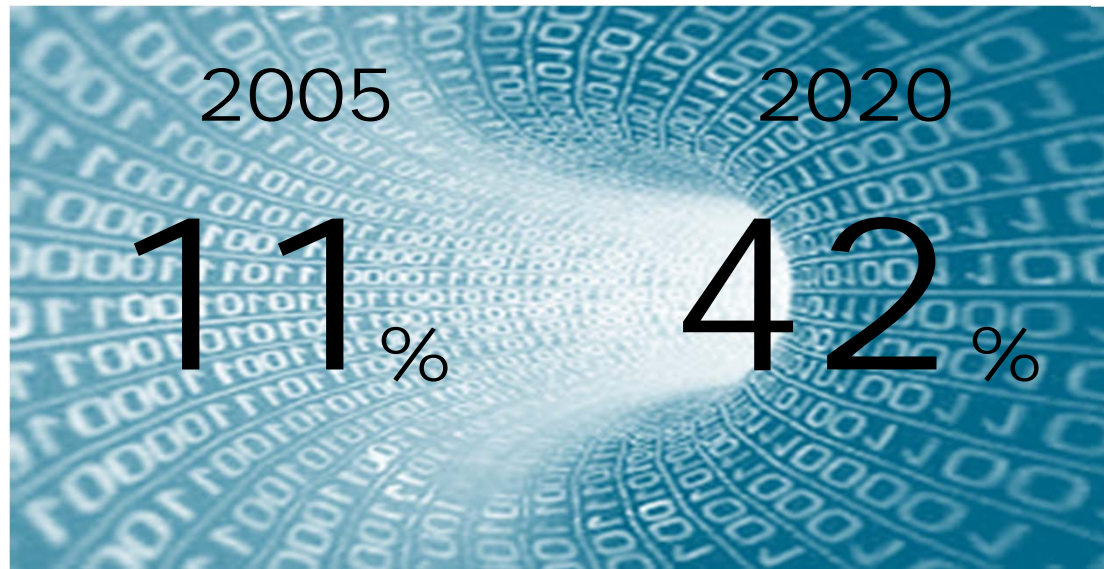
Source: IDC Digital Universe

# Internet of Things





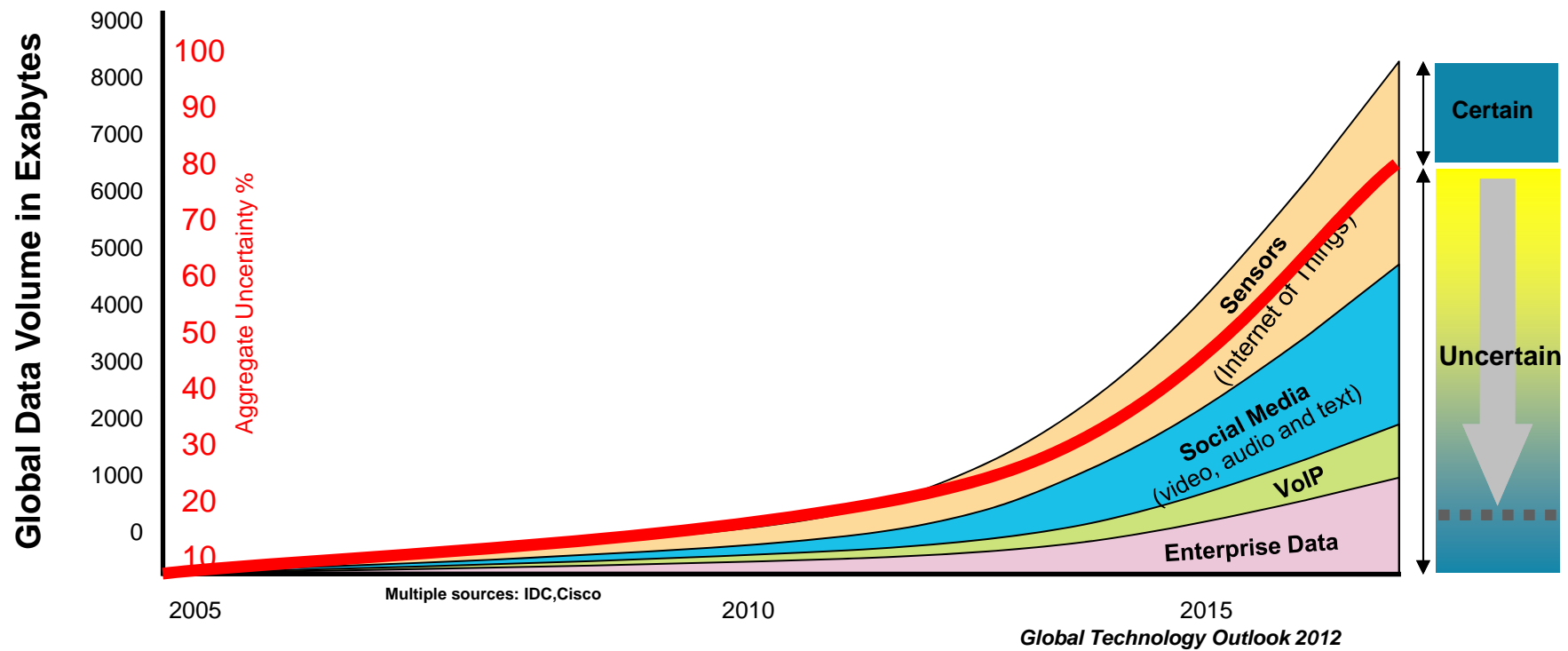
## *Big data to be accelerated by IoT*



Ratio of the data generated by sensors

Source: IDC Digital Universe

# Capacity of communication Infrastructure exceeds its limit in 2020

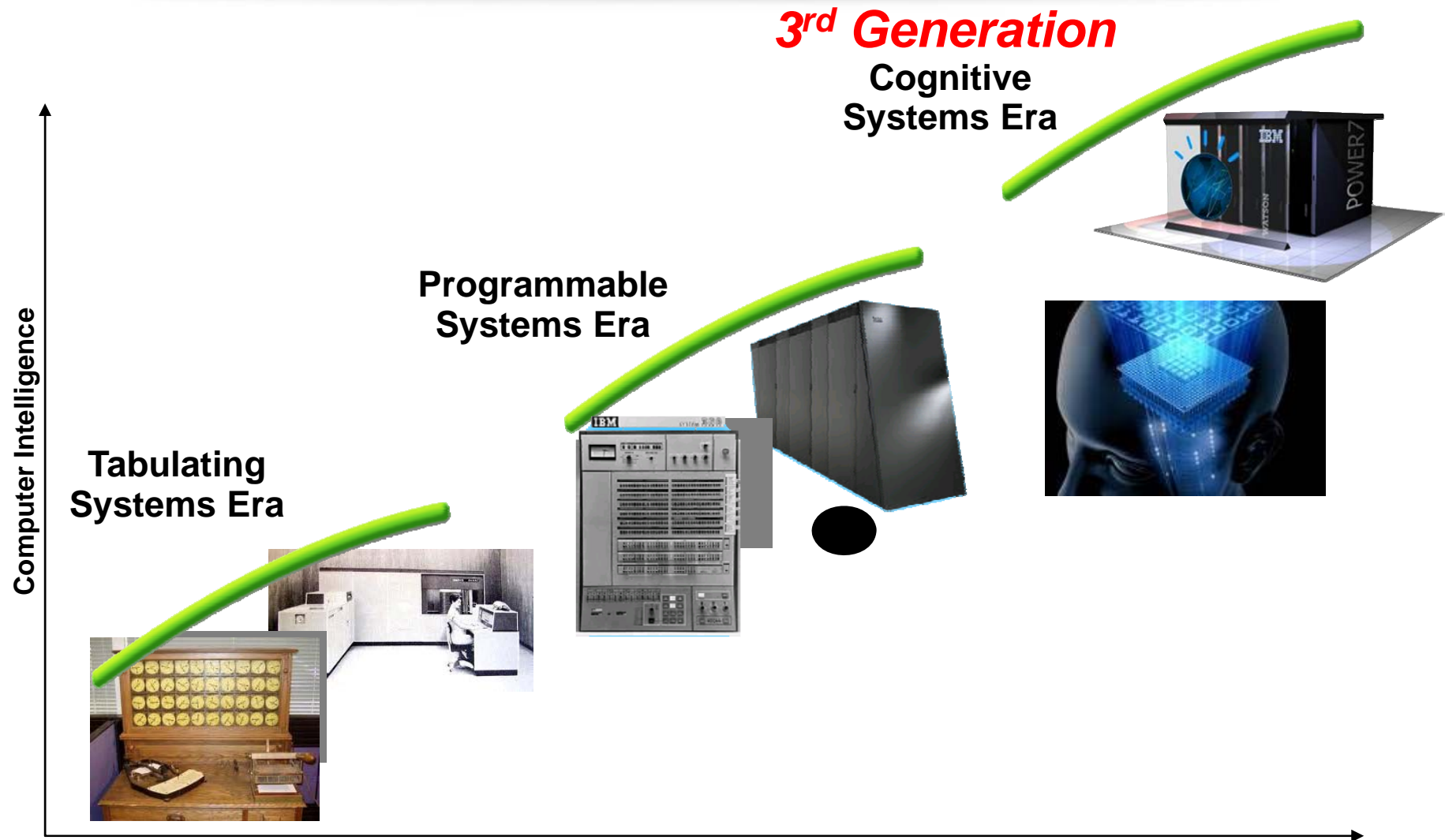




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# Cognitive Systems: A new era of computing



# IBM Watson Project



- ✓ 15TB Memory
- ✓ 2,880 Processor core
- ✓ 200KW



- ✓ Ken Jennings, who won a record 74 consecutive "Jeopardy!" games in 2004-05
- ✓ Brad Rutter, who is the biggest all-time money winner.

It is expected to apply the technologies for Watson to many applications.

System to backup more rapid and accurate **medical diagnosis**.

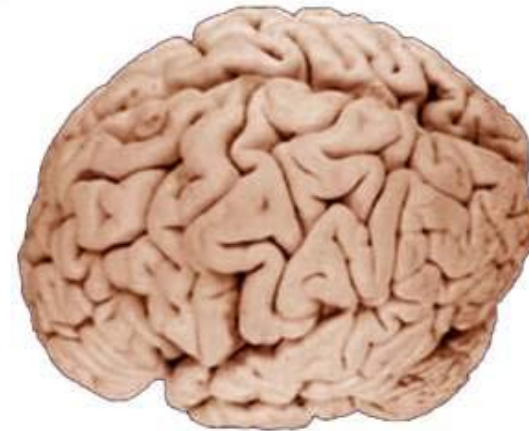
System to check **potential coactions between medicines**.

System to **refer past authority** by lawyers and benches.

System for **hypothesis scenario and legal compliance** in finance sector.



# Computers and the Brain are Different and Complementary



3.55 GHz, sequential, linear      10 Hz, parallel, high fanout

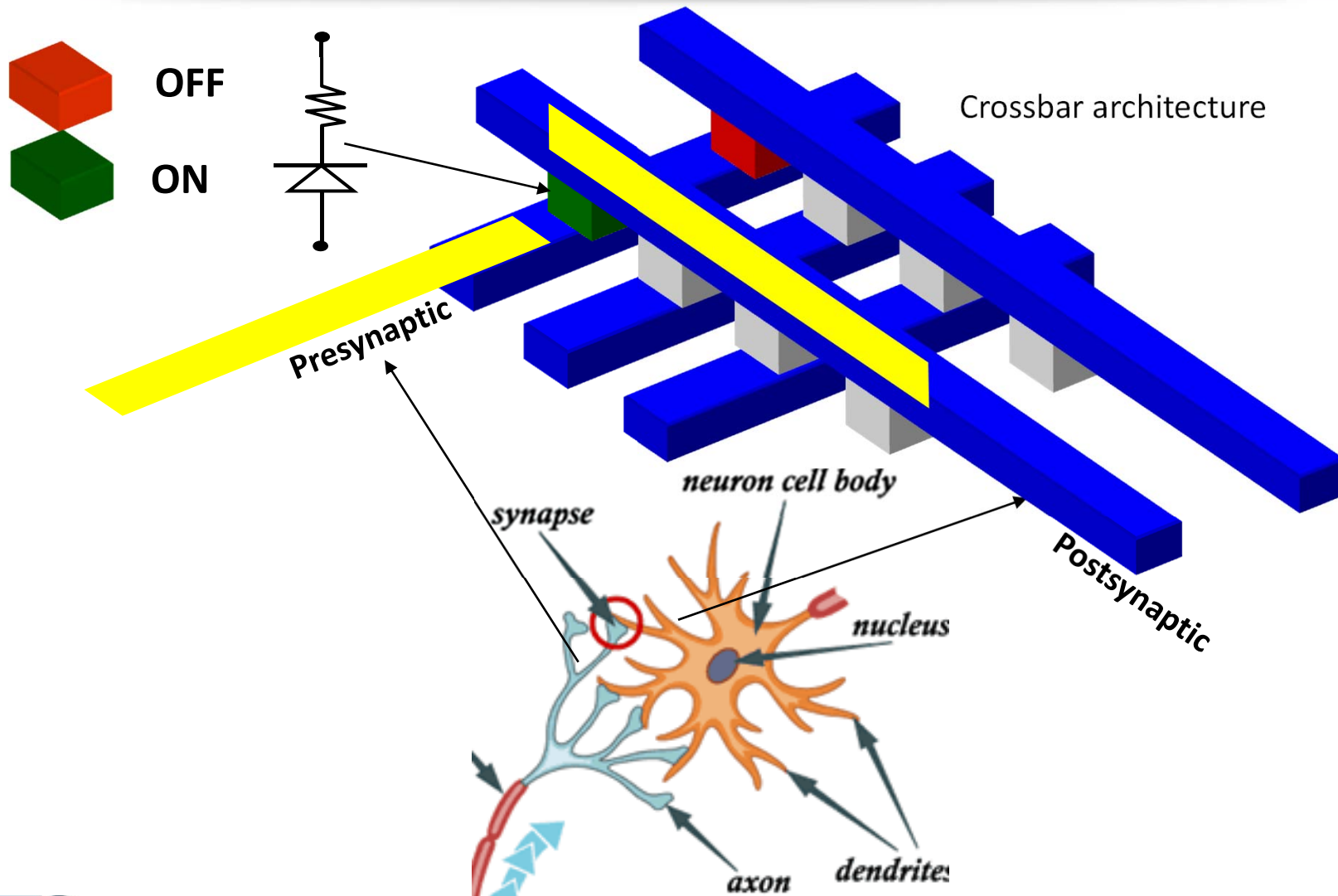
200kW      20W

12,000 L      1.2 L

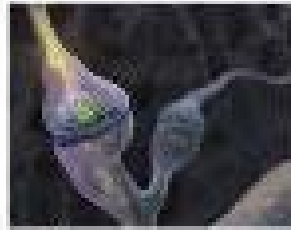
~5,000 connections/cm<sup>2</sup>      10<sup>6</sup> neurons/cm<sup>2</sup>

Separates memory      Integrates memory

# IBM Creating New Cognitive Technologies



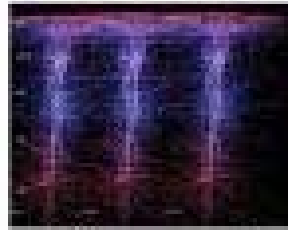
# Brain-inspired Chip



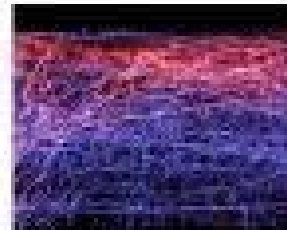
$\sim 10^{10}$  synapses/cm<sup>2</sup> <sup>2</sup>



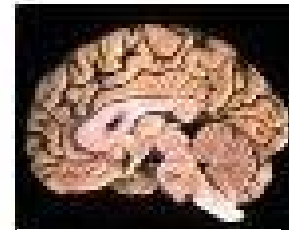
$\sim 10^6$  neurons/cm<sup>2</sup> <sup>2</sup>



$\sim 10^4$  neurons/  
cortical column



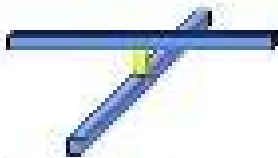
$\sim 5 \times 10^3$  long range  
axons @ 1 Hz



Biological Brain <sup>1</sup>

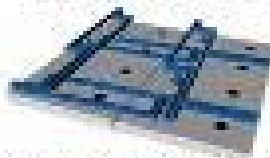


CROSSBAR  
JUNCTION



$\sim 10^{10}$  intersections/  
cm<sup>2</sup> @ 100 nm pitch

CMOS  
SUBSTRATE



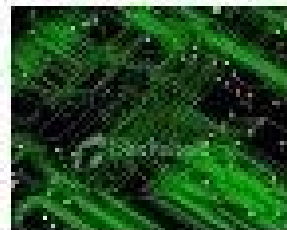
$5 \times 10^8$  transistors/  
cm<sup>2</sup>  
@500 transistors/  
neuron

LAMINAR  
CIRCUIT



Layered cortical  
circuits with  $\sim 10^6$   
neurons/cm<sup>2</sup>

HIGH SPEED BUS



Multi-Gbit/sec  
Digital comms

Brain



Electronic Brain <sup>1</sup>

(Ref. [http://archive.hpcwire.com/hpcwire/2011-08-18/ibm\\_reveals\\_cognitive\\_computing\\_chips.html](http://archive.hpcwire.com/hpcwire/2011-08-18/ibm_reveals_cognitive_computing_chips.html))

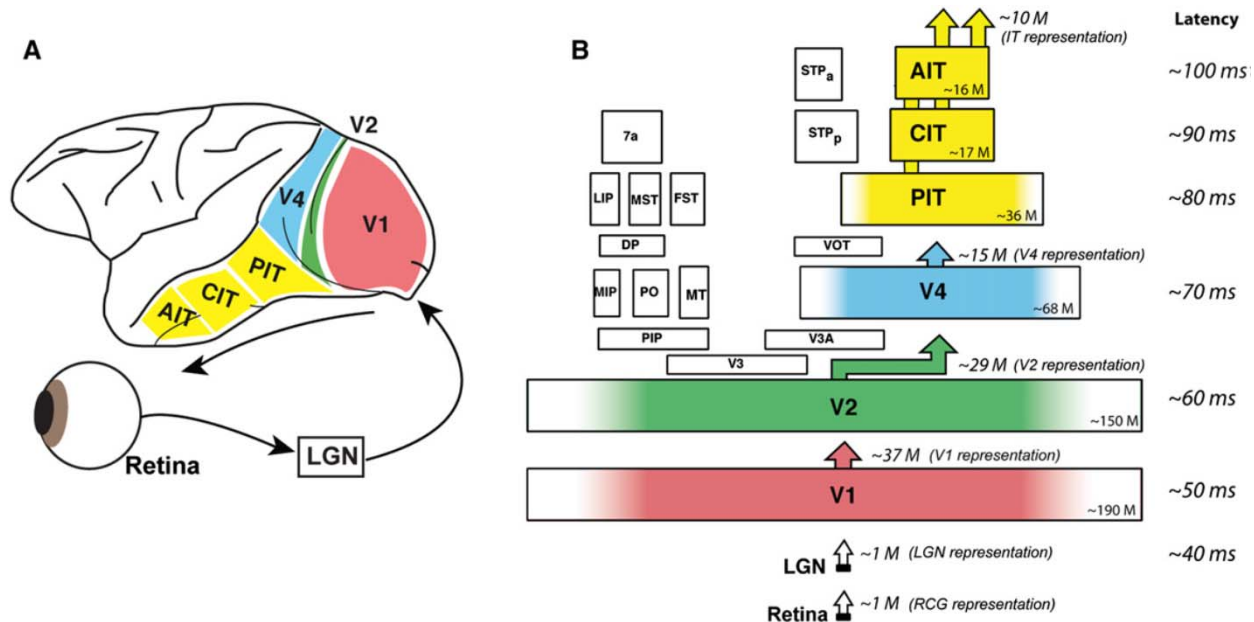


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# Human's brain

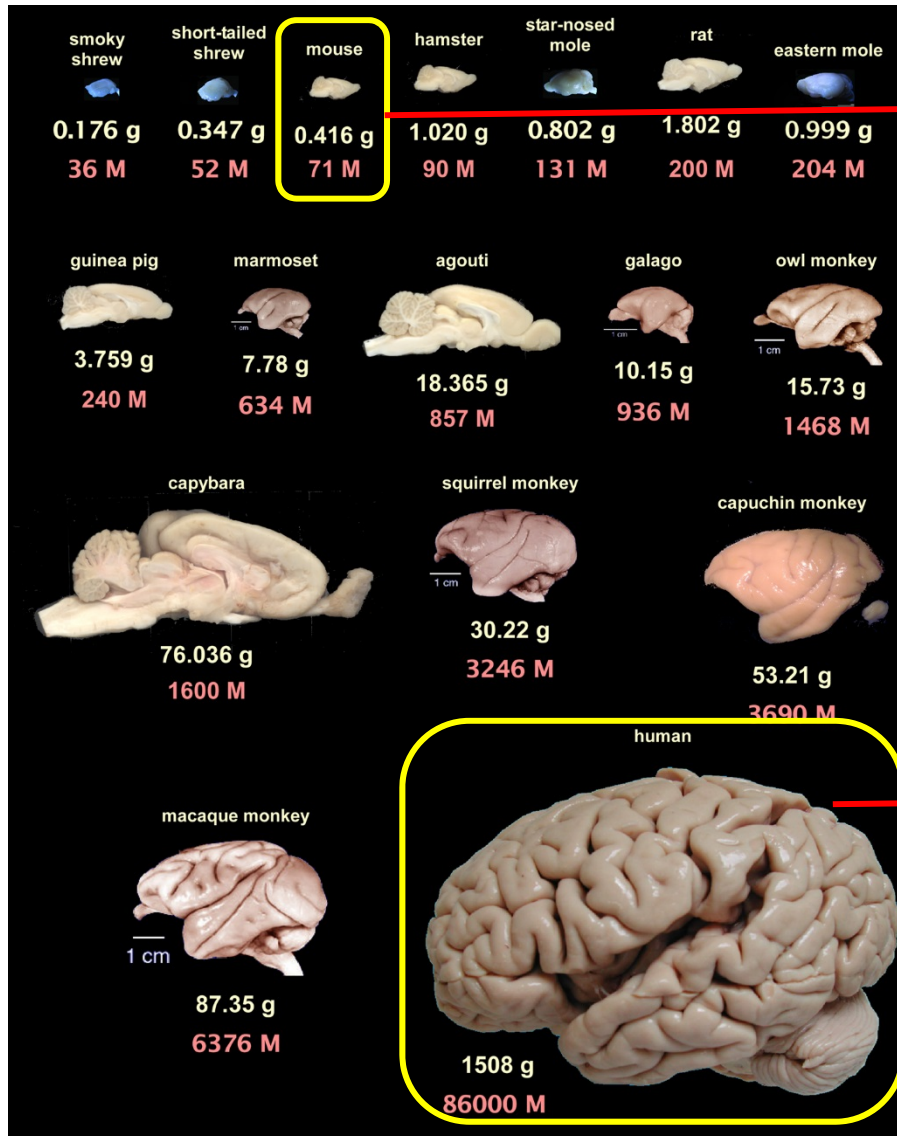
- Human's brain:  $10^{11}$  (100Billion) neurons  
 $10^{15}$  (1000Trillion) synapses



J. DiCarlo et al., Neuron, 2012

Eye: 1B neurons  
 10T synapses

# Brain size of mammals



Mouse's brain:  
**70M neurons**  
 700B synapses

Mouse's vision (est.):  
 0.7M neurons (~1M)  
 7B synapses (~**10B**)

Human's brain:  
**100B neurons**  
 1,000T synapses

Human's vision:  
 1B neurons  
 10T synapses



# Package Outline on Implementation

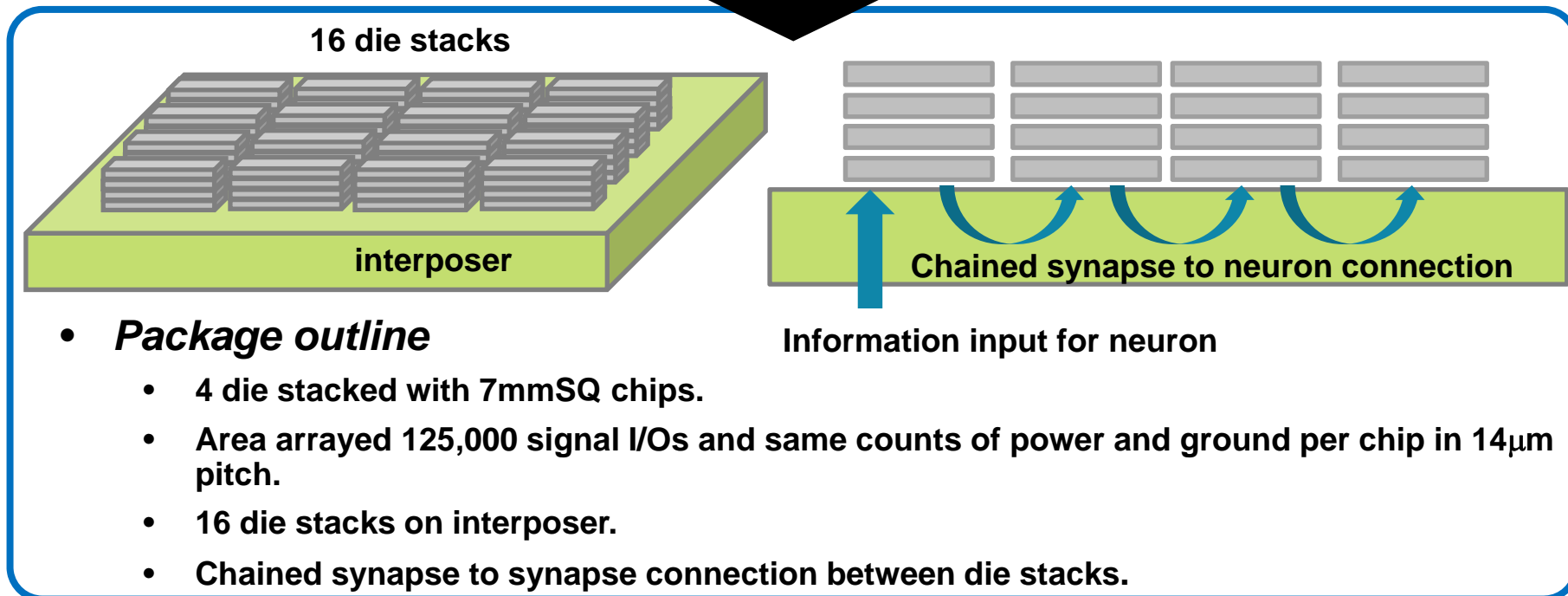
- **Assumption : Mouse's eye (synapse=10B, # of neurons=1M)**

## Number of I/O estimation

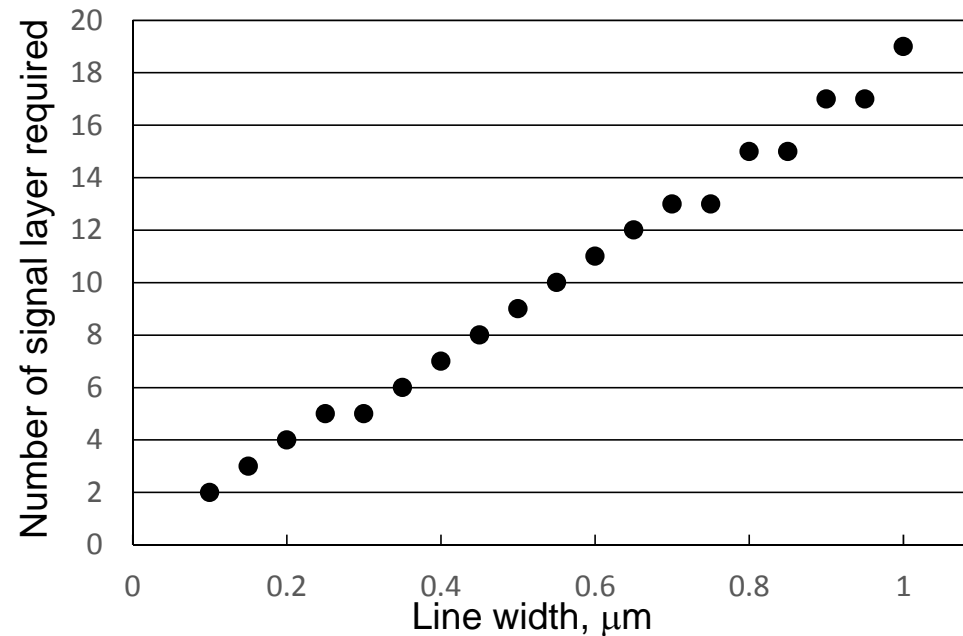
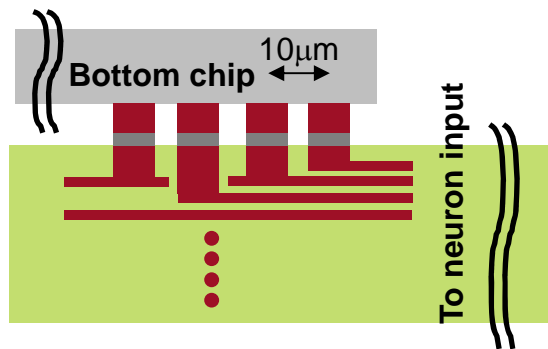
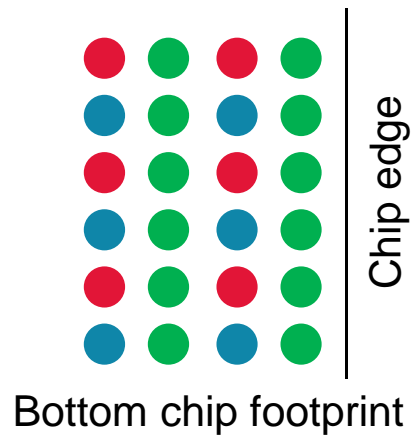
- Total signal I/O of neurons:  $1M \times 2$
- Total I/O with power & ground: 4M
- Layers of RBM: 16 (= number of stacked chip)
- Total I/O with power & ground of a stack (4dies)  
:  $1M \times 2 \times 2 / 16 = \underline{250,000}$

## Die size estimation

- Total drivers of a stack (4 dies) :125,000
- # of driver on a die:  $125,000 / 4 = 31,250$
- Area of driver (45nm):  $25 \times 50 = 1,250 \mu m^2$
- Area of die:  $0.00125 \times 31,250 \mu m^2$   
=  $39.0625 mm^2 \rightarrow \underline{6.25 mm^2}$



# Wiring Study of Interposer



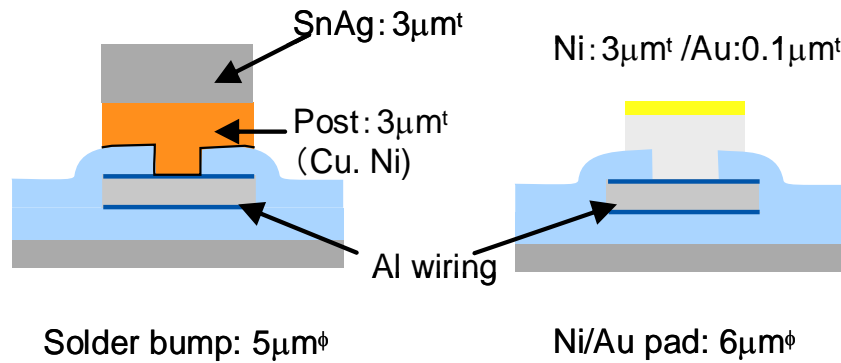
- Interposer technology innovation required
  - Most likely [less than 0.5µm line and spacing](#)
  - Land-less capability for via connection between layers
  - Appropriate pad surface finishing for [10µm interconnection](#)

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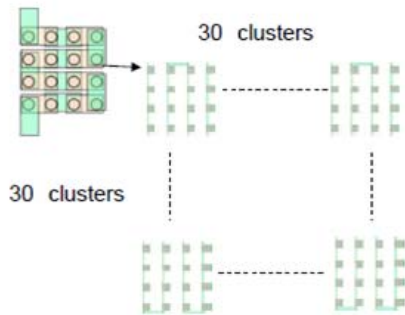
# 10micron pitch interconnection

## - Bump/Pad structure

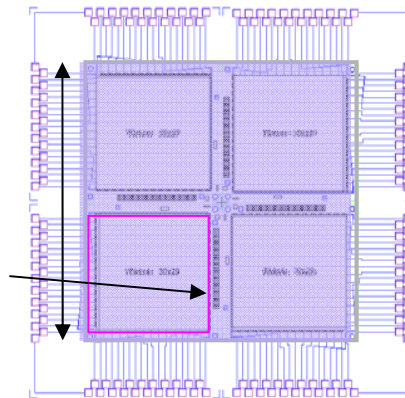


## - Wiring on chip/substrate

4X4 10 µm-pitch cluster bumps



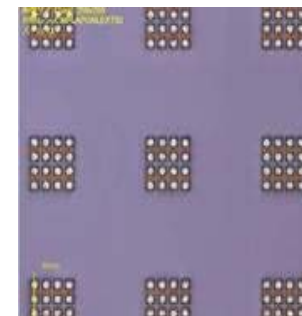
Chip  
7mmx7mm



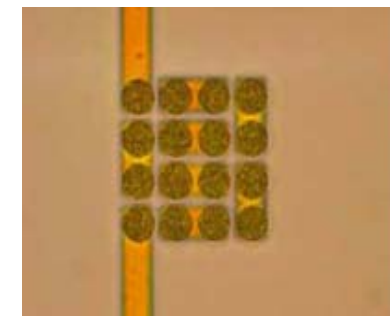
30X30 100 µm-pitch cluster array

Substrate : 10mmx10mm

	As depo.	After hydrogen radical treatment + wetback
Cu-post		
Ni-post		



10 µm pitch SnAg bump



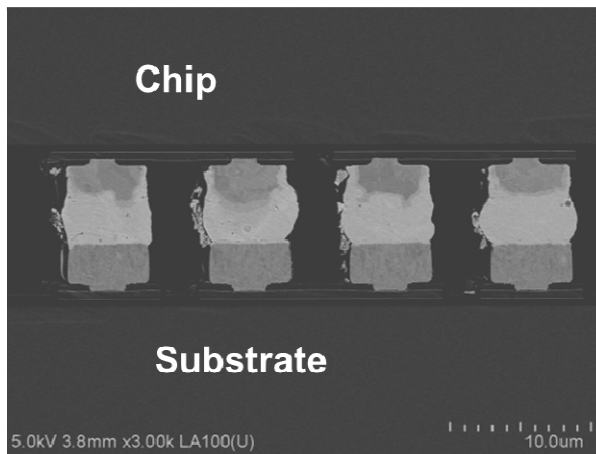
10 µm pitch Ni/Au pad



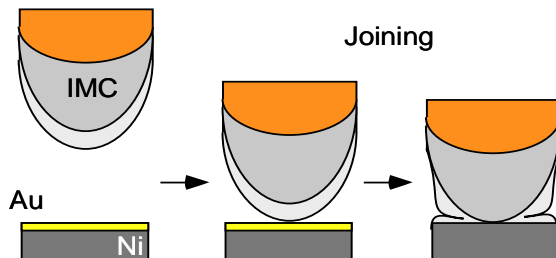
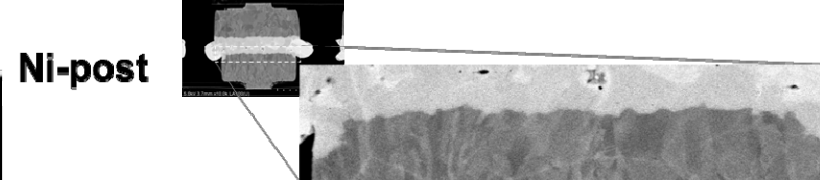
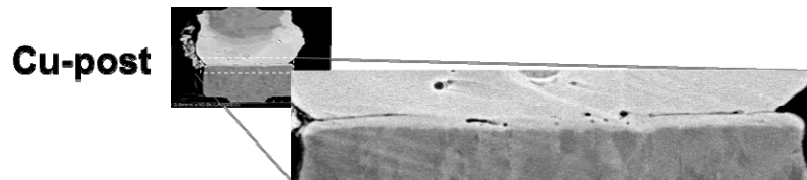
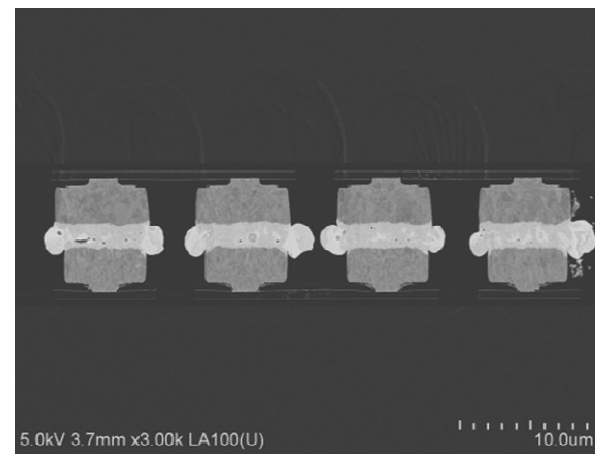
# 10micron pitch interconnection

- Bonding with contact-retry alignment method
- Bonding condition: 300 deg. C, 10N

**Cu-post**



**Ni-post**

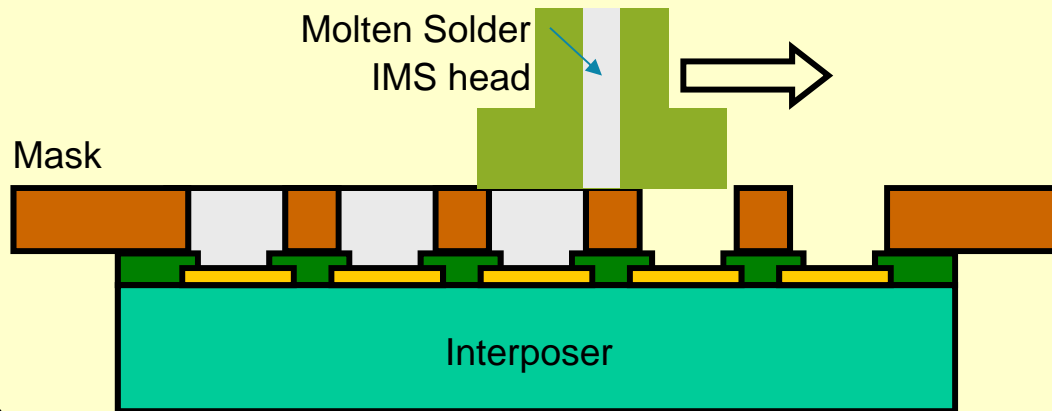


**Ni-post: Good continuity, IMC growth**

**Cu-post: Void generated due to consumed solder**

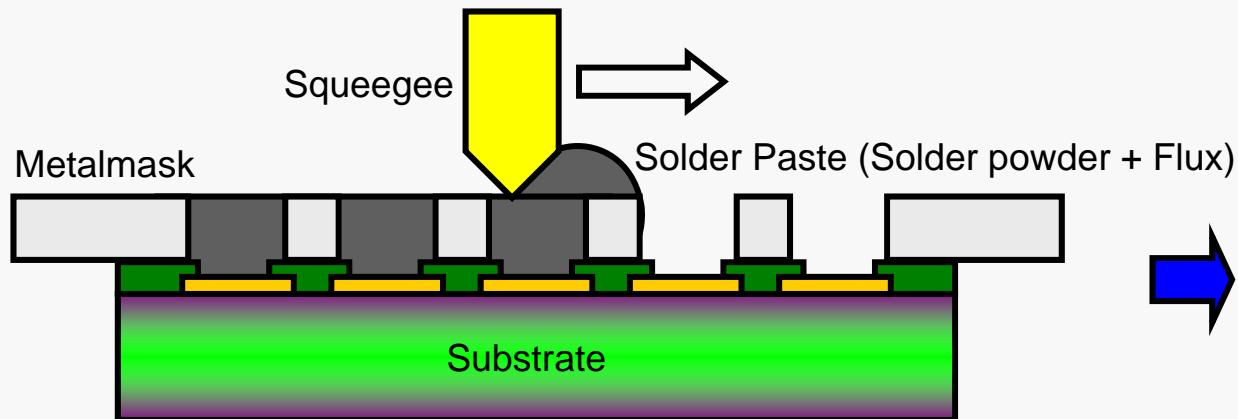
# IMS (Injection Molded Solder) technology

## - Molten Solder Injection Method -



- ◆ Very simple process
- ◆ Green process
  - No flux, No formic acid
  - Minimum solder waste
- ◆ Pure solder injection
  - Higher solder volume
  - Extendible to very fine pitch
  - Solder alloy flexibility
- ◆ One pass for multiple solder sizes

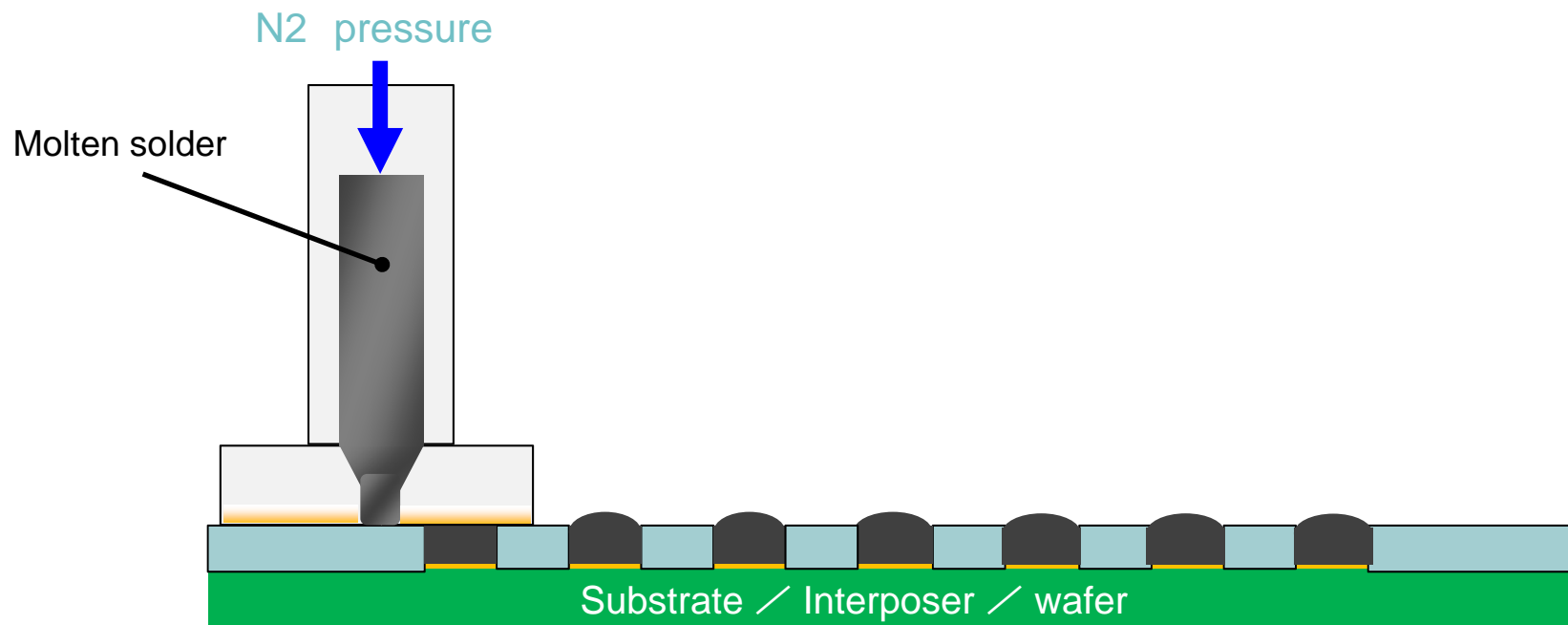
## - Solder Paste Printing Method -



reference

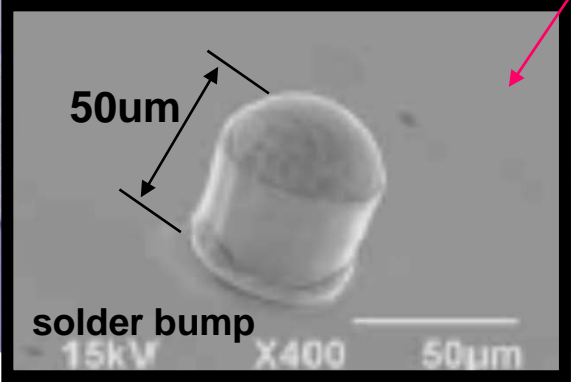
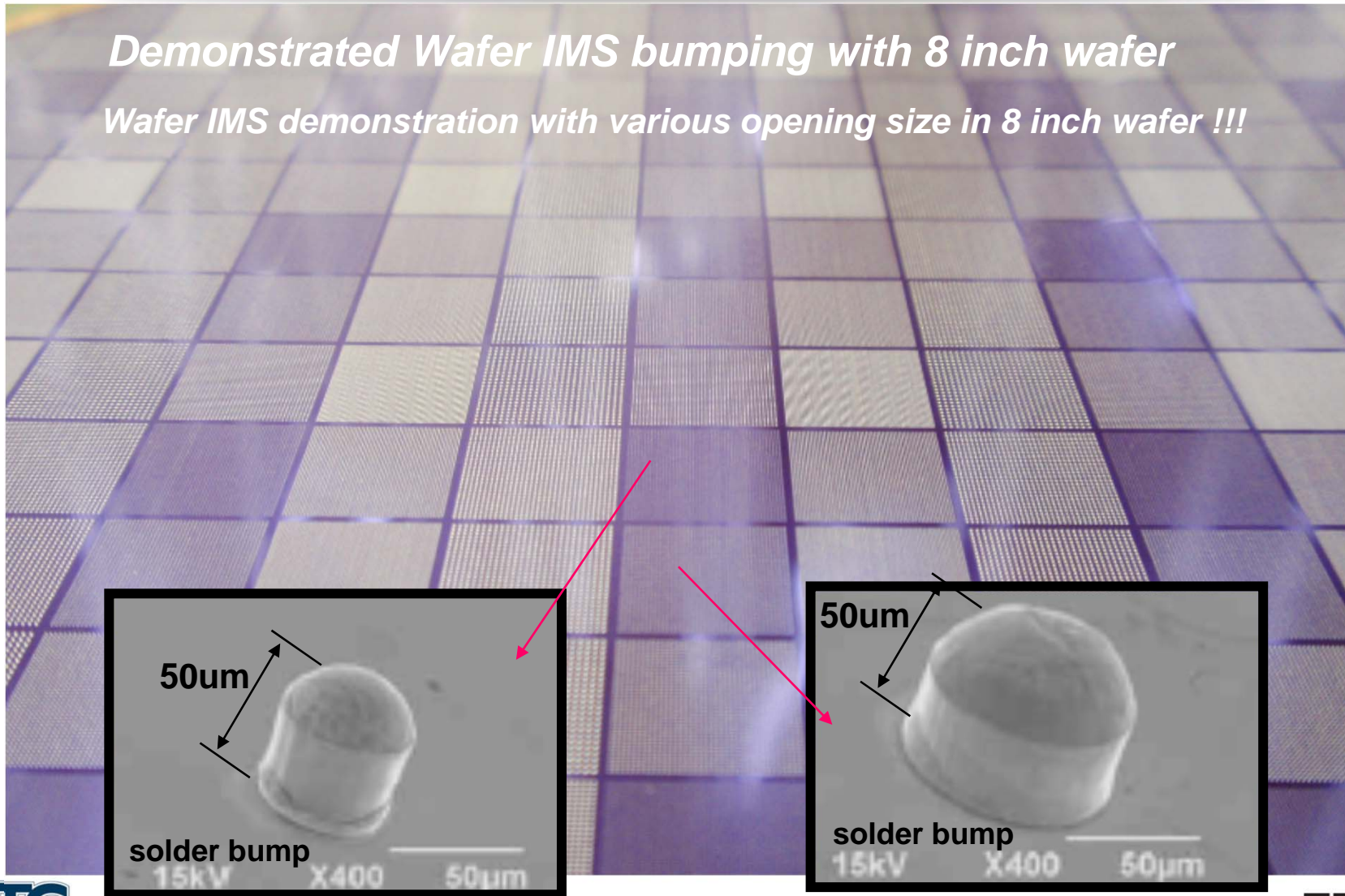
Reflow + Cleaning

# IMS (Injection Molded Solder)

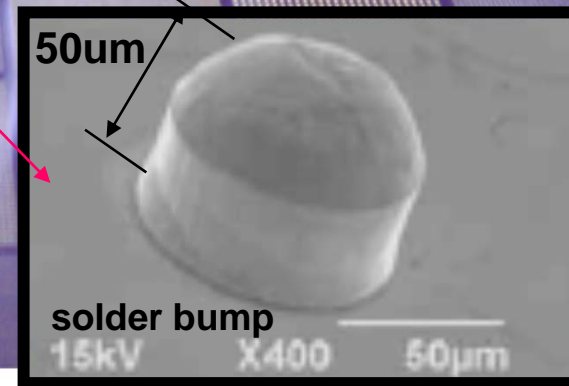


# ▶ Wafer IMS technology : Demonstration with 8' wafer

*Demonstrated Wafer IMS bumping with 8 inch wafer*  
*Wafer IMS demonstration with various opening size in 8 inch wafer !!!*



50um diameter



75um diameter



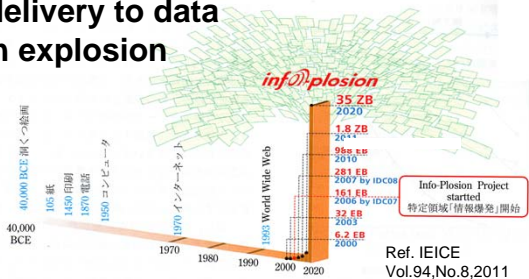
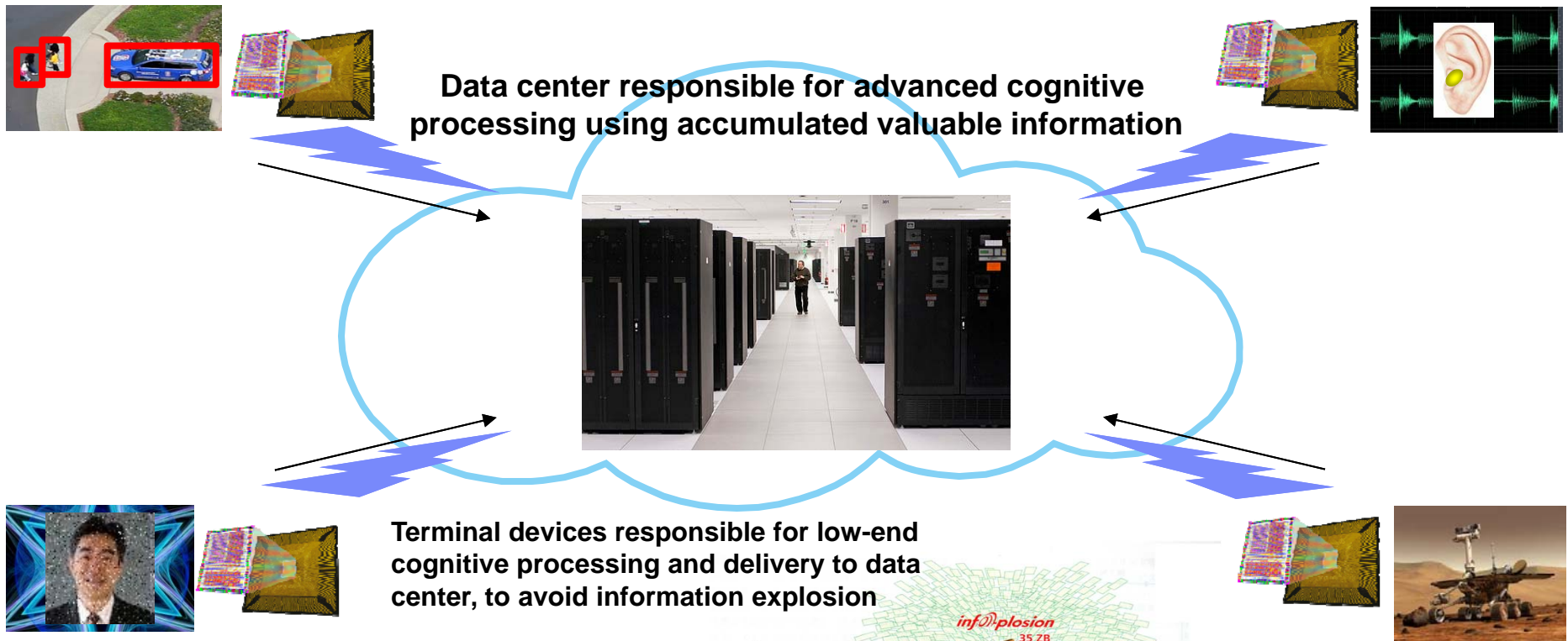
# Experimental Results of IMS Technology



	30 $\mu$ m	40 $\mu$ m	50 $\mu$ m	75 $\mu$ m	100 $\mu$ m
Before Stripping					
After Stripping					

# A Future led by Cognitive technology

Terminal devices enable cognitive processing.  
Workload is balanced b/w data center and terminals.



Ref. IEICE  
Vol.94, No.8, 2011



# Mission for IBM Research Tokyo

*System technology research and element technology research for new era computing will be performed under collaboration among universities and partners.*

System technology research

Current computer



*von Neumann architecture*

*Toyosu*



*Universities*



*Shin-Kawasaki*



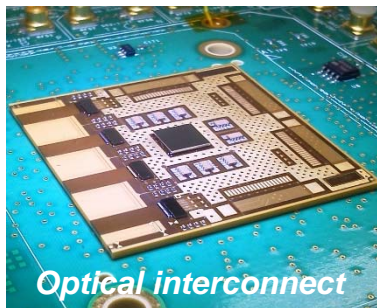
*Partners*

Future computer



*Cognitive & Bio-inspired*

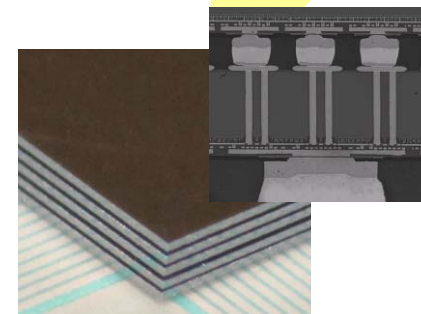
Element technology research



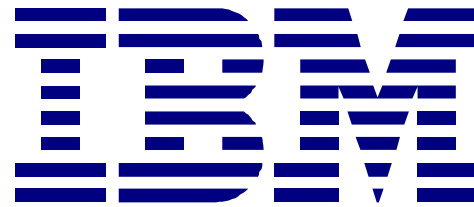
*Optical interconnect*



*Wireless interconnect*



*Metal Interconnect*



Thank you for your attention !