IEEE ROADMAPS

outline Technology Innovations for humanitarian Solutions

Dr. Rakesh Kumar*, IEEE Life Fellow*

IEEE Roadmaps Committee Chair

rakesh@tcxinc.com

EDS Chapter Webinar 9/27/2023

About Me

- Long time Industry professional
  - 2 Start-ups, Cadence, Unisys, Motorola
- Long term IEEE Volunteer
  - Past President, Solid-State Circuits Society
  - TAB Hall of Honor
  - Led TAB efforts at 2 Sections Congress events
- Currently
  - Chair, IEEE Roadmaps Committee
  - Chair, IEEE Data-based Strategy Ad Hoc
  - Chair, IEEE DataPort

IEEE ROADMAPS™

www.ask.ieee.org

IEEE

Outline

- Technology Directions
- IEEE Roadmaps
  - IRDS, HIR, ITRW, INGR
  - “In the works” Roadmaps
- Humanitarian applications

Technology has changed Lives….

…Many of *you* are creating solutions….

…Many Many more challenges & solutions on the way!!!….

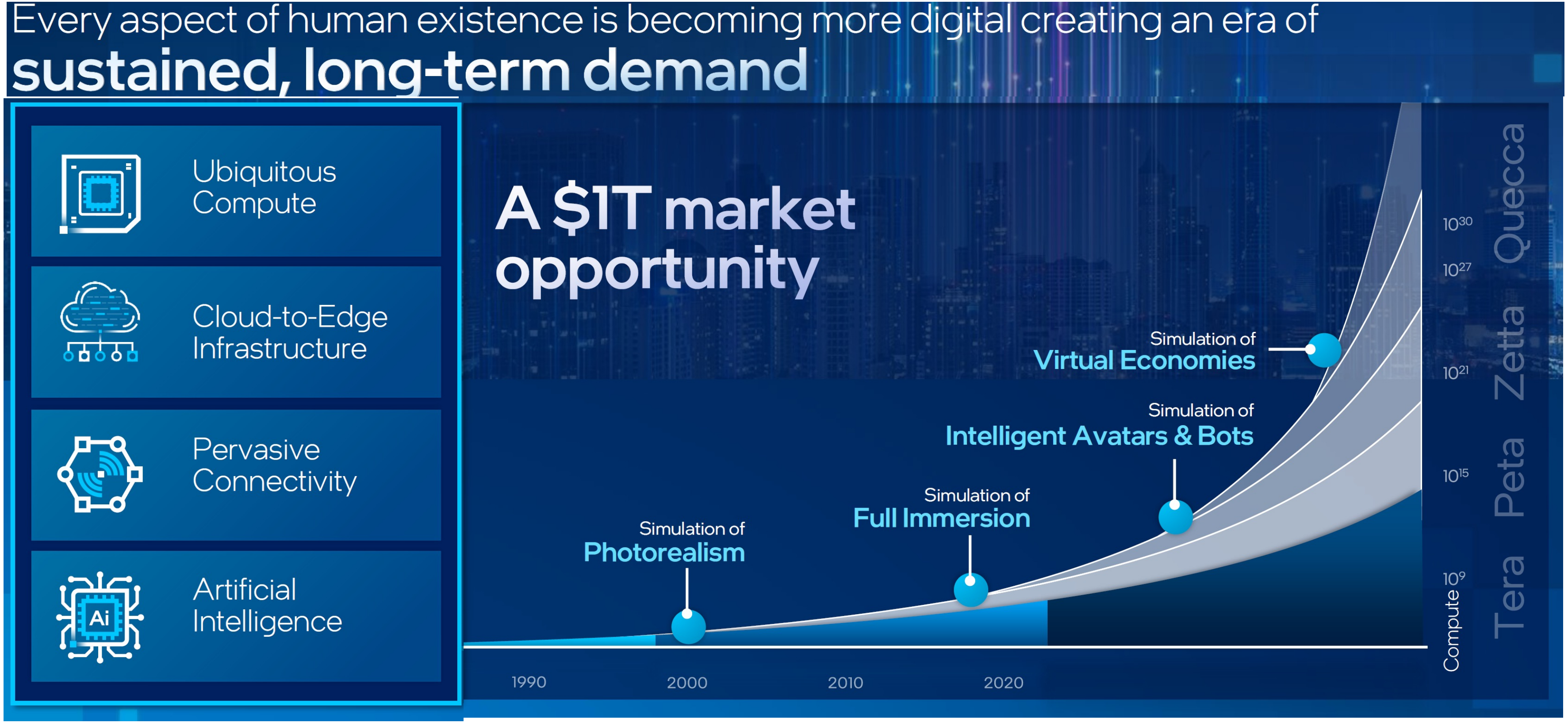
…Many New PRODUCT Opportunities…

…Many TECHNOLOGY Innovations needed…
Multi-disciplinary Integrations

IEEE ROADMAPS™

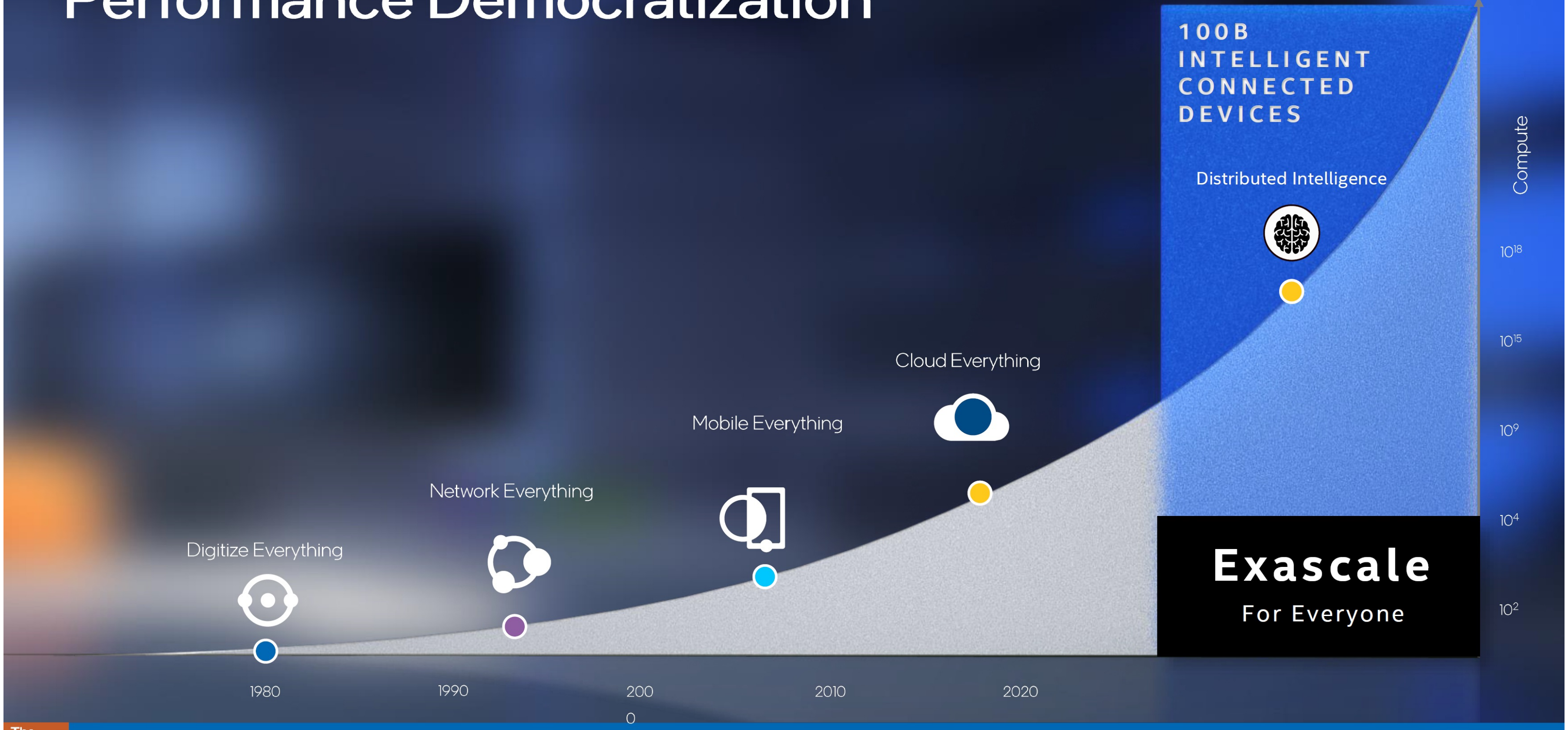
IEEE

From **Pat Gelsinger, Intel CEO…**



Ref: Pat Gelsinger, Intel Investor Day, June 2022

Performance Democratization



Evolution of the Digital Phone

1980's	1990's	2000's	2010's	2020's	2025-30
1G	2G	3G	4G	5G	"Next Gen"
					Better Speed Lower Latency Capacity/BW Reliability **"Pervasive Applications"**
				Better Speed Lower Latency Capacity/BW Reliability IoT AI VR/AR Robotics Cloud//Edge Computing SDN	
			Video Better Speed Lower Latency		
		Internet connectivity Wireless connectivity Digital n/w			
	Text				
Voice Analog n/w					

If you work in the Industry....you might want to know

- The industry direction…
- What Technologies are coming in 3-5 years or longer
- What are the Roadblocks and possible Solutions

IEEE Roadmaps positioned to create this value

The IEEE Technical Roadmaps committee coordinates…

- 4 published Technical* Roadmaps https://roadmaps.ieee.org
- Many more ‘on the horizon’

* Companies usually have **“Product”** Roadmaps
these provide them vision and competitive advantage

Each Roadmap brings together International experts…

- From the industry, academia, government, research entities
- Forms Working Groups
- Discusses Tech Trends
- Makes predictions for 5-10-15+ years
- Refreshed every 1-2 years

Identifies “Base” Technology Trends

- Serves as an **independent, unbiased REFERENCE resource**

Identify Gaps and “Brick Walls”

IEEE ROADMAPS™

IEEE

A Semiconductor & Devices Roadmap [“IRDS”]

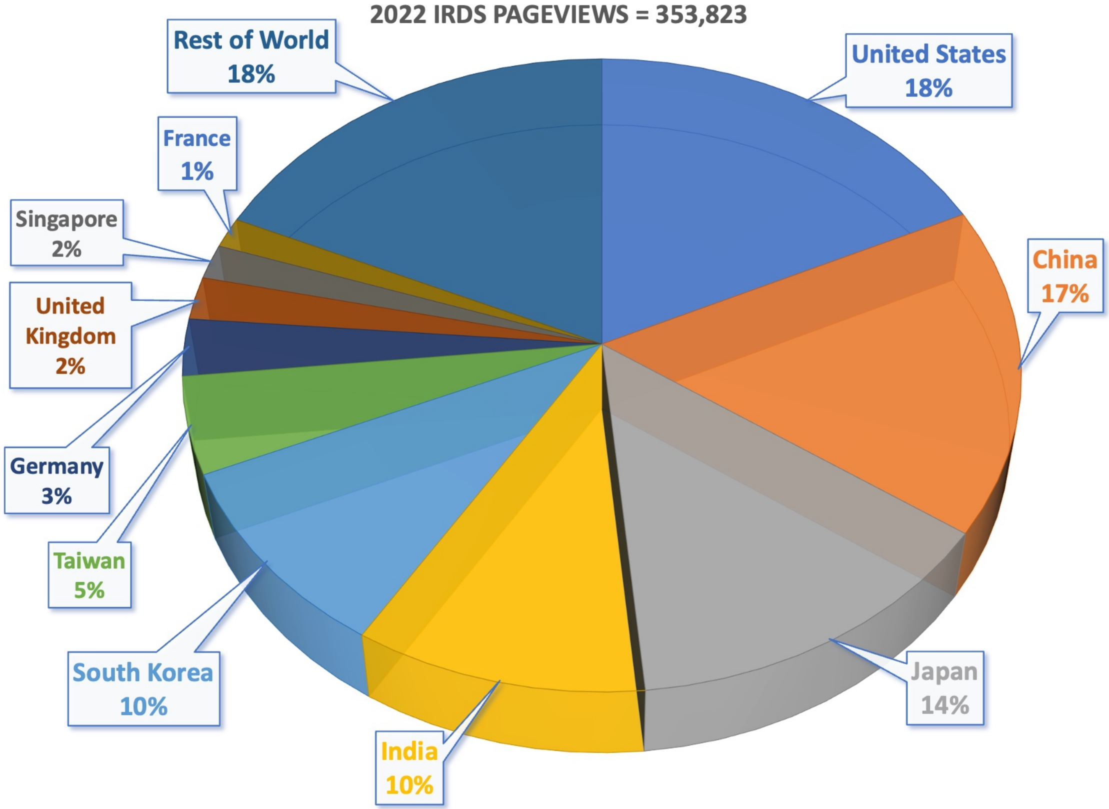
- >1M views in 2022
- In the EU Chips Act
- In the Japan Chips Act
- Referenced in US Chips Act
- Many Presentations

https://irds.ieee.org

IEEE ROADMAPS™

IEEE

Over 1M cumulative Page Views



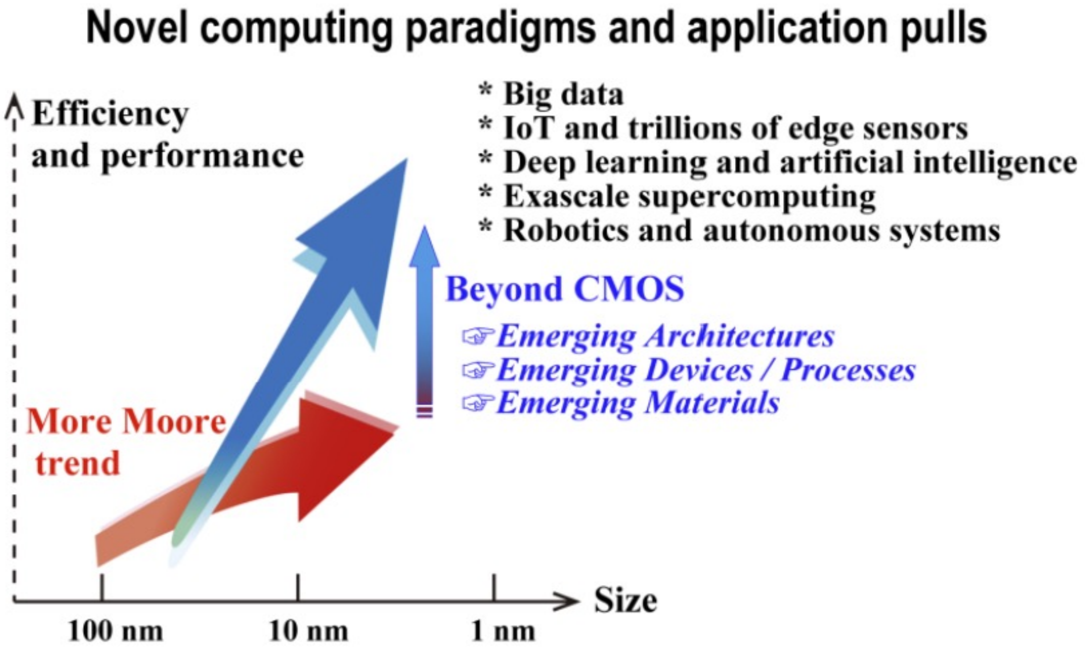
2022 Pageviews			353,823
1	United States	18%	63370
2	China	17%	59281
3	Japan	14%	48959
4	India	10%	36529
5	South Korea	10%	34012
6	Taiwan	5%	17485
7	Germany	3%	10298
8	United Kingdom	2%	7720
9	Singapore	2%	6231
10	France	2%	5440
	Rest of World	18%	64498

IEEE ROADMAPS™

IEEE

Toward Energy-Efficient, Data-intensive, Cognitive Applications

→ Novel Computing Paradigms and Massive Parallelism, Bio-inspired mechanisms



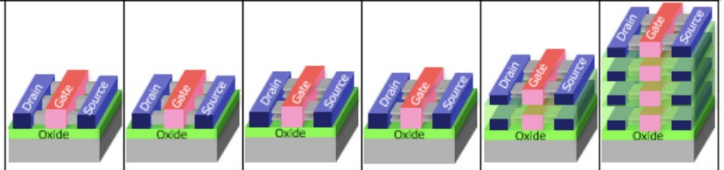
Relationship of More Moore, Beyond CMOS, and Novel Computing Paradigms and Applications (Courtesy of Japan beyond-CMOS Group)

IRDS example of Roadblocks

Table MM-7 Device Architecture and Ground Rules Roadmap for Logic Devices.

Note: GxxMxx/Tx notation refers to Gxx: contacted gate pitch, Mxx: tightest metal pitch in nm, Tx: number of tiers. This notation illustrates the technology pitch scaling capability. On top of pitch scaling there are other elements such as cell height, fin depopulation, DTCO constructs, 3D integration, etc. that define the target area scaling (gates/mm^2).

YEAR OF PRODUCTION	2021	2022	2025	2028	2031	2034
	G51M30	G48M24	G45M20	G42M16	G40M16/T2	G38M16/T4
Logic industry "Node Range" Labeling (nm)	"5"	"3"	"2.1"	"1.5"	"1.0 eq"	"0.7 eq"
IDM-Foundry node labeling	i7-f5	i5-f3	i3-f2.1	i2.1-f1.5	i1.5e-f1.0e	i1.0e-f0.7e
Logic device structure options	FinFET	finFET LGAA	LGAA	LGAA	LGAA-3D	LGAA-3D
Platform device for logic	finFET	finFET	LGAA	LGAA	LGAA-3D	LGAA-3D



LOGIC DEVICE GROUND RULES	2021	2022	2025	2028	2031	2034
Mx pitch (nm)	36	32	24	20	16	16
M1 pitch (nm)	34	32	23	21	20	19
M0 pitch (nm)	30	24	20	16	16	16
Gate pitch (nm)	51	48	45	42	40	38
Lg: Gate Length - HP (nm)	18	16	14	12	12	12
Lg: Gate Length - HD (nm)	20	18	14	12	12	12
Channel overlap ratio - two-sided	0.20	0.20	0.20	0.20	0.20	0.20
Spacer width (nm)	7	6	5	4	4	4
Contact CD (nm) - finFET, LGAA	19	20	21	22	20	18
Contact CD (nm) - VGAA						
Device architecture key ground rules						
FinFET pitch (nm)	28.0	24.0				
FinFET Fin width (nm)	6.0	5.0				
FinFET Fin height (nm)	50	64				
Footprint drive efficiency - finFET	3.79	5.54				
Lateral GAA lateral pitch (nm)			22.0	20.0	20.0	20.0
Lateral GAA vertical pitch (nm)			18.0	16.0	14.0	14.0
Lateral GAA (nanosheet) thickness (nm)			7.0	6.0	5.0	5.0
Number of vertically stacked nanosheets			3	3	4	4
LGAA width (nm) - HP			30	25	20	15
LGAA width (nm) - HD			15	11	6	6
LGAA width (nm) - SRAM			7	6	6	6
LGAA total height (nm)			53	48	57	57
Footprint drive efficiency - lateral GAA - HP			4.93	4.77	5.88	5.52
Device effective width (nm) - HP	106.0	133.0	222.0	186.0	200.0	160.0
Device effective width (nm) - HD	106.0	133.0	132.0	102.0	88.0	88.0
Device lateral pitch (nm)	28	24	22	20	20	20
Device height (nm)	50.0	64.0	53.0	48.0	57.0	57.0
Device width (nm) - HP	6	5	30	25	20	15
Device width (nm) - HD	6	5	15	11	6	[illegible]
Device width (nm) - SRAM	6	5	7	6	6	[illegible]

Screenshot

First Demonstration of GAA Monolayer-MoS_2 Nanosheet nFET with 410 µA/µm I_D at 1V V_D at 40nm gate length

Yun-Yan Chung[1], Bo-Jhih Chou[2], Chen-Feng Hsu[1], Wei-Sheng Yun[1], Ming-Yang Li[1], Sheng-Kai Su[1], Yu-Tsung Liao[2], Meng-Chien Lee[2], Guo-Wei Huang[3], San-Lin Liew[3], Yun-Yang Shen[4], Wen-Hao Chang[4], Chien-Wei Chen[5], Chi-Chung Kei[5], Han Wang[6], H.-S. Philip Wong[1], T. Y. Lee[1], Chao-Hsin Chien[2]*, Chao-Ching Cheng[1]* and Iuliana P. Radu[1]*

[1]*Corporate Research, Taiwan Semiconductor Manufacturing Company, Hsinchu, Taiwan *E-mail: chengcca@tsmc.com*

[2]*Institute of Electronics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan *E-mail: chchien@nycu.edu.tw*

[3]*Failure Analysis Division, Taiwan Semiconductor Manufacturing Company, Hsinchu, Taiwan*

[4]*Department of Electrophysics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

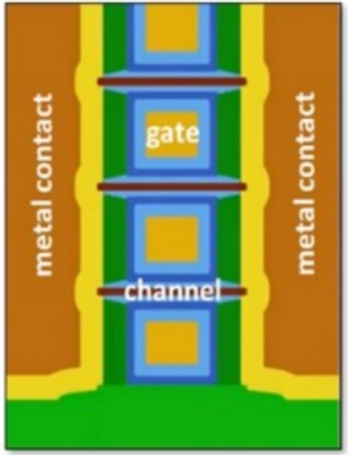
[5]*Taiwan Instrument Research Institute, National Applied Research Laboratories, Hsinchu, Taiwan*

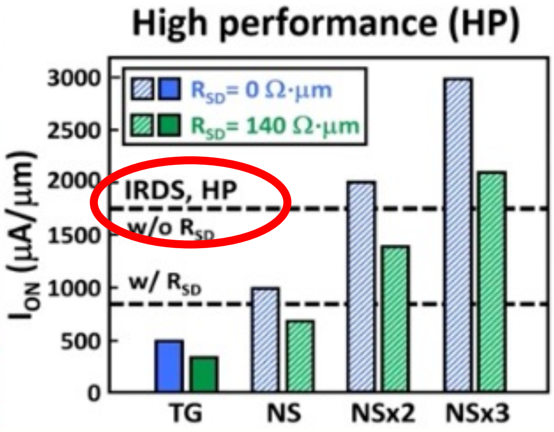
[6]*Corporate Research, Taiwan Semiconductor Manufacturing Company, San Jose, USA*

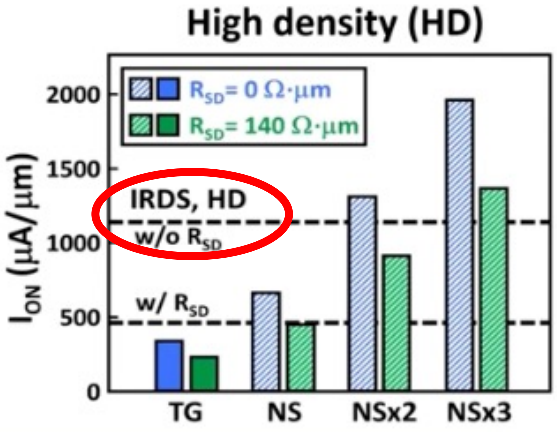
Stacked 2D Performance Simulation

Parameter	L_G	V_{DD}	Mob	EOT	R_C
Value	12 nm	0.6V	70 $cm^2/V{\cdot}s$	0.95 nm	140 Ω·μm [1]

[1] P. C. Shen *et al.*, Nature, 593, pp. 211-217, 2021.
[2] IRDS website: https://irds.ieee.org/editions/2021.





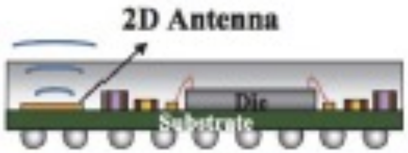
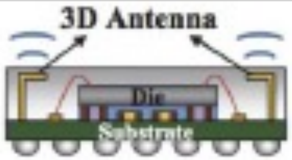


At least 2-stacked 2D nanosheet to meet the 2034 HP and HD target in IRDS.

A Heterogeneous Integration Roadmap [“HIR”]

- Referenced in US Chips Act
- Many Presentations

https://eps.ieee.org/technology/heterogeneous-integration-roadmap.htm

Item	Traditional SiP	New TV SiP
Dimension (mm)	16 x 12	12 x 12
Package Structure		
Passive Component	Side by Side	Die Stacking on Passive
Antenna Integration	2D Antenna Structure	3D Antenna Structure

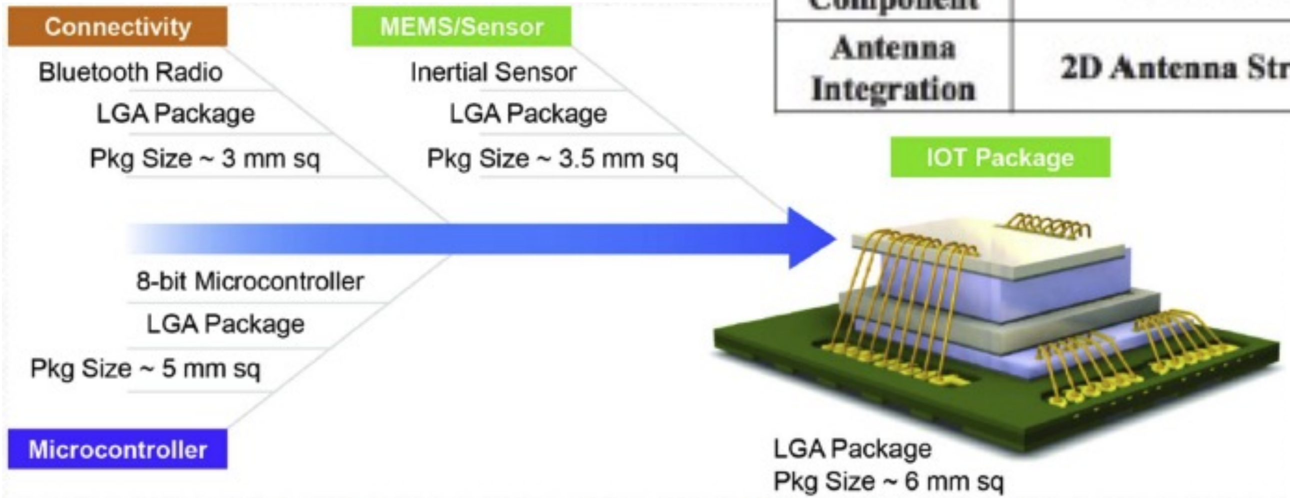
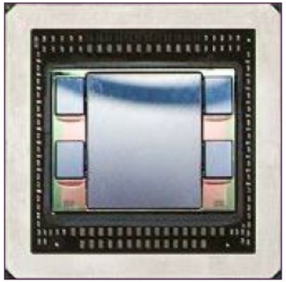


Figure 16. Heterogeneous Integration of IoT Basic Elements [33]

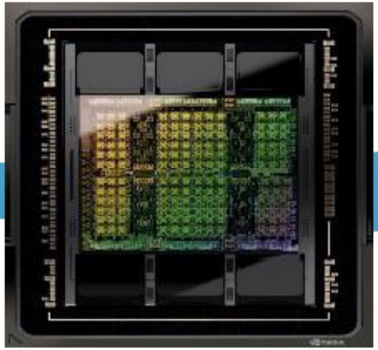
Examples of Multi-die Hi-performance Compute Servers



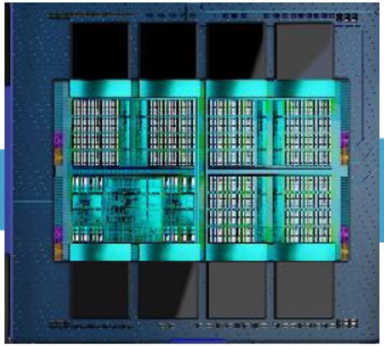
AMD:
Radeon R9
FURY X
(2015)

NVIDIA:
Tesla P100
(2016)

2



2022: NVIDA Hopper H100
GPU core: 80 Billion Transistors
50MB L2, 80GB HBM3 – 3TBps bandwidth

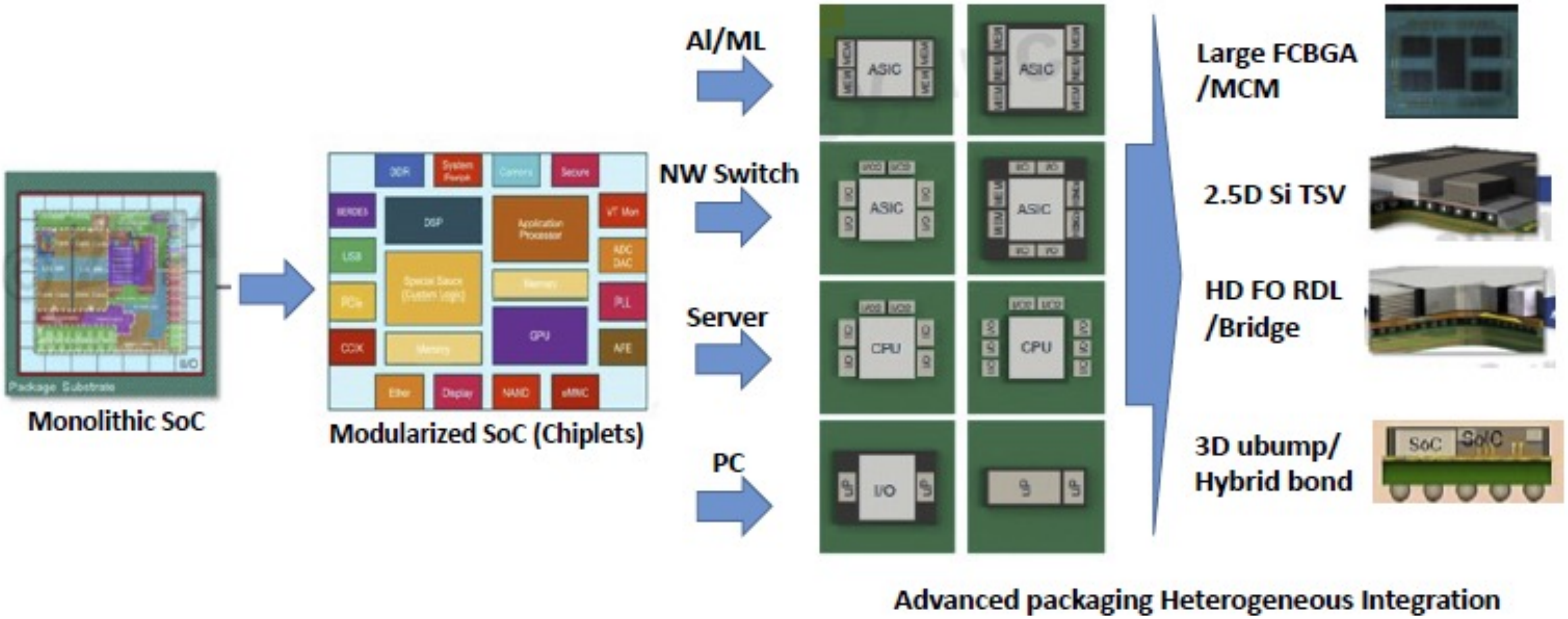


2023: AMD MI300
3GPU+1 CPU
8 HBM3

ITF Semicon USA

IEEE ROADMAPS
IEEE

A "Chiplets" example…



Reference: "The March Towards Chiplets" Ed Sperling & Karen Heyman, December 15, 2022. Semiconductor Engineering

A Wide Bandgap Semiconductor Roadmap [“ITRW”]

https://resourcecenter.ieee-pels.org/roadmap/PELSPRO0020.html

A Network Generations Roadmap ["INGR"]

IEEE INGR
International Network Generations Roadmap

Applications and Services	Millimeter Wave and Signal Processing
Artificial Intelligence / Machine Learning	Optics
Connecting the Unconnected	Satellite
Deployment	Security and Privacy
Edge Services and Automation	Standardization Building Blocks
Energy Efficiency	Systems Optimization
Massive MIMO	Testbed

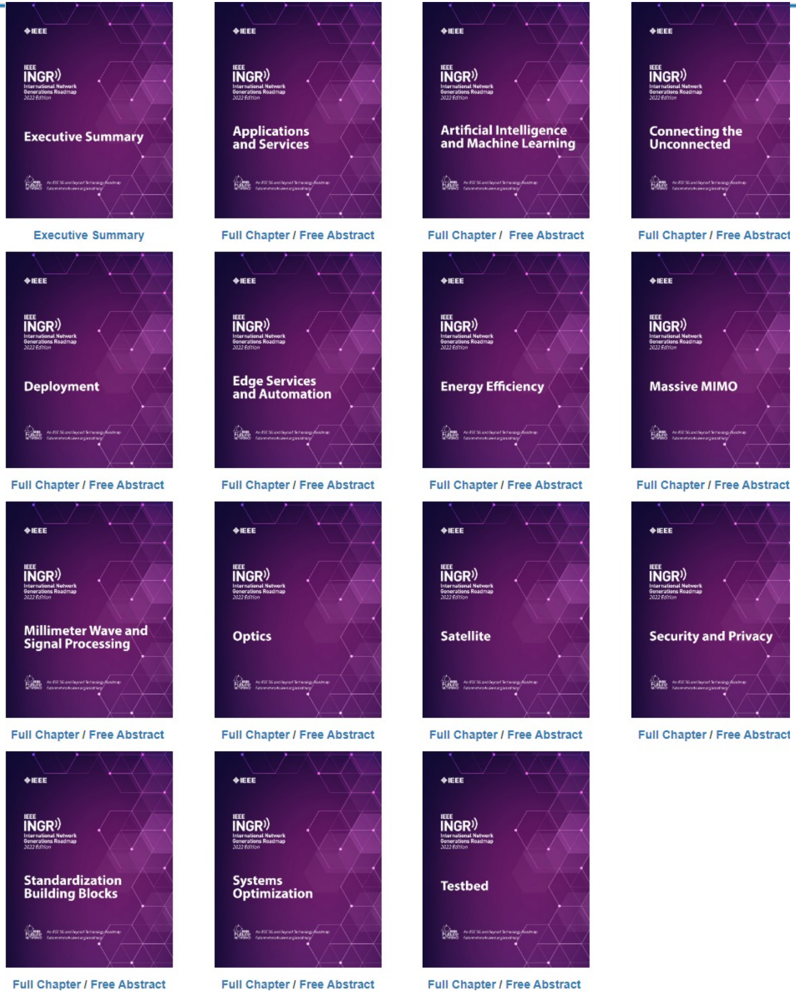
- >1.5k Views per month
- Many Presentations
  - >6 Conferences
  - 7 Webinars
  - 2 Technical Workshops
  - Podcast series
  - >2k registrants

https://futurenetworks.ieee.org/roadmap/

IEEE ROADMAPS™
IEEE

INGR

14 Working Groups



IEEE ROADMAPS™

IEEE

"Connecting the Un- and Under-Connected" WG

…Identify GAPS to be filled for increased Access and Relevance

3+ Billion people have no Internet connectivity!

- System-level customization & optimization of Technologies
- Affordable
- Relevant
- Local Language or HCI* for the Illiterate
- Spectrum allocation to increase reach and coverage
- Enable deployment in remote areas thru use of renewable energy

IEEE ROADMAPS™

IEEE

* HCI – Human Computer Interface

CTU – Architecture Model for CTU

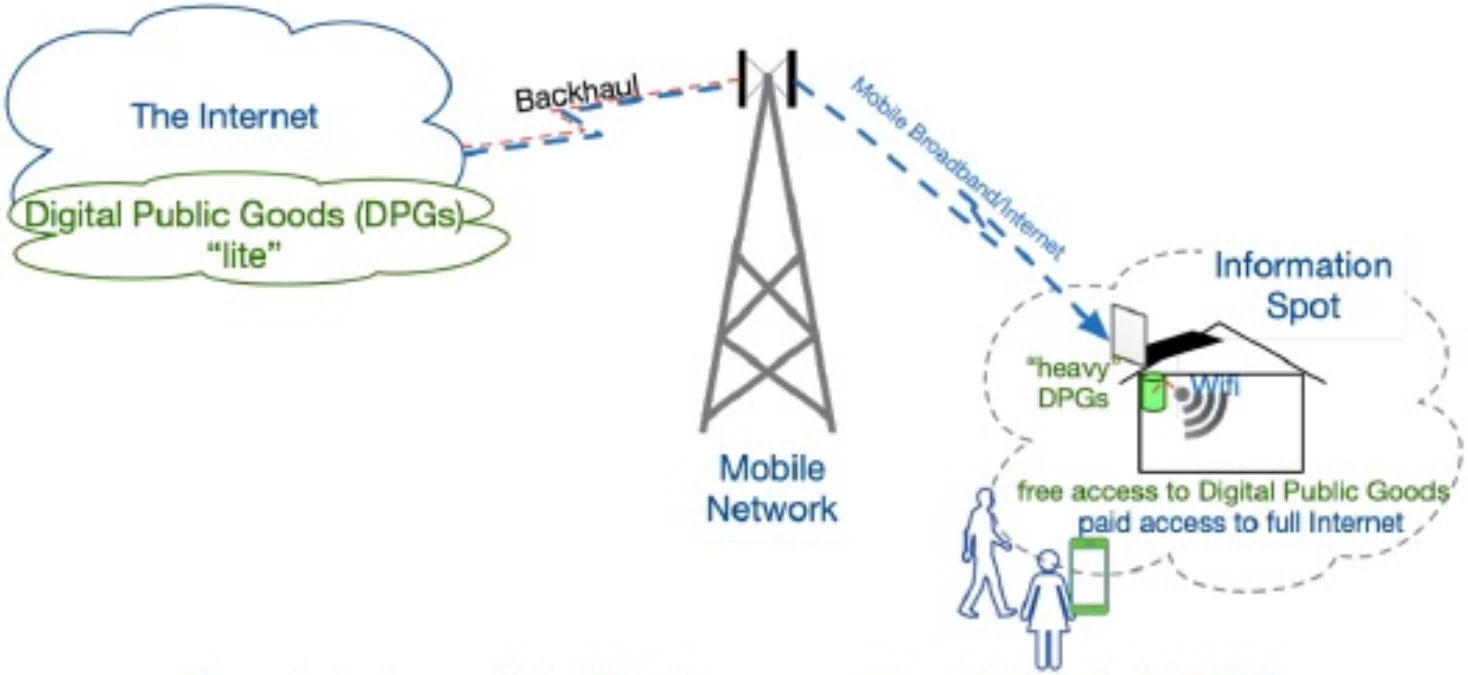


Figure 6. Architectural Model for free access to Digital Public Goods (DPG).

Check out BasicInternet.org

CTU – IEEE 802.22 Wi-FAR Standard

Figure 13. Benefits of IEEE 802.22 Wi-FAR® standard.

INGR – Applications and Services WG

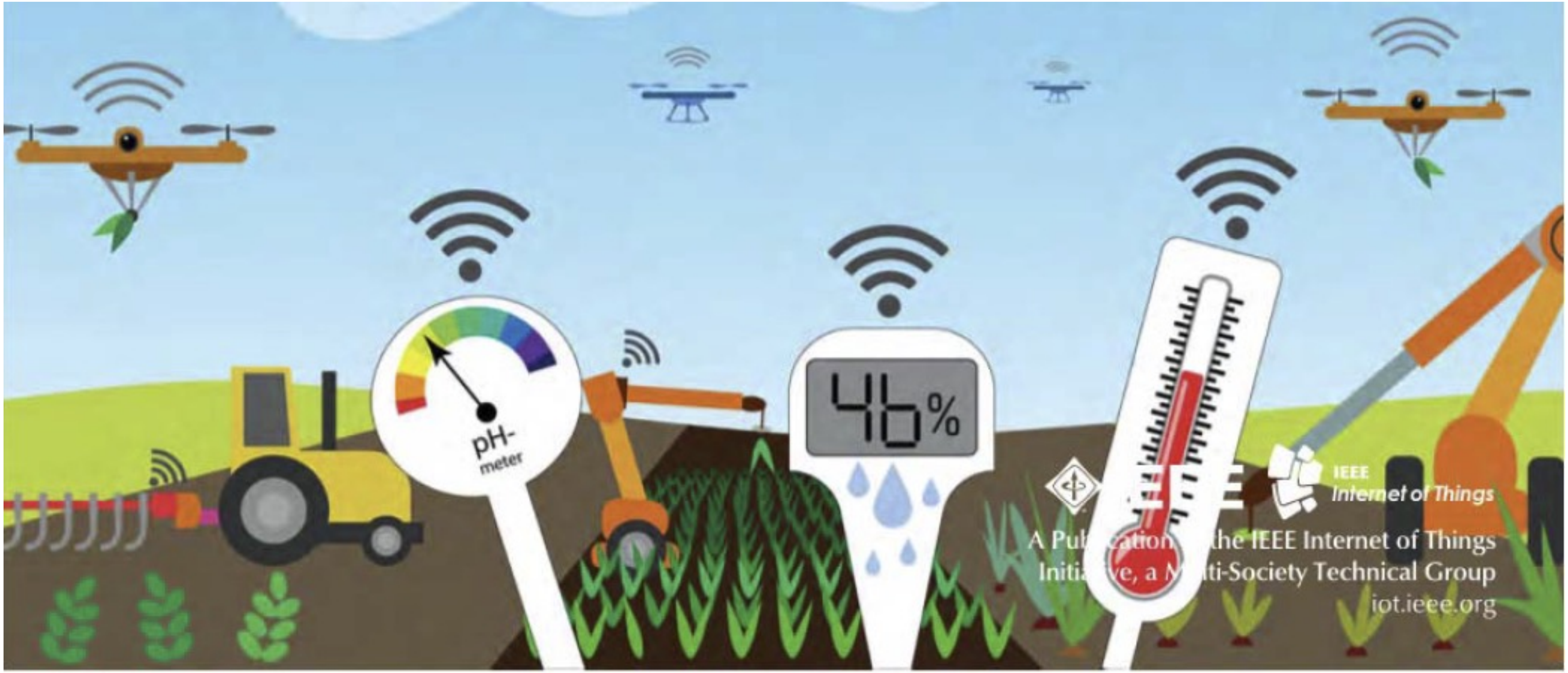
…Multi-disciplinary Framework for Networks and Ecosystems, and Governance

- New industries and public works functions:
  - Agriculture
  - Education
  - Healthcare
  - Electrical Power
  - Media and Entertainment
  - Public Safety
  - Transportation
  - Water treatment and Wastewater treatment

IEEE ROADMAPS™

IEEE

IoT, Networking & Computing in Precision Agriculture



Ref: IoT Magazine Dec. 2019

IEEE ROADMAPS

IEEE

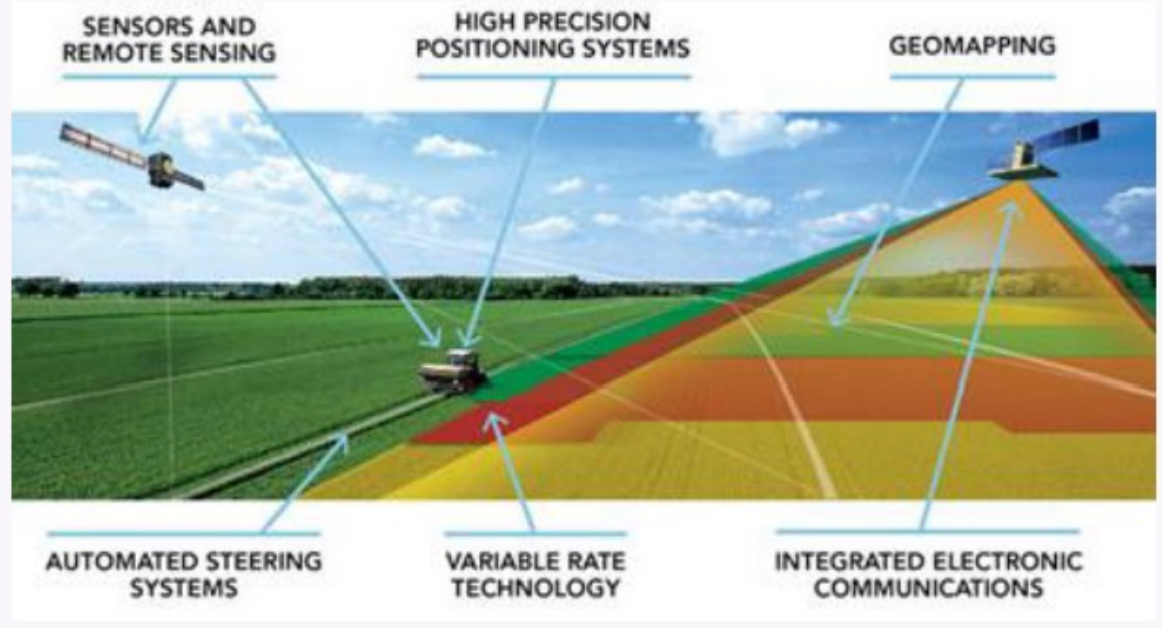
Precision Agriculture

Combines…

- ➢ Remote sensing
- ➢ GPS (global positioning system)
- ➢ Mapping software

Enables Decision Making…

- ➢ Site-specific
- ➢ Variable rates for fertilizers, pesticides etc.



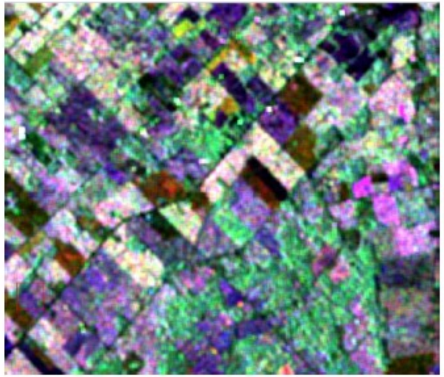
Ref: Jinfei Wang, Western Ontario University, August 2022

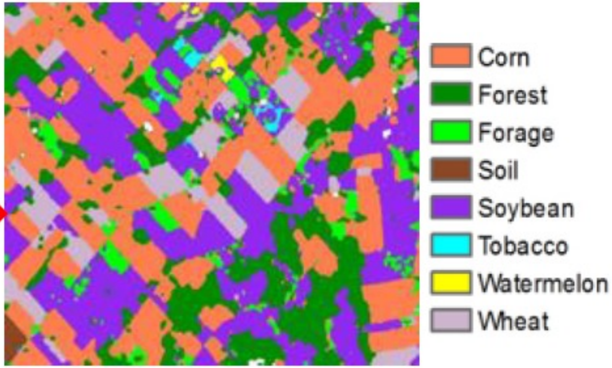
IEEE ROADMAPS™ IEEE

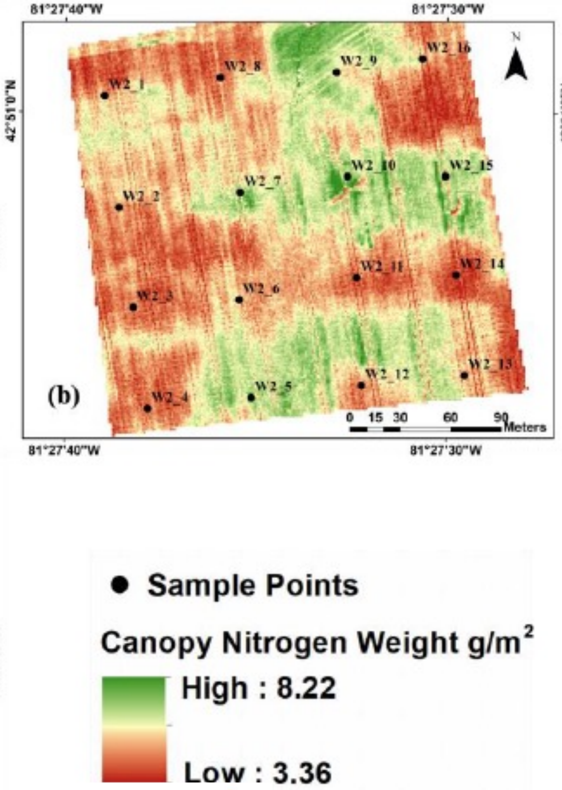
Precision Agriculture

UAV-derived N_2 estimation maps

Multi-temporal radar satellite data







Ref: Jinfei Wang, Western Ontario University, August 2022

Precision Agriculture – Disease detection examples

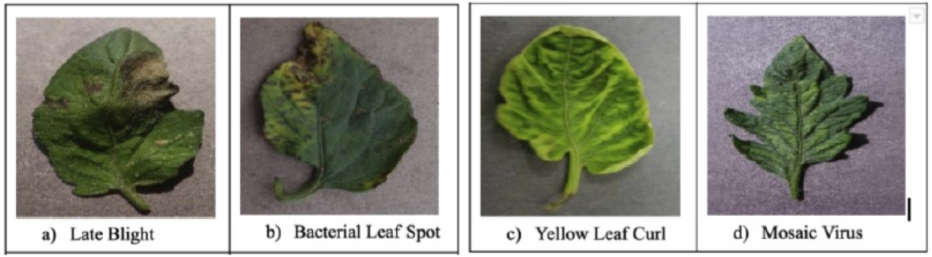


Fig. 2. Some examples of disease classes from training dataset

Ref: Chung et.al., “Remote Crop Disease Detection Using Deep Learning with IoT”, 2022 IEEE GHTC, September 2022

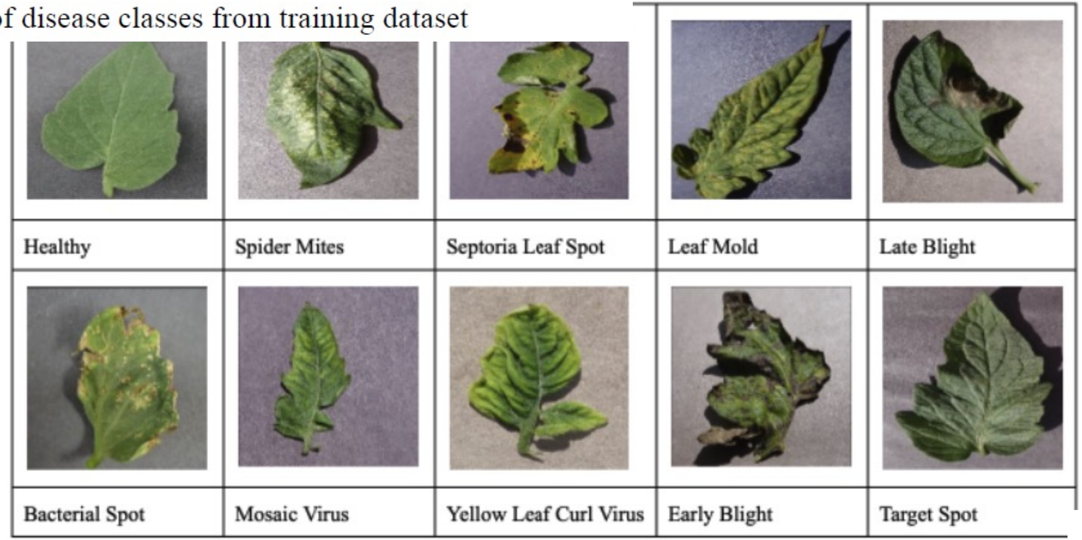


Fig. 5. Different Tomato Disease Classes in Our Dataset

Towards a 5G Testbed…*Present 5G has Many Limitations*

- Limited range due to Spectrum mid- and high-band
- Limited mmWave integration
- Security and Privacy issues
- Limited deployment of Standalone mode
  - Limited thruput, latency etc.

Operators need a Testbed to evaluate 5G enhancements

IEEE ROADMAPS™
IEEE

A 5G/6G Innovation Testbed

...launched by IEEE Future Networks to enable the Industry

- **Test**
  - Efficient, economic 5G conformity testing within the 3GPP standards ecosystem
- **Experiment**
  - Flexible, scalable, and "always on" for proof-of-concept development within a wide range of 5G use cases and scenarios
- **Collaborate**
  - Partner with other companies to test compatibility or enhance quality of service in secure, private environments
- **Innovate**
  - Adjust, transform, and integrate new network functions or features

IEEE 5G/6G Innovation Testbed™

testbed.ieee.org

IEEE ROADMAPS™

IEEE

"On the horizon" Roadmaps

Int'l Tech Roadmap of Power Electronics for Distributed Energy Systems

IEEE PES Power & Energy Society®

Sustainable Energy

IEEE ROADMAPS™

IEEE

Other Roadmaps under way

IEEE brain

Instrumentation & Measurements for Brain [or Healthcare Systems]

Smart Lighting

Telepresence

LEOS *(Lo Earth Orbit Satellites)*

Public Safety

Reliability

IEEE ROADMAPS™

IEEE

What can YOU do?

- **Participate** in the Development
- **Use** the Roadmaps
- Help industry participants **Develop** a Roadmap at their company using our methodology
  - ***Especially Young Professionals!!***

Contact:
roadmaps@ieee.org