Drone surveillance and tracking using cost-effective 3D AESA Radar

Speaker:

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Chairman & C.E.O, Tron Future Tech Inc.

Tron Future Tech Inc.

Our Mission:

- We help our customers collect, analyze and utilize valuable data through fundamental sensor and communication inventions.

Area of Focus:

- Ultrathin all-digital/hybrid phased array based radar/communication turnkey systems.
- Value-added data processing infrastructure.

About Us:

>25% employee with Ph.D. degrees from Caltech/USC/MIT/UCLA/NTU/NCTU/NTHU etc.

Our Taiwanese customers in 2020:

- National Space Program Office.
- Changhua offshore wind farms.
- R.O.C. Military.
- Demonstration roadshows to Asian, European and the U.S. partners/customers.

Address:

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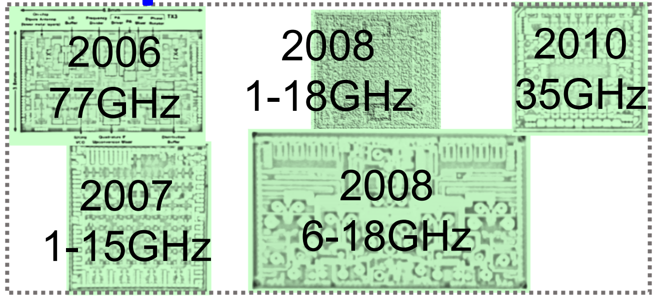
Hsinchu City 30069, Taiwan, R.O.C.

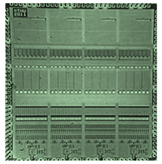
Our History and Experiences

~ 2008 | ~2010 | 2011 | 2012 | 2013 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

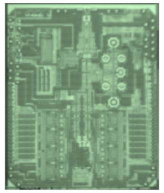
Chip Level



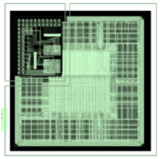
Phased-Array ICs (Participation)



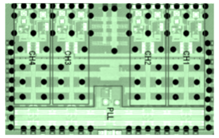
IR Radar



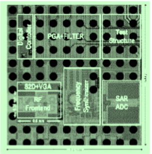
79GHz Radar



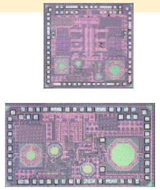
Heterogeneous Integration Platform



Ka-Band Phased Array



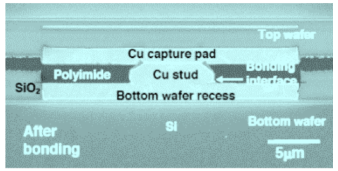
X-band Digital RF Front-End



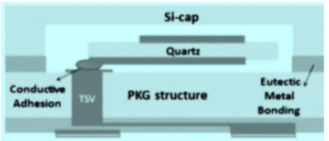
S-band Digital RF Front-End

Wideband X-band Digital RF Front-End

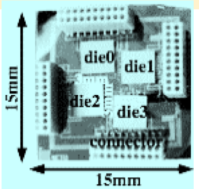
Package Level



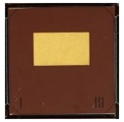
2008 3D Device Stacking



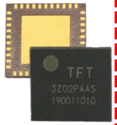
Crystal Resonator



3D Flexible System



Patch AiP

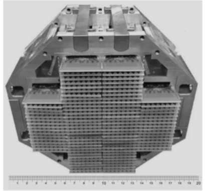


QFN Production

High-reliability packaging

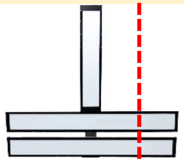
System

Total Solution



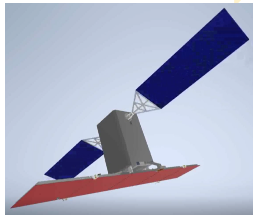
35GHz 768-Element Hybrid AESA

X-band Digital AESA Demonstrator



S/X-band Portable AESA Radar

Data API



Satellite Downlink,

Satellite SAR

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Agenda

- **Drone detection technologies**

- **Cost-effective AESA Design for Drone Detection**
  - **Cost reduction requirements.**
  - **Doppler processing requirements.**
  - **3D requirements.**
  - **Development updates.**

- **Summary**

Drone is hard to be detected by naked eyes.

Why Radars miss Drones?

- Major reasons is low-cost, small, slow-moving drone is never a threat until the last decade.

- Technological reasons:
  - Small size ➔ small RCS signal buried in many noisy environments.
  - Slow-moving ➔ moving target detector sets a higher threshold.
    - Ground/Sea clutters.
    - Related to drone pulses, PRF, RPI, CPI design etc.
  - Earth geometry and landscape blockage.
  - Too many similar targets for be tracked.

- Trade-offs between:
  - "false alarm" versus "missed targets"
  - "cost" and "performance".

<u>Radars need to be tailored to be able to detect drones.</u>

Drone Detection Technologies

Technology	Pro	Cons
Microphone (Array)	❑ Low cost solution for evidence of existence. ❑ Can use sound signatures to identify drone types.	❑ Provides angular but not distance information. ❑ Limited sensitivity in noisy environments.
Point-to-Zoom Camera (EO), IR	❑ Suitable for secondary device for target confirmation.	❑ Limited View of Field (FOV). ❑ FOV and range trade-offs. ❑ Sensitive to weather conditions.
RF	❑ Can be completely passive. ❑ Can also locate the drone operator. ❑ Can use RF signatures to identify drone types.	❑ Not working for autonomous drone.
2D Radar	❑ Weather-proof. ❑ Relative low cost.	❑ Extract 2D path without altitude information.
3D Radar	❑ Weather-proof. ❑ Extract 2D path without altitude information.	❑ Typically expensive.

Supplier surveys: **“https://dronecenter.bard.edu/files/2019/12/CSD-CUAS-2nd-Edition-Web.pdf”**

Agenda

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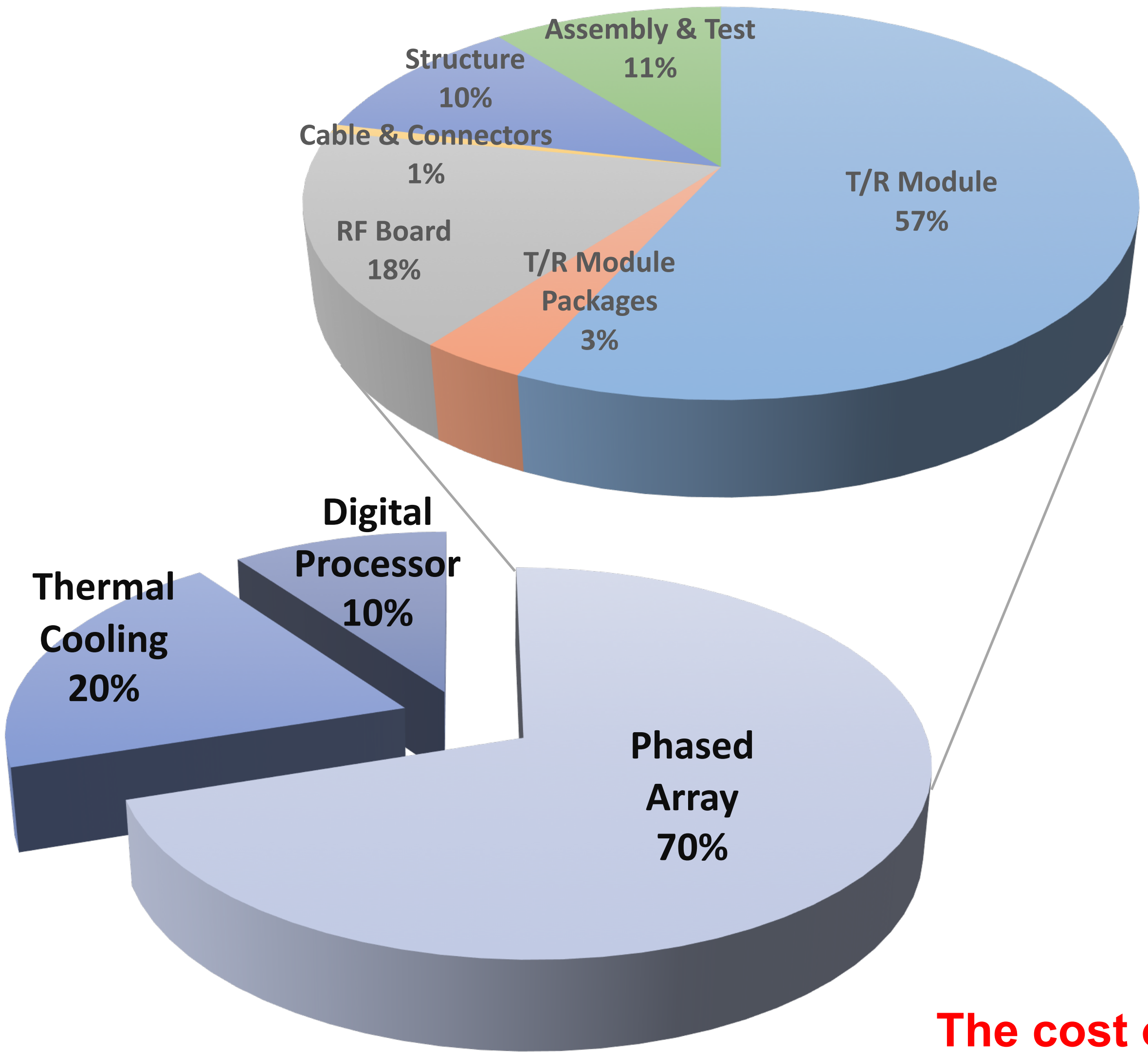
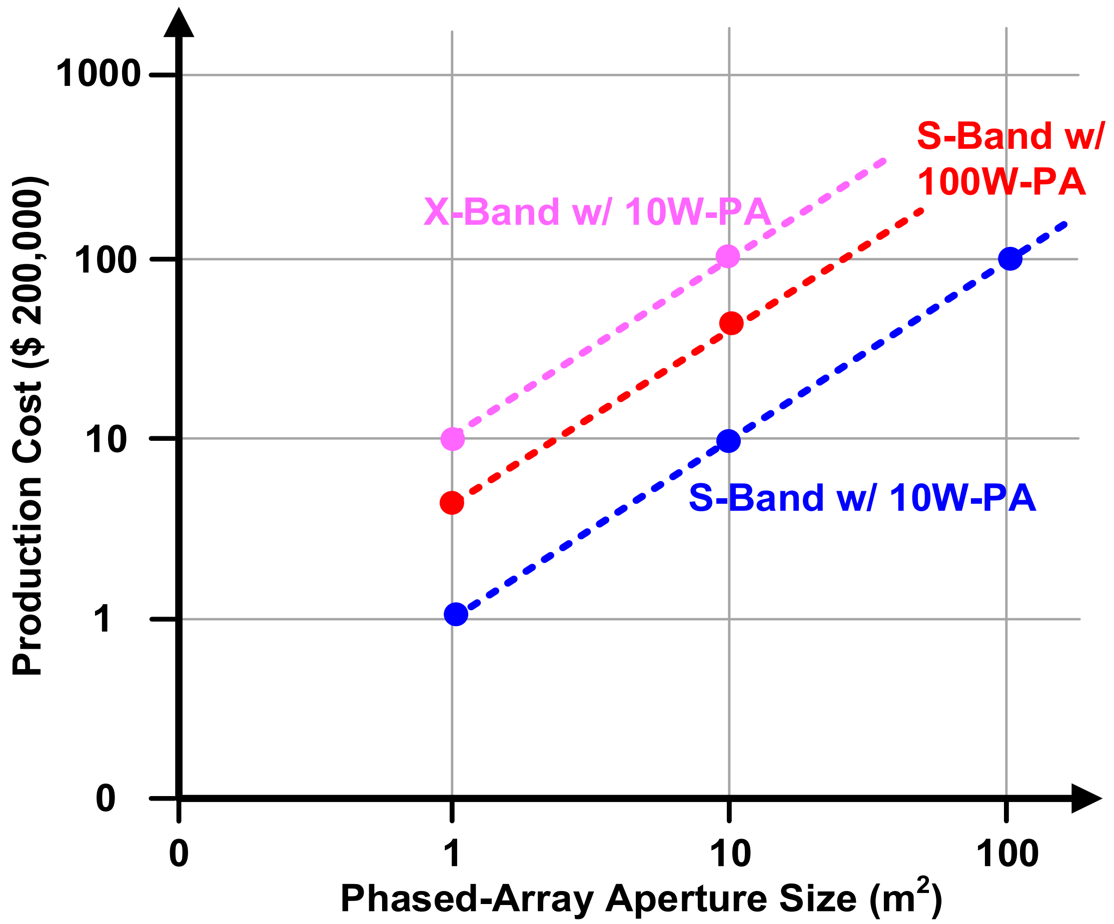
AESA Radar Cost Issues

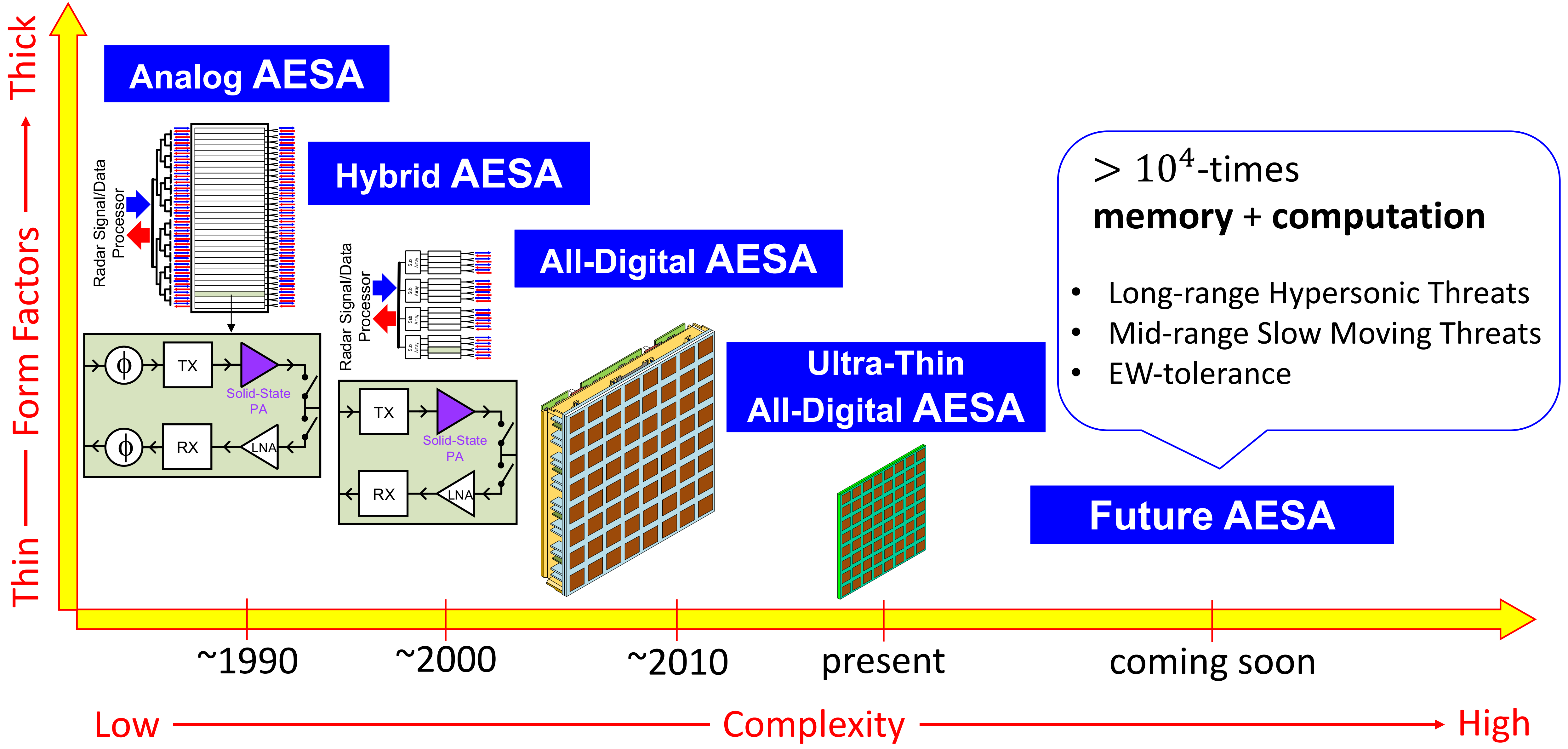




The cost of phased array is proportional to the total no. of array elements and PA power.

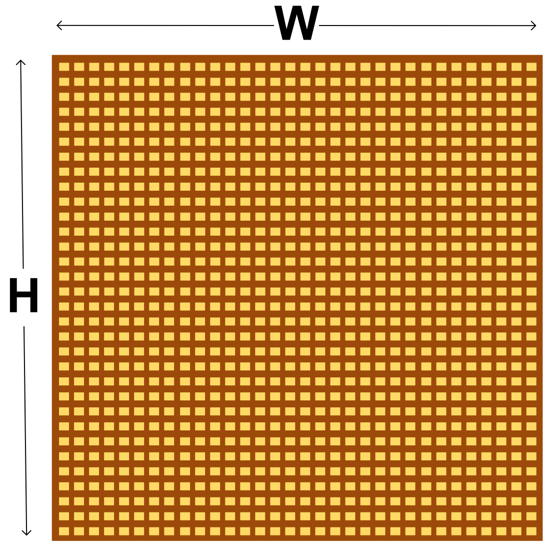
[Ref] Herd J.S., Conway M.D. The Evolution to Modern Phased Array Architectures. *Proceedings of the IEEE*, 2016, Vol. 104, No. 3, pp. 519-529.

AESA Trend and Our Design Strategy

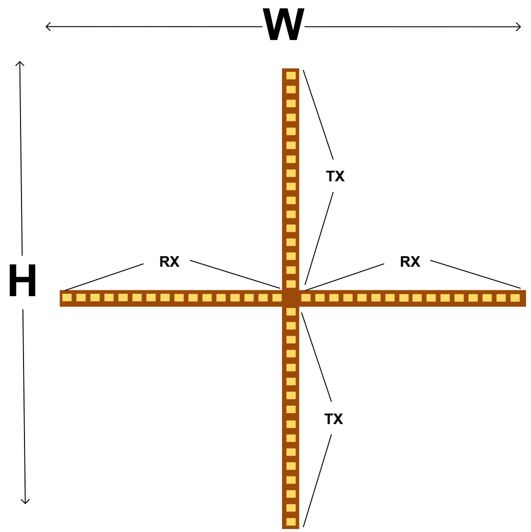


3D AESA Cost Reduction

- Fully Populated Planar AESA.
- Orthogonal Linear Digital AESA.



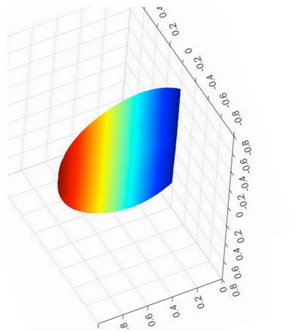
Comparable side-lobe suppression, mainlobe.



No. of Elements	W*H	H (TX), W (RX)	1024 ➔ 32 (3% cost)
Peak Power	$P_0 * W * H$	$\sim P_0 * (H)$	3% original power
Antenna Gain	$\propto W * H$	$\propto W$ (RX), $\propto H$ (TX)	3% gain for RX & TX
Max. Dwell Time	T_0	T_0* H	32 times with RX multibeam
SNR	SNR_0	$SNR_0 \cdot H/H^3$	1/1024 ➔ (18% detection range)
Cost per Area	C_0	C_0	Similar cost per coverage area.

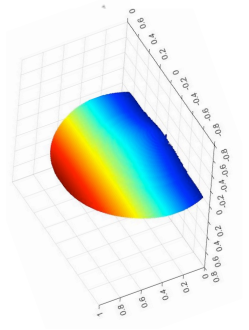
Basic Operational Concepts

- **Transmitter fan-shaped pattern.**



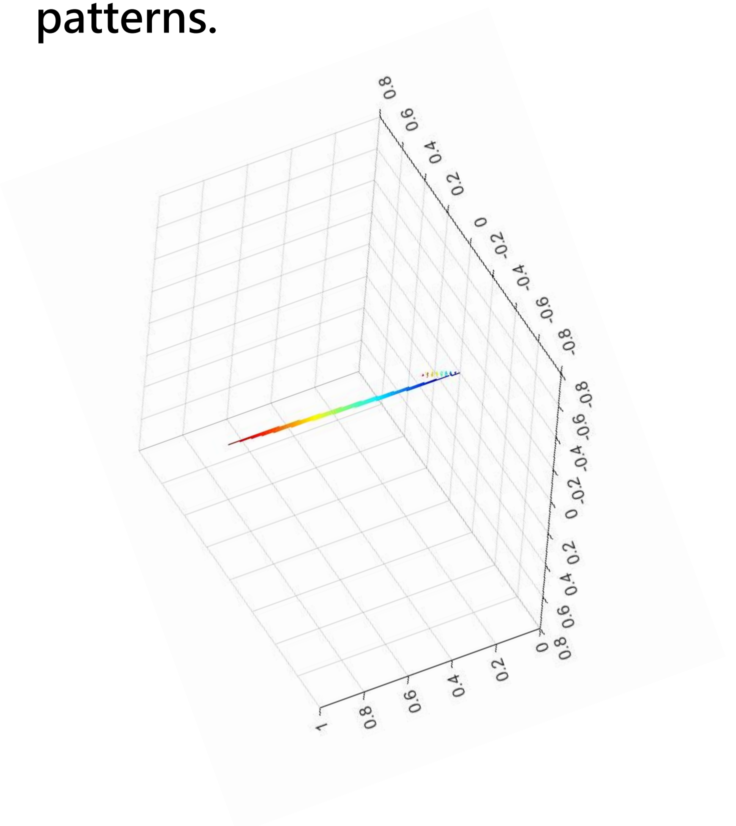
- TX Horizontal Scanning.

- **Receiver multi-beam pattern.**



- RX Vertical Multibeam Scanning.

- **Equivalent transmit-to-receive patterns.**

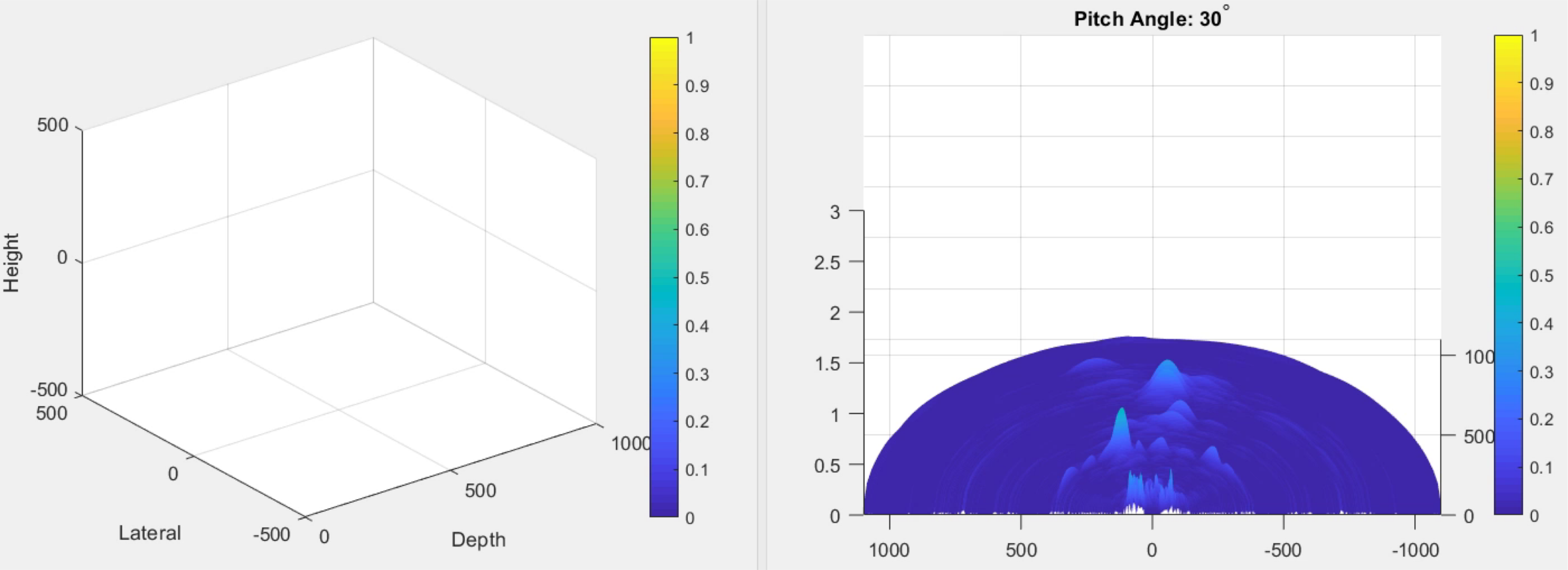


- Equivalent Radar Beam Pattern

- **This is just an example of how to achieve 3D radar using small RTX elements; but this approach is insufficient for drone detection.**

An Urban Surveillance Scenario

16TX 16RX 3D Digital Beamforming Example



- **Demonstrations from an early low-power (<1W) proof-of-concepts.**

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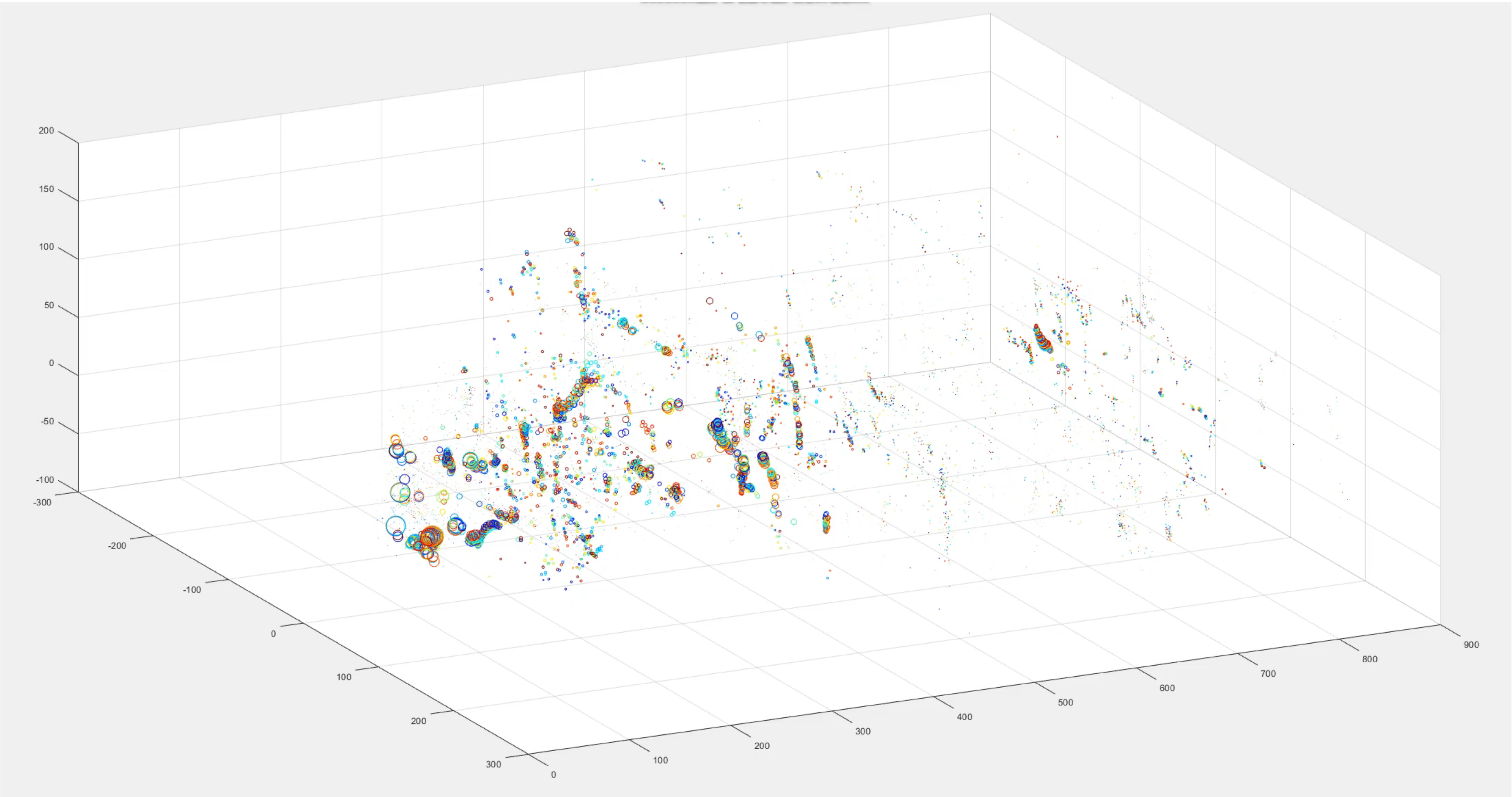
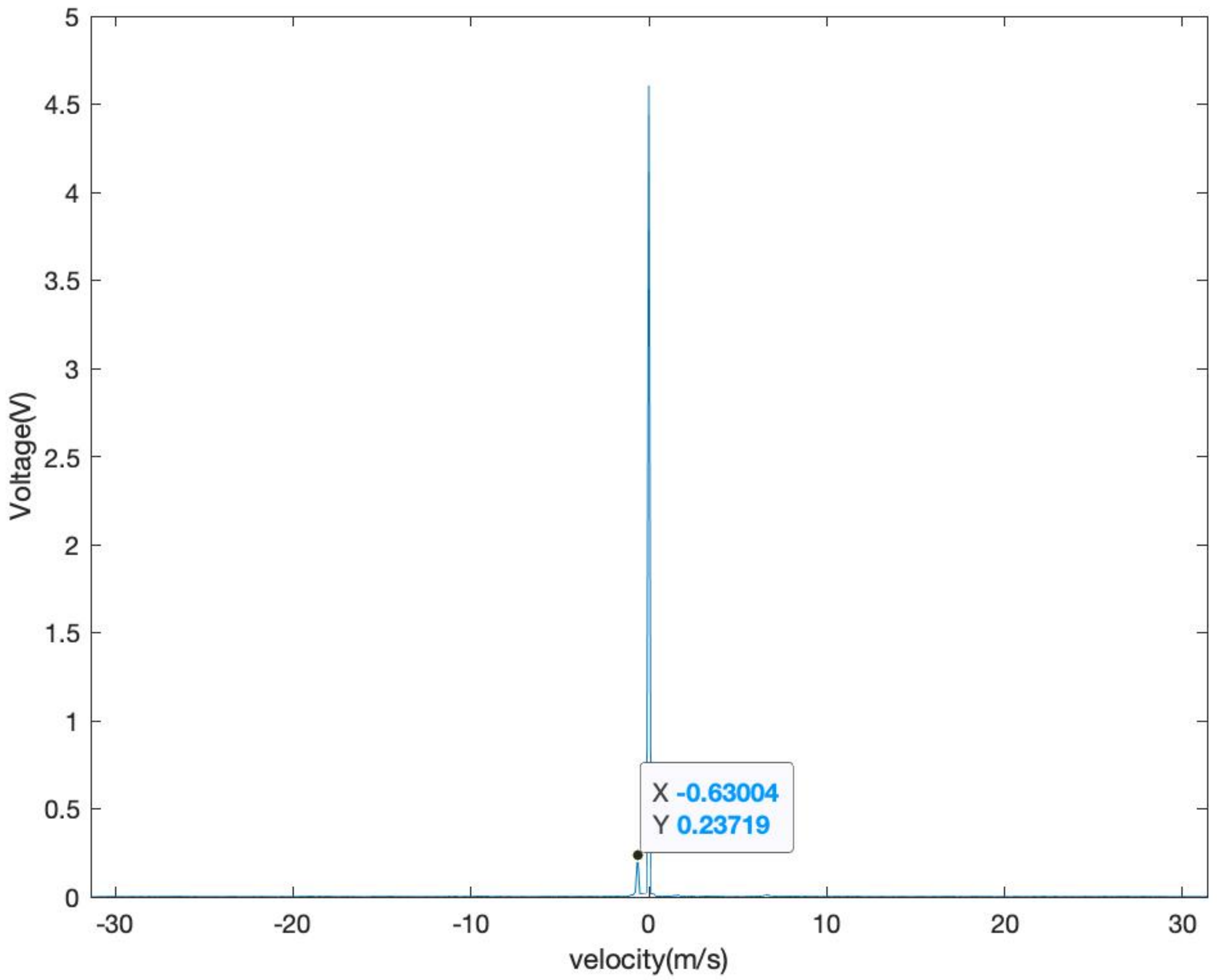
3D Eigenspace-based Beamforming



- Eigenspace-based Beamforming achieve fine 3D resolution (16 Horizontal RX, 16 Vertical RX)
- Clutter (building, artifacts) dominates detection results

A Typical Slow-moving Drone Target



velocity spread:

Ground clutter	-1m/s ~ +1 m/s
Drone velocity	-20m/s~ +20 m/s
Automobile velocity	-30m/s ~ +30m/s

- We need to remove the strong ground clutter using doppler processing.

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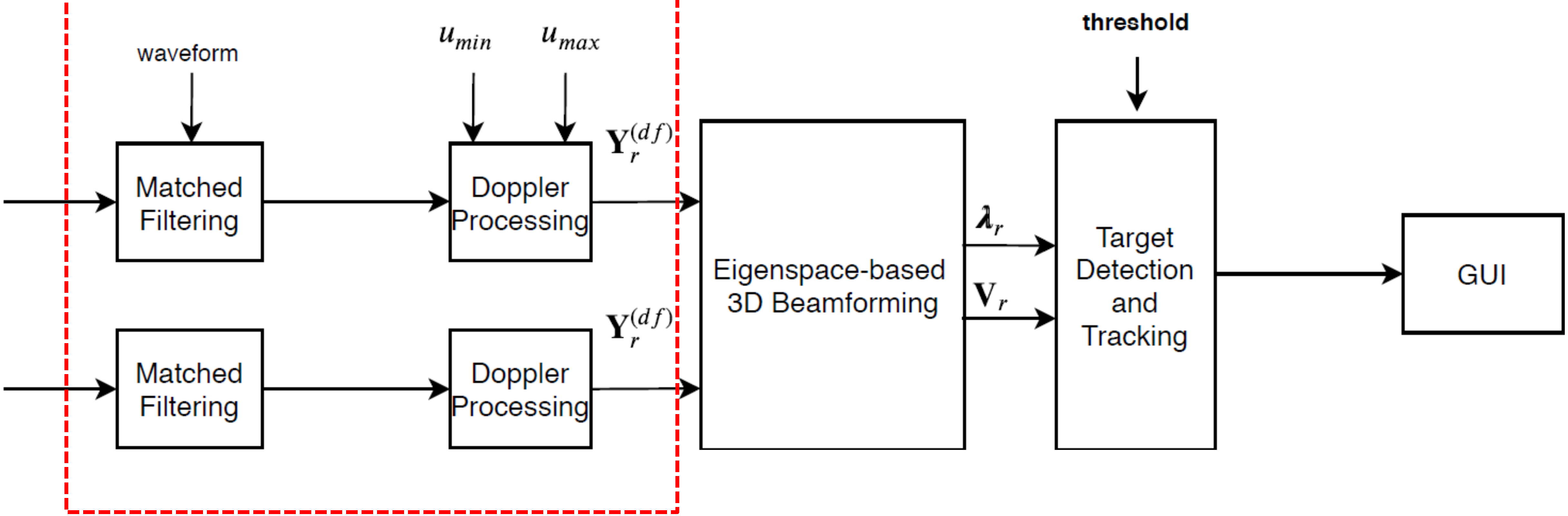
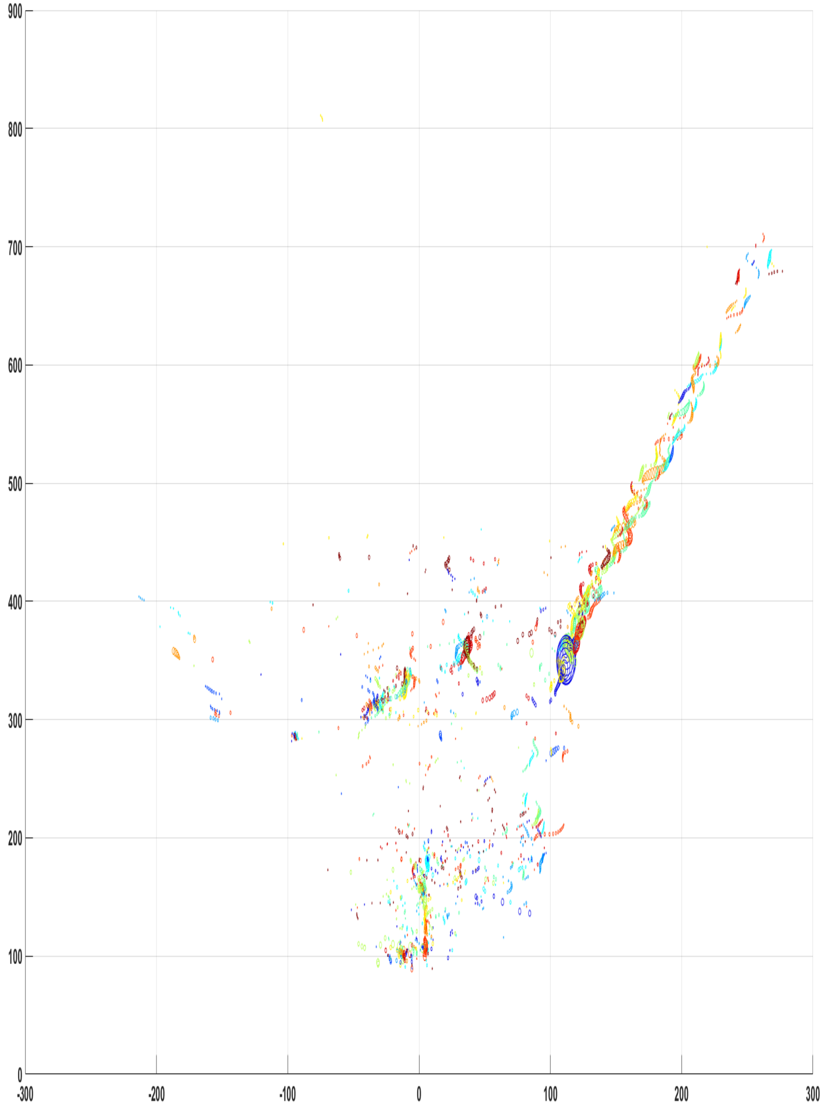
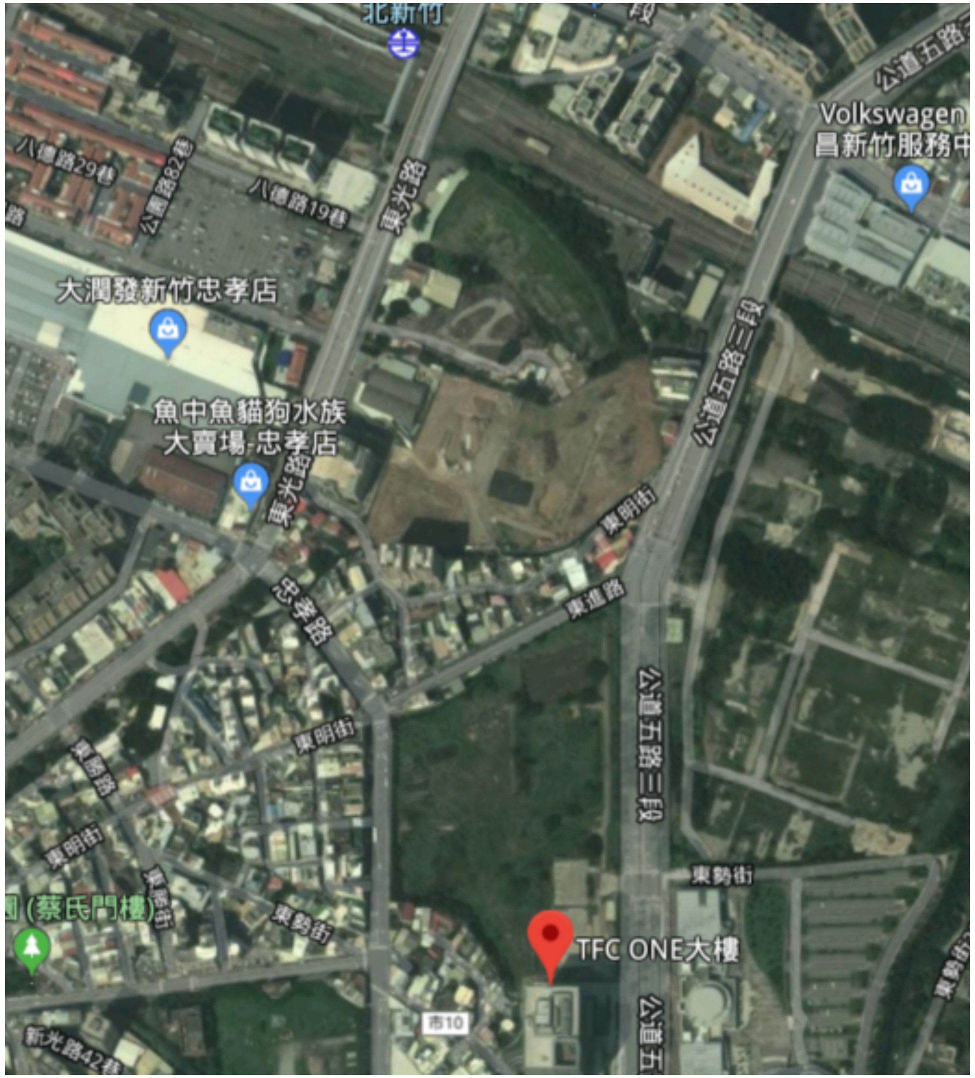
Radar Signal Processing Architectures



- All-digital AESA architecture.
- **(Range discrimination):** Wide-band large duty-cycle radar pulse waveforms.
- **(Velocity discrimination):** Pulsed-Doppler processing for better clutter performance.
- **(Spatial discrimination):** Eigenspace-based beamform processing to achieve 3D super high angular resolution, with smaller number of RTX elements.

2D Radar with Doppler Moving Target Detector





- **Moving targets (cars) in urban areas will affect drone detection.**
- **Ground surface or target pattern recognitions needs to used to identify drone from cars.**

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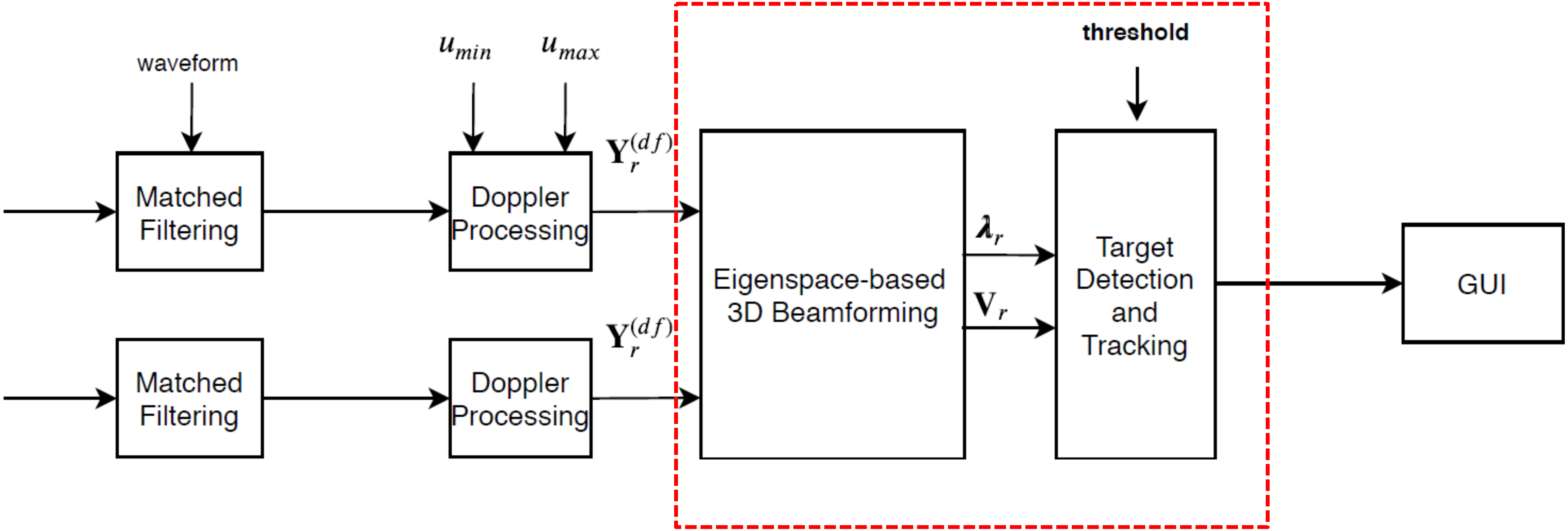
Radar Signal Processing Architectures



- All-digital AESA architecture.
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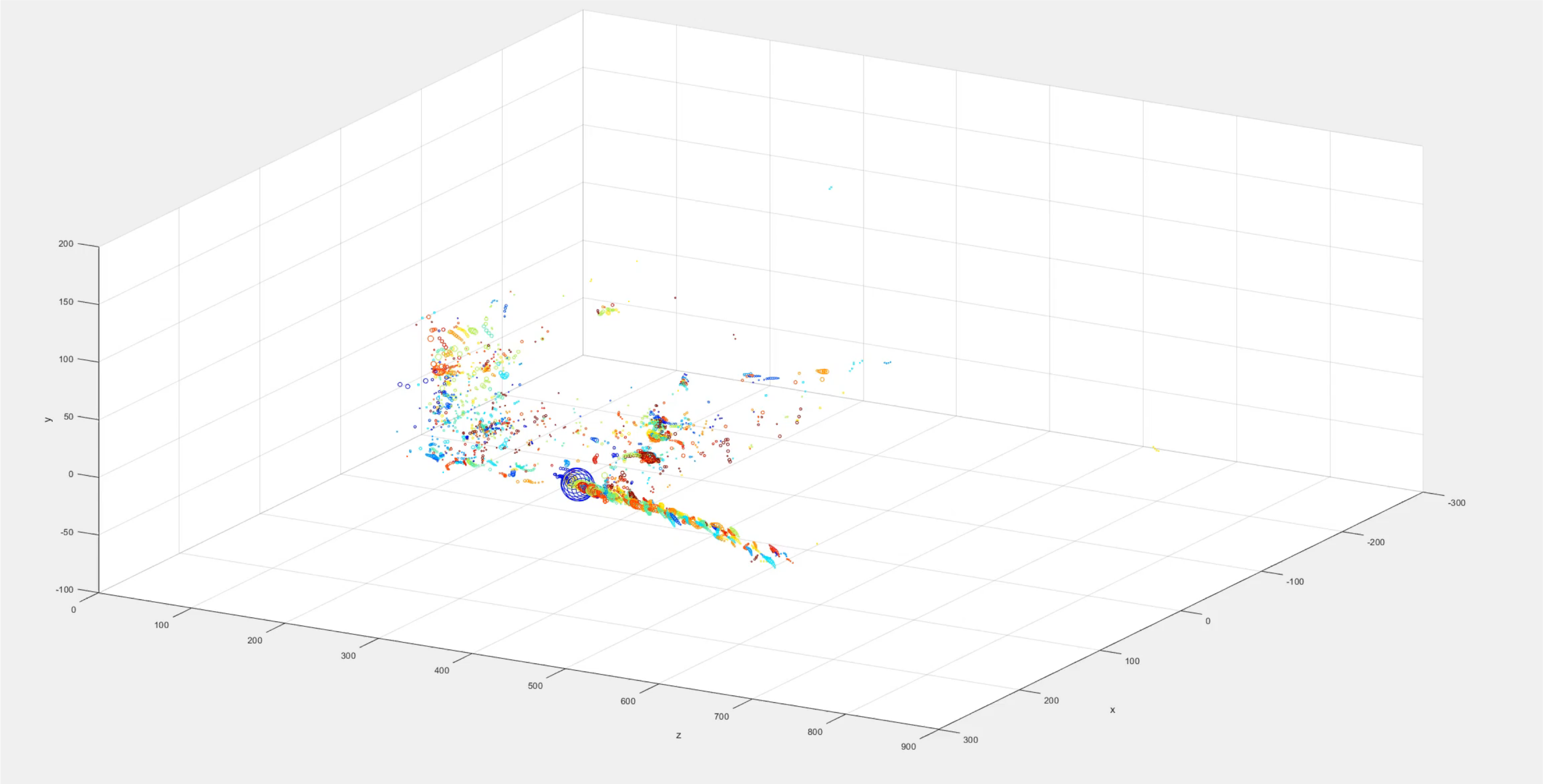
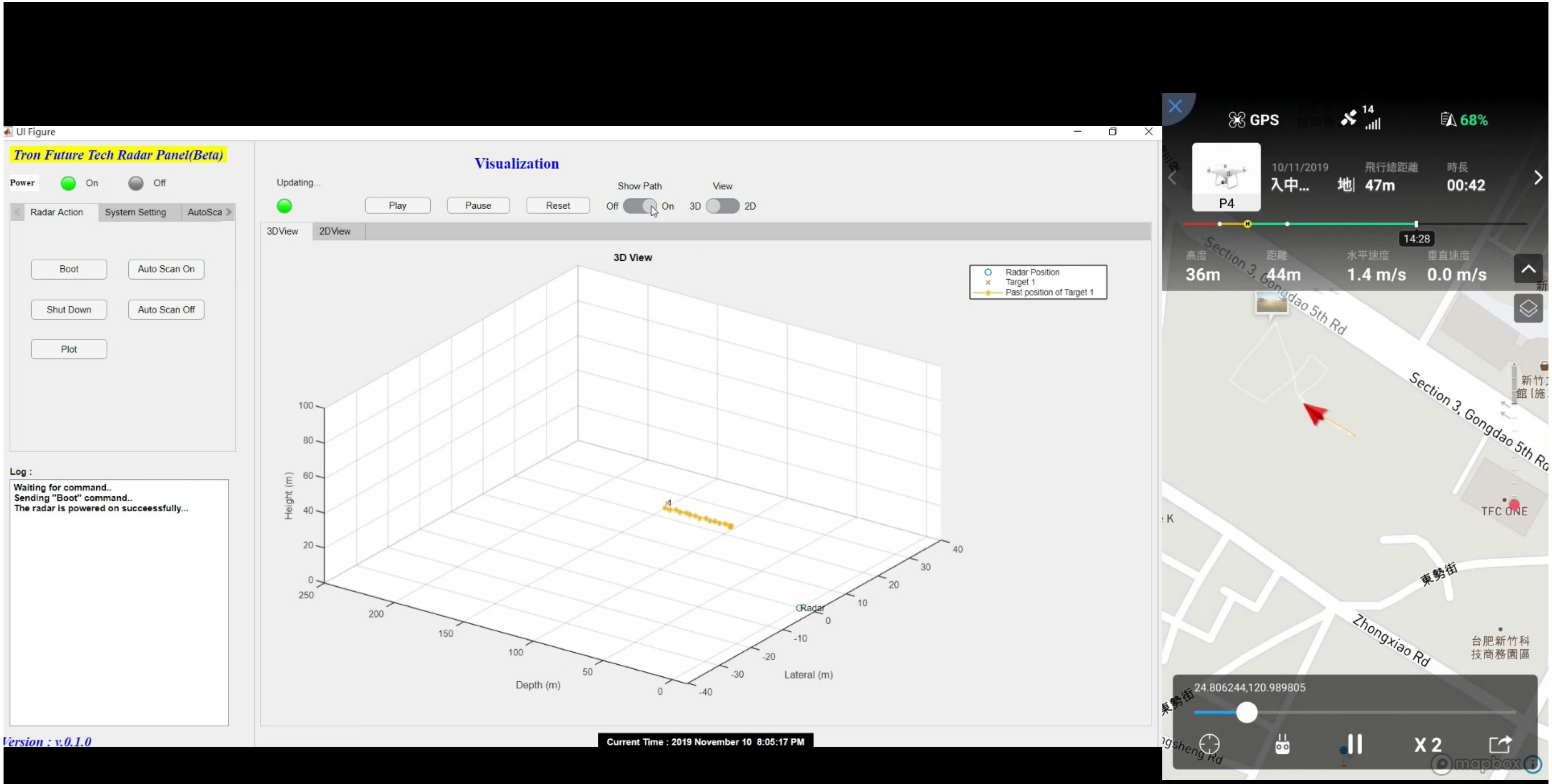
3D Pulsed-Doppler Radar with only 32 RX.



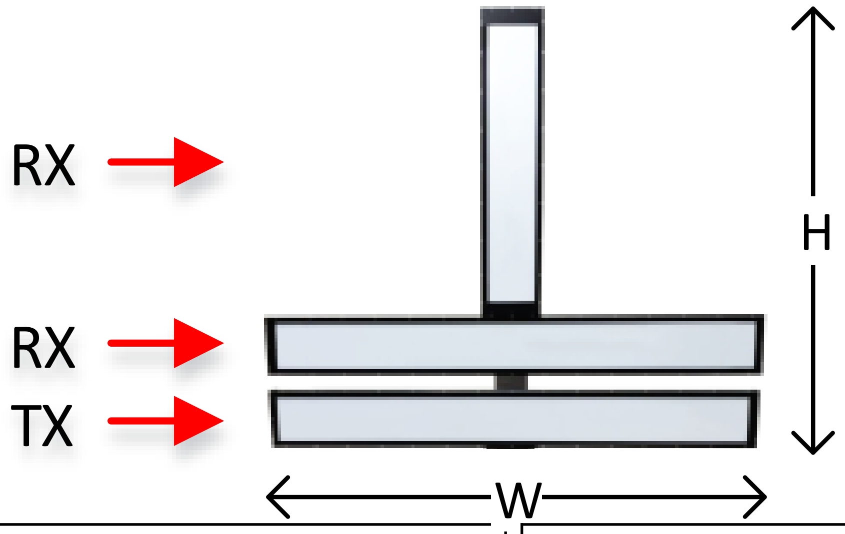
Ground surface estimation and target pattern recognition needs to used to identify drone from cars.

Drone Tracking



Drone tracking processed data (accelerated replay of early demonstrations)..

S/X-band Cost-Effective AESA



Band	S-band (2.9-3.1GHz)
No. of Elements	32 TX, 48 RX
AESA Width/Height/Weight	180cm / 145cm / 50KG
Peak EIRP	>20kW
Power Consumption	700W
Beamwidth	3.5°(H), 7°(V)
Detection Range **Simulated Detection Range**	2km@0.01m² ， >2Hz Tracking 4km@0.01m² ，
First Shipping for Field Test	Q4, 2019

Band	X-band (9.0-9.5GHz)
No. of Elements	64 TX, 96 RX
AESA Width/Height/Weight	125cm / 120cm / <40KG(Est.)
Peak EIRP	>15kW
Power Consumption	300W (Est.)
Beamwidth	1.7°(H), 3.4°(V)
Detection Range **Simulated Detection Range**	 1.8km@0.01m² ， >2Hz Tracking
First Shipping for Field Test	Scheduled Q3, 2020

- **The weight will be 15-20kg and the structure will be foldable in late 2020.**

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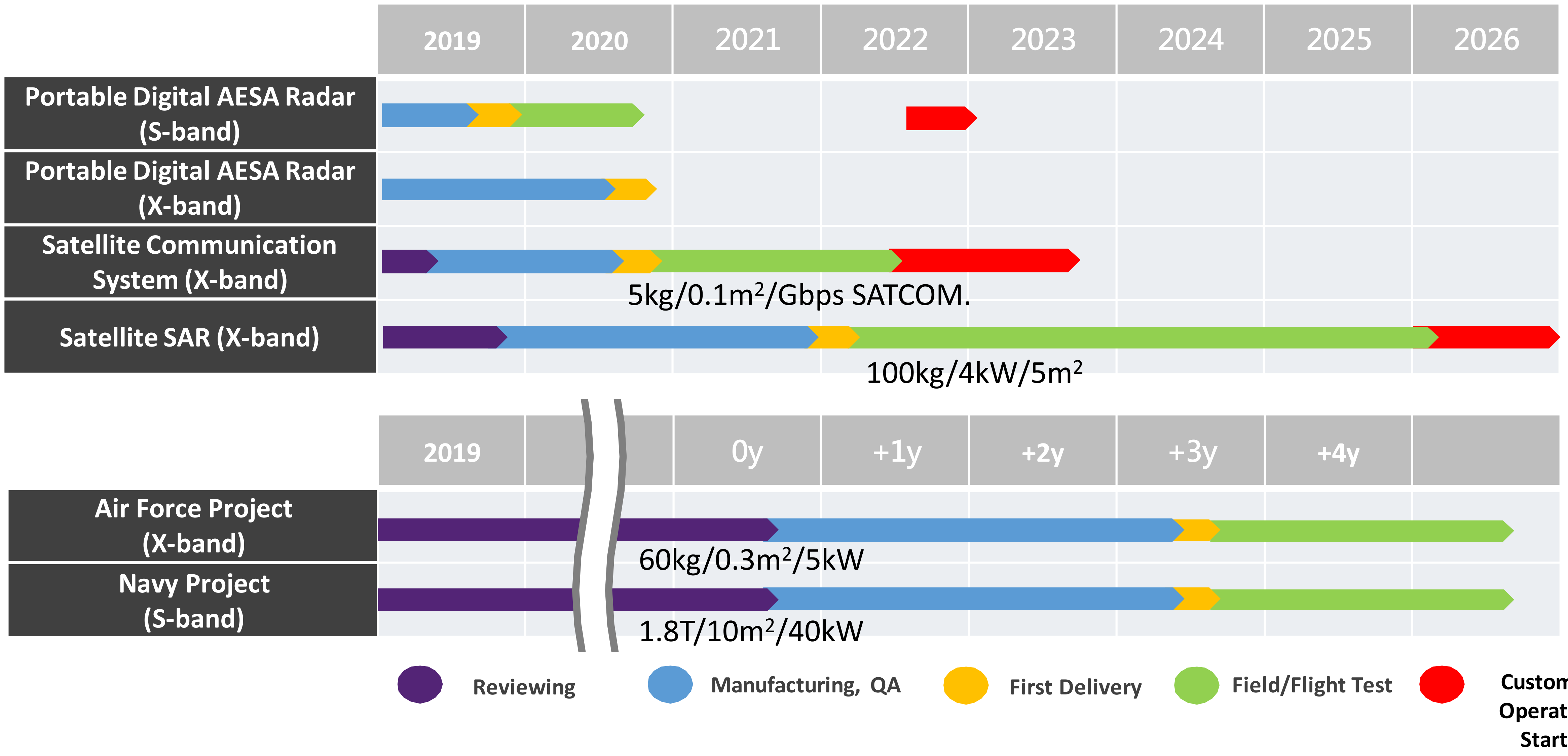
Technology Readiness



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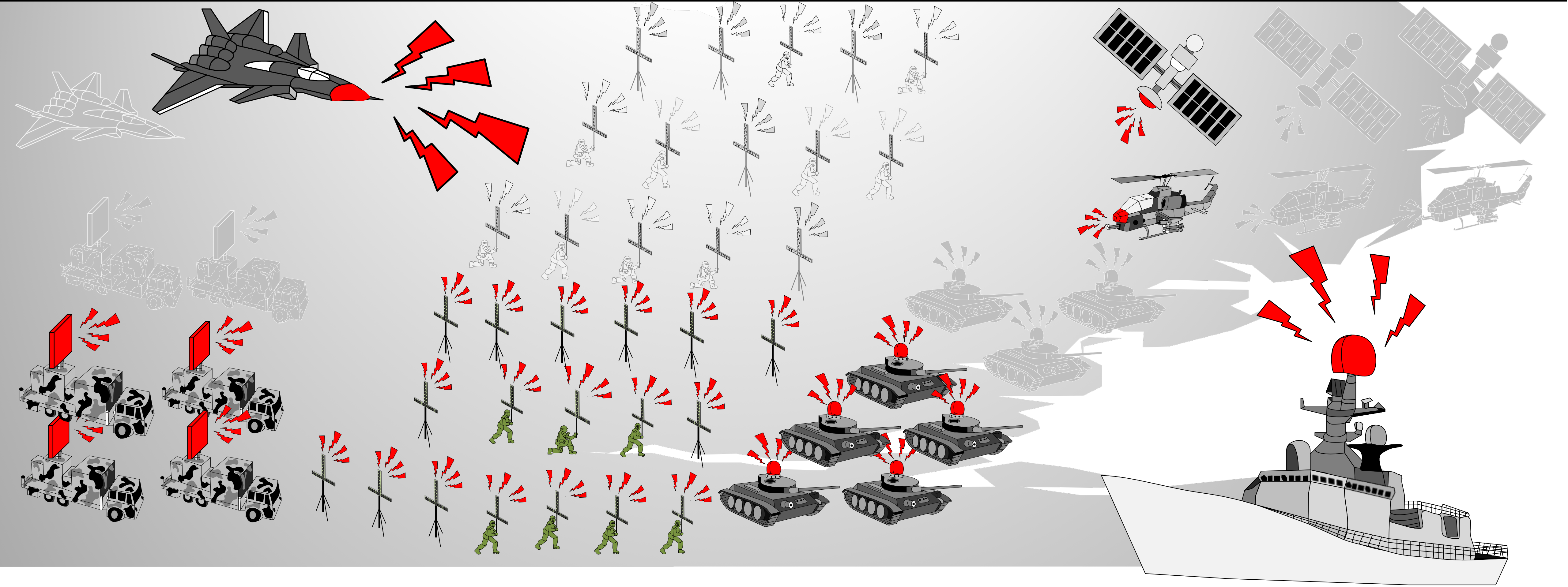
Cost-Effective Portable AESA in Future War



- Cost-effective AESAs begin to be pervasive to complement existing high-performance AESAs.
- Chip-scale atomic/GPS clocks enable massive software-defined AESA platform.
- Software is key to fully utilize the massive number of AESA.

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Summary

- Radars need to be tailored to be able to detect small RCS, slow-moving drones.

- Cost-effective AESA is suitable for Drone Detection
  - Cost reduction through linear orthogonal topology.
  - Doppler processing for moving target detection.
  - Eigenspace signal processing extract 3D position of targets.
  - Currently under field tests in Taiwan to cover more use cases.

- Cost-effective AESA will be readily available for future surface operations in addition to drone detection.

Q & A

- Let's know how you will like digital AESA to develop or apply to!
- Critiques, questions, and suggestions are highly welcome.
- Thank you for your attentions.
- Email: yw@tronfuturetech.com

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