Engineering the Ideal Array

Mark Rosker

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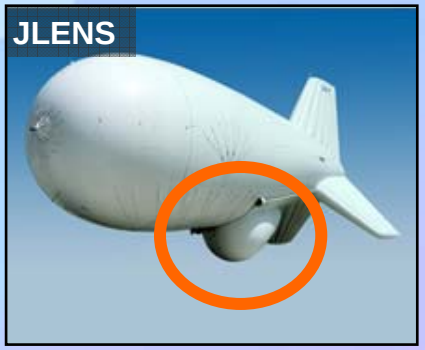
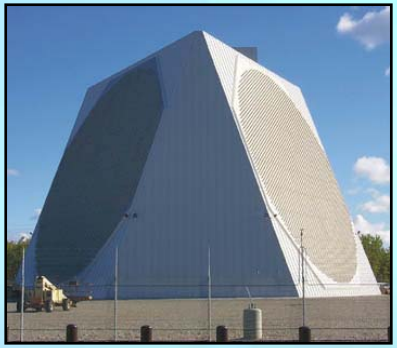
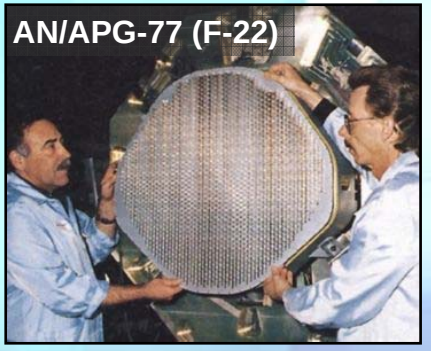
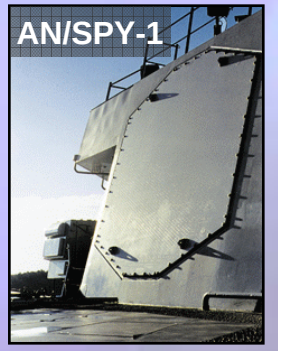
RF Arrays in Military Systems









Arrays are the heart of sensor systems for many military platforms

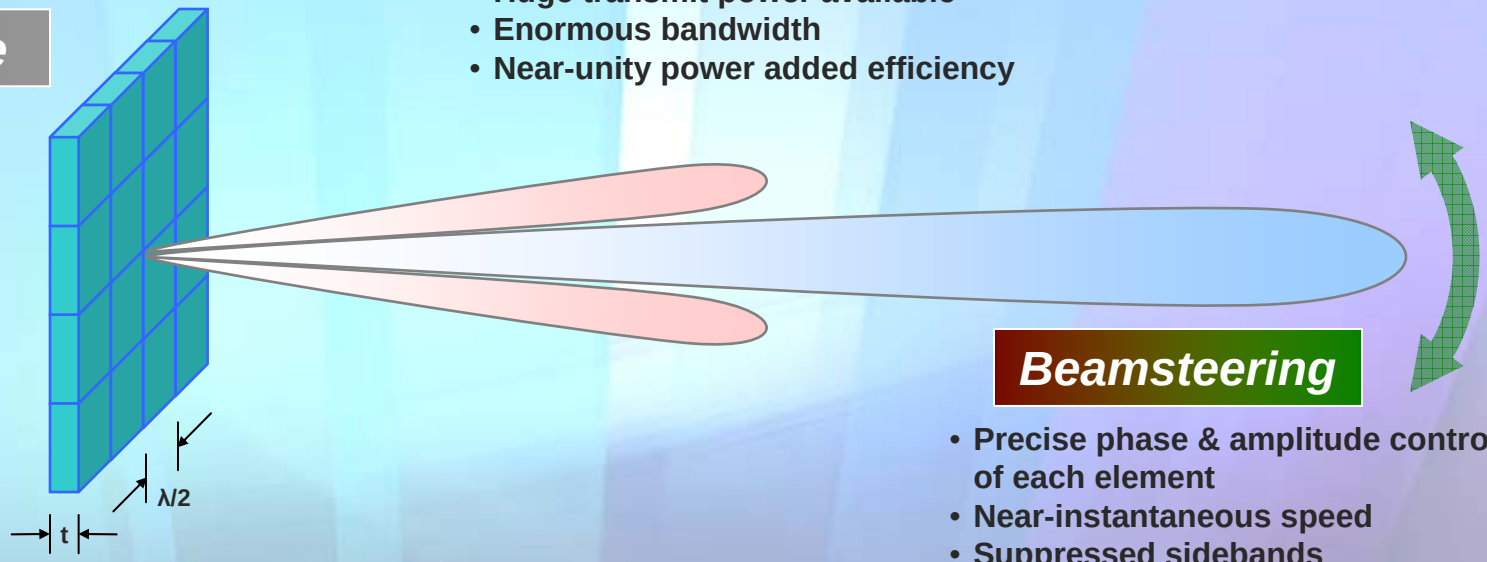
Ideal Array: The Vision

Transmit

- Huge transmit power available
- Enormous bandwidth
- Near-unity power added efficiency

Architecture

- Scalable
- Reconfigurable
- Embedded thermal management
- Negligible mass
- Wafer-thin
- Dirt cheap



Beamsteering

- Precise phase & amplitude control of each element
- Near-instantaneous speed
- Suppressed sidebands

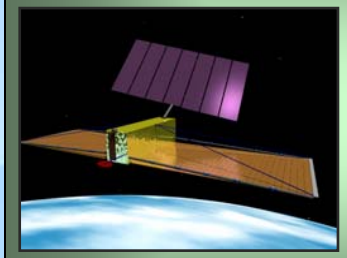
Receive

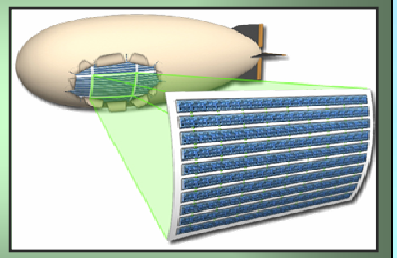
- Near-zero noise figure
- Enormous dynamic range
- Minimal power dissipation

All we need now is a bit of technology…

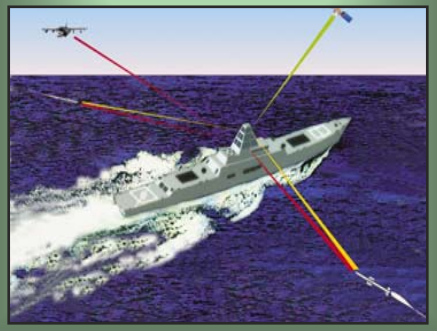
What Does it Enable?

Massive Sensor Arrays



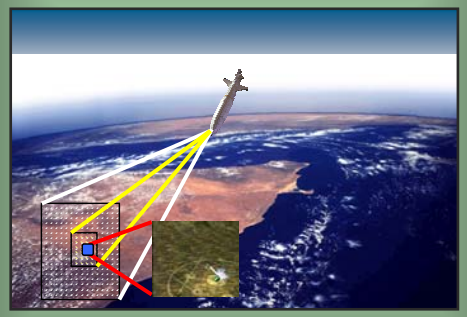


Multi-function Systems



Conformal Sensors

Frequency Agile Sensors

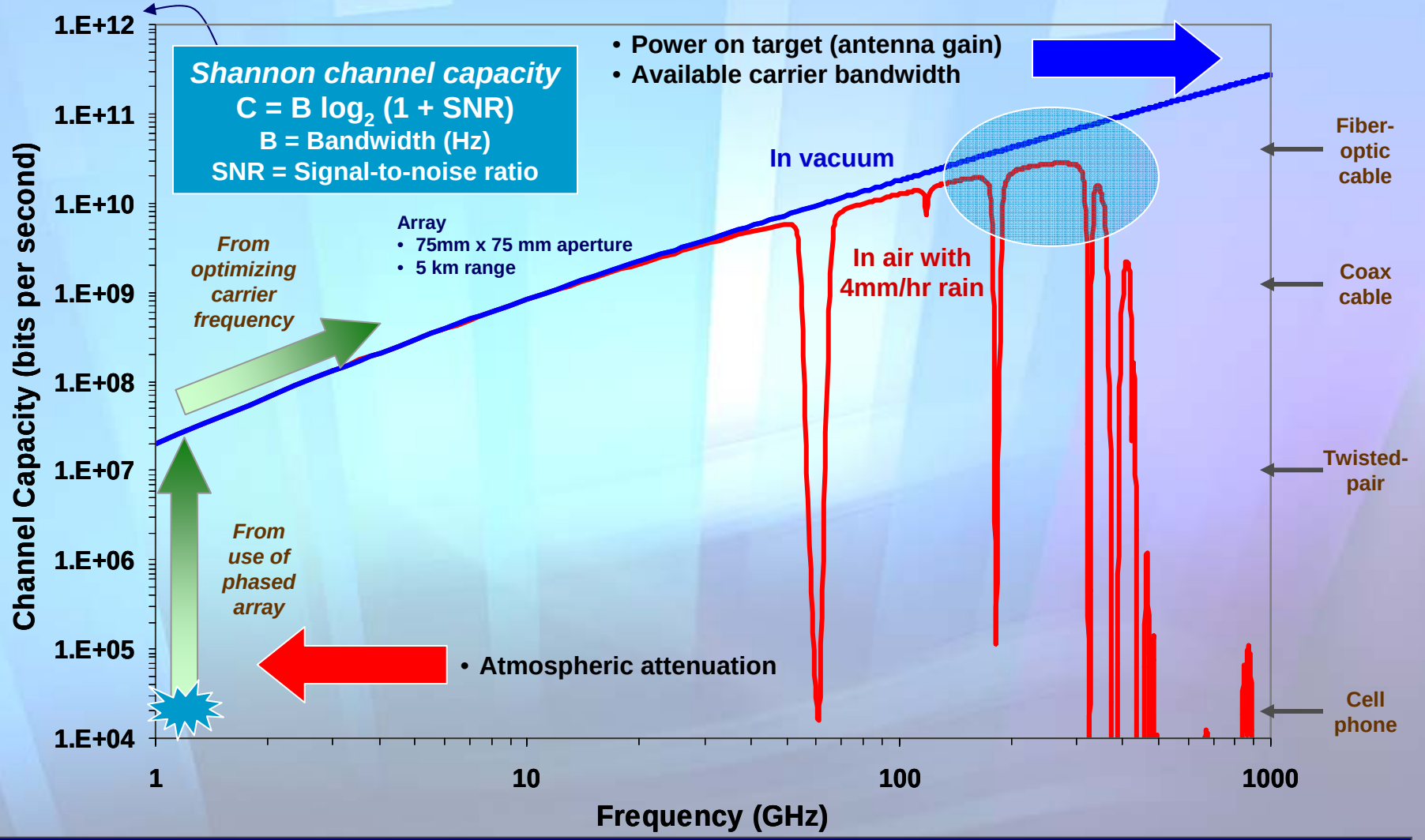


Greater Range

Reduced System Size

Compact, robust, intelligent sensor and communications systems

The Ideal Array and Frequency



For many applications, the ideal array is a millimeter-wave array

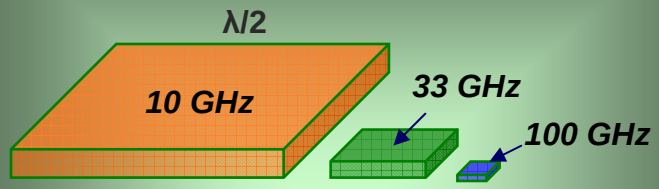
Arrays in Military Systems

Which of these are millimeter-wave arrays?

Arrays are the heart of sensor systems for many military platforms

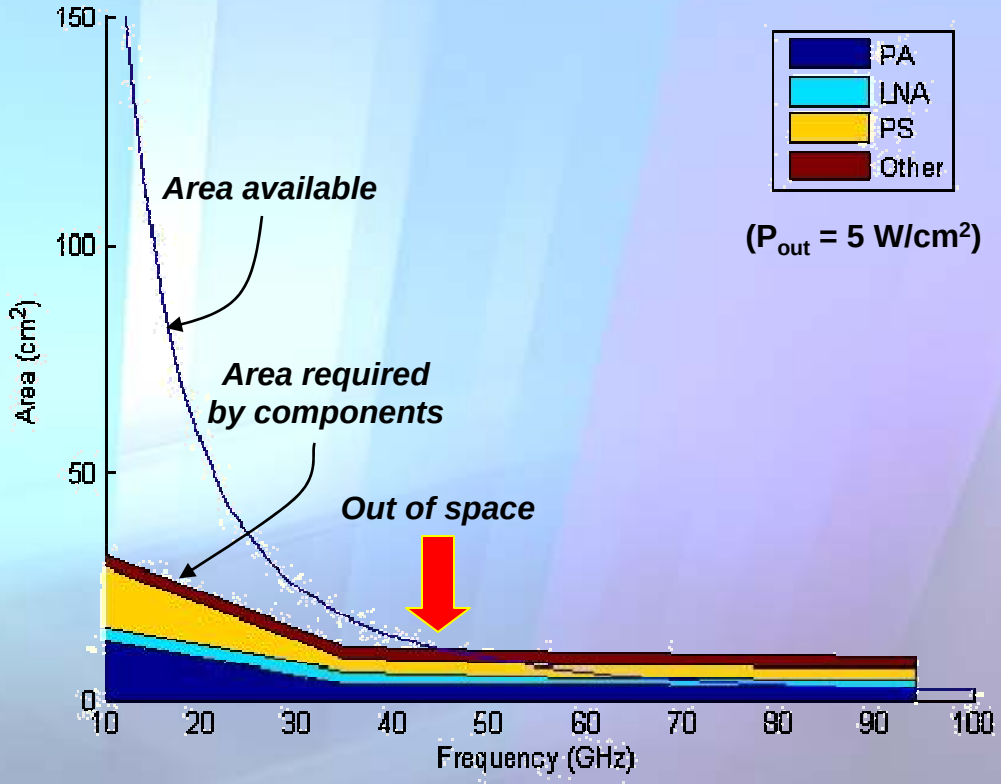
The High Frequency Array

Area of an array cell scales like f^2



Each cell must still contain…

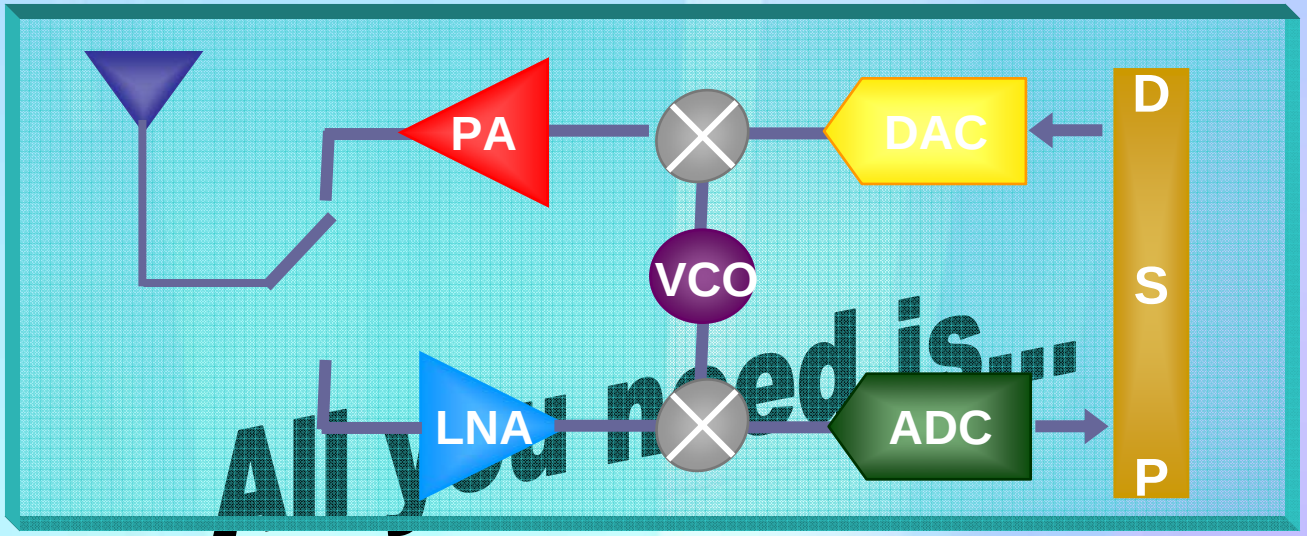
- LNA
- Power amp
- Filtering
- Diplexer/ circulator
- Phase shifting
- Limiter
- Digital control
- ...



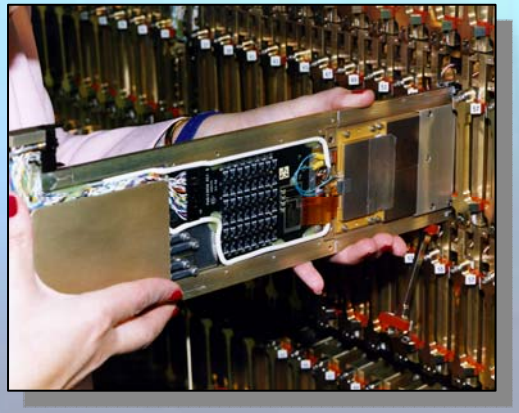
3D is only way to cram functionality into increasingly smaller pitch

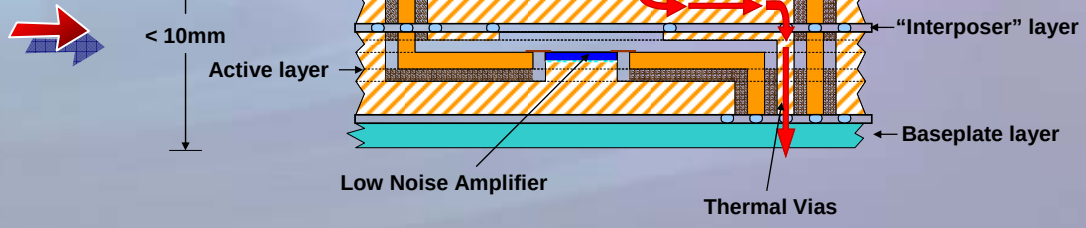
Challenges for an Ideal Array

Ideal circuit components



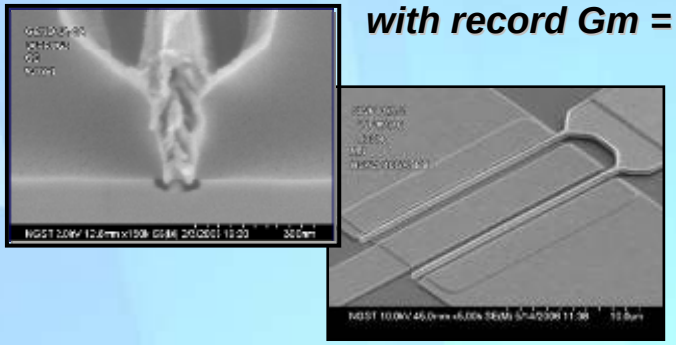
Ideal integration methods



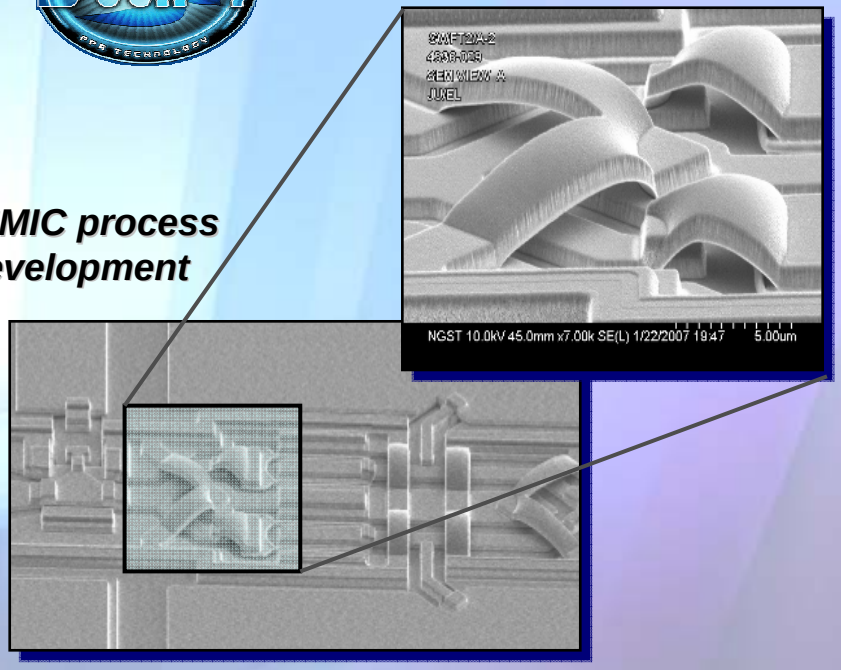


The High Frequency Integrated Circuit

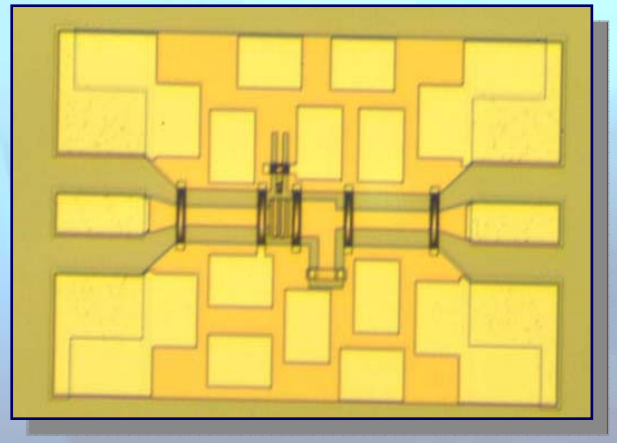
35nm gate InP HEMT transistor with record Gm = 2300mS/mm



S-MMIC process development



347 GHz Integrated Circuit: World's First "s-MMIC"



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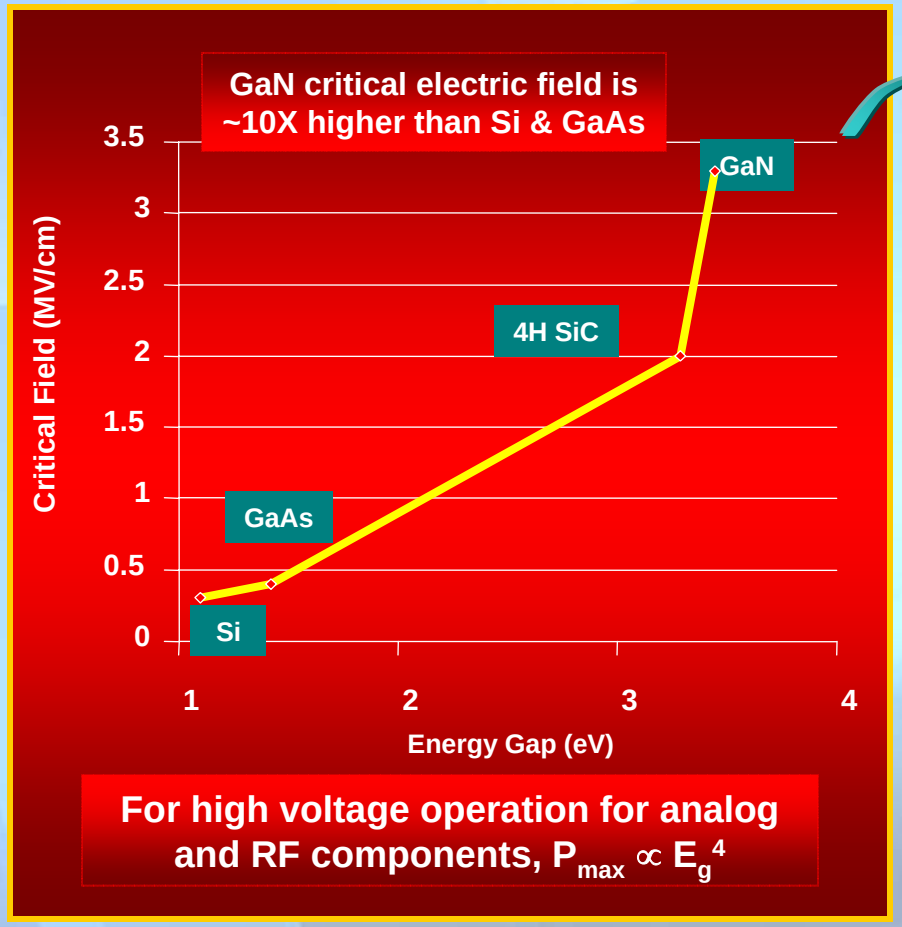
THz frequency integrated circuits are becoming a reality

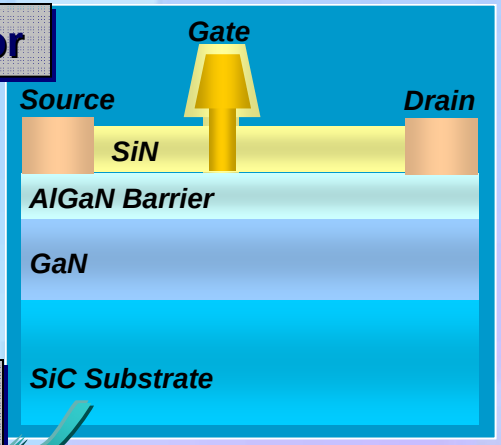
Wide Bandgap Semiconductors



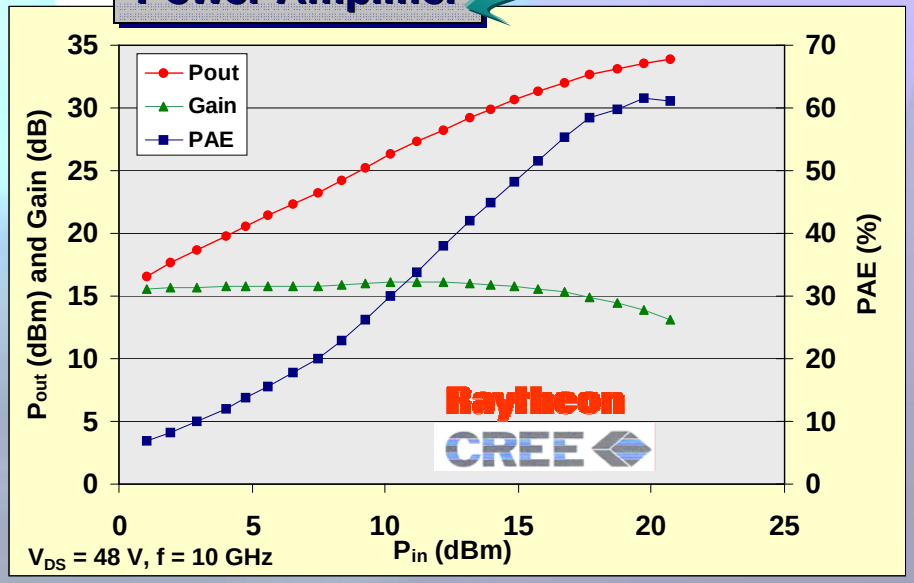
For high voltage operation for analog and RF components, $P_{max} \propto E_g^4$

GaN HEMT Transistor

Dramatically higher:
- Output power
- Efficiency
- Bandwidth



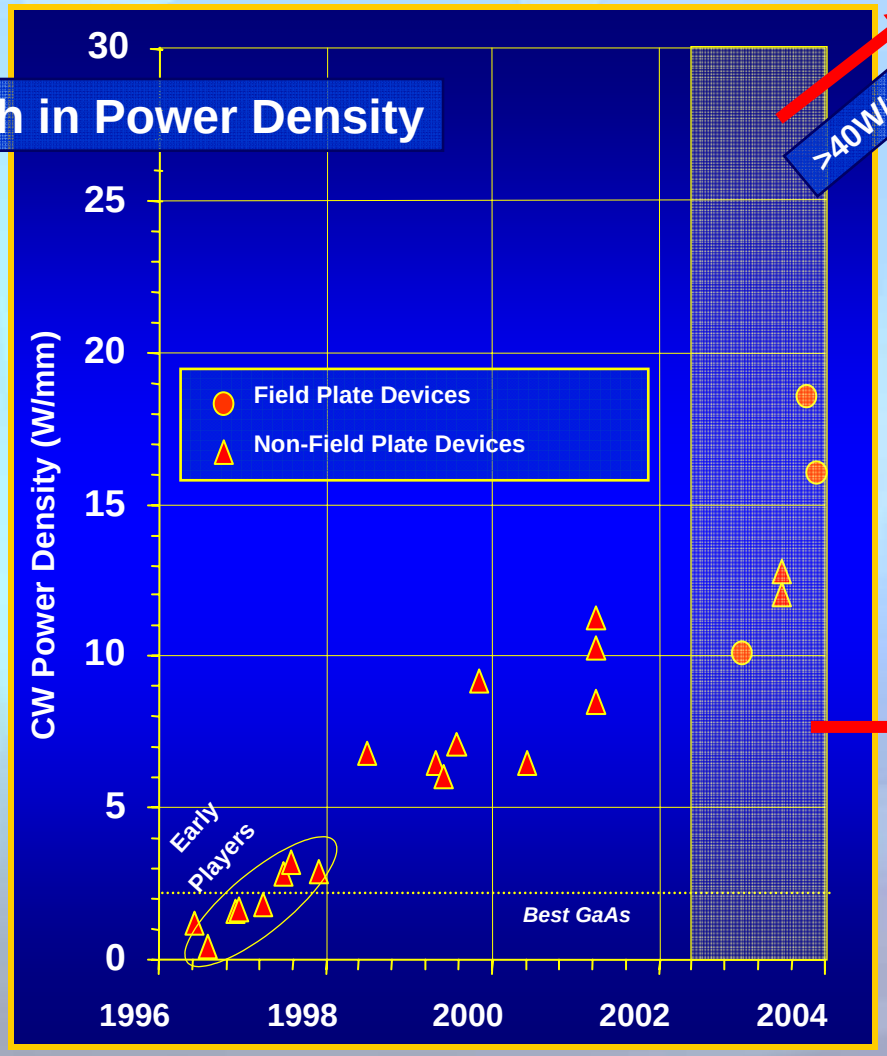
GaN HEMT Power Amplifier



The ideal array demands the ideal power amplifier transistor material!

GaN & Power Density

A Breakthrough in Power Density

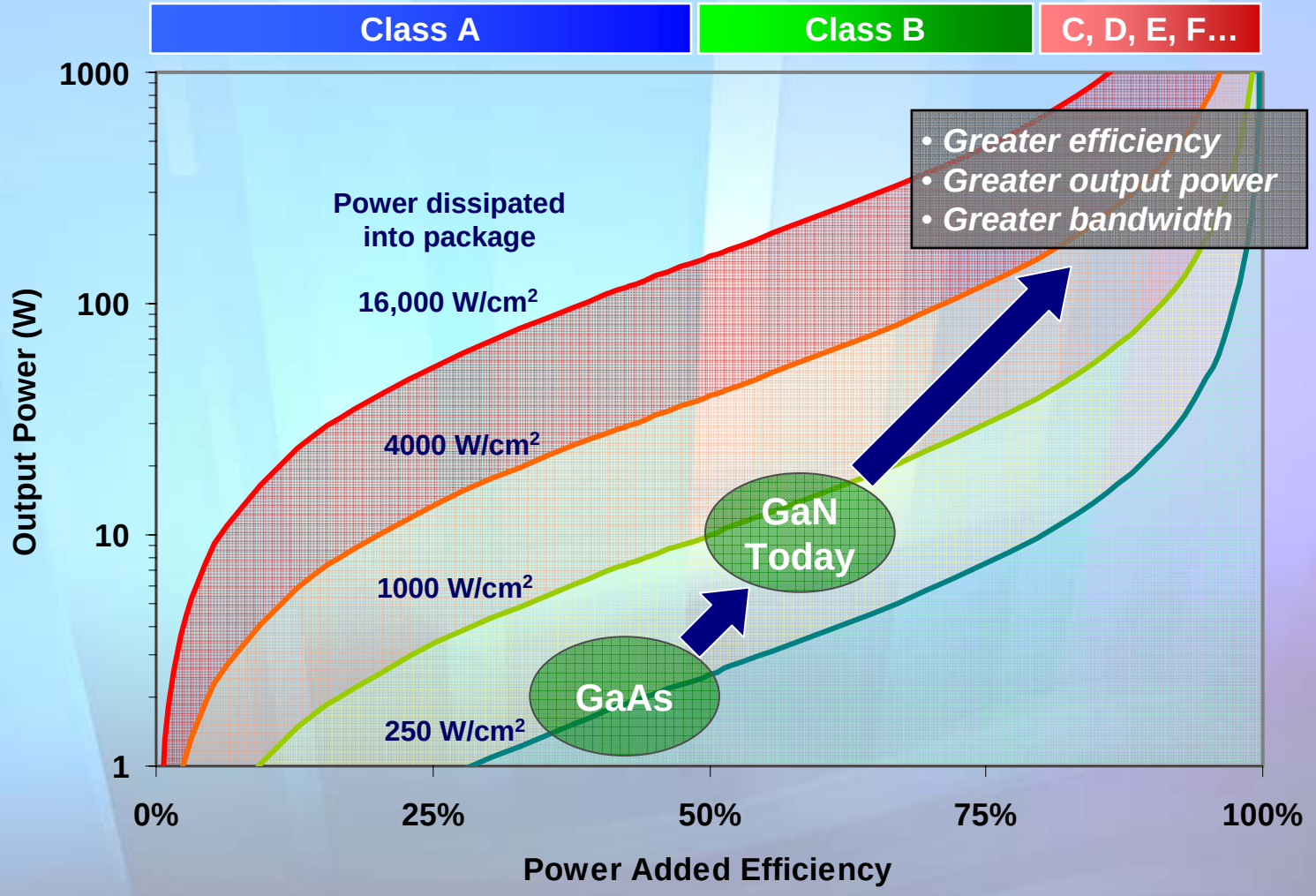


Small Devices

Large Devices

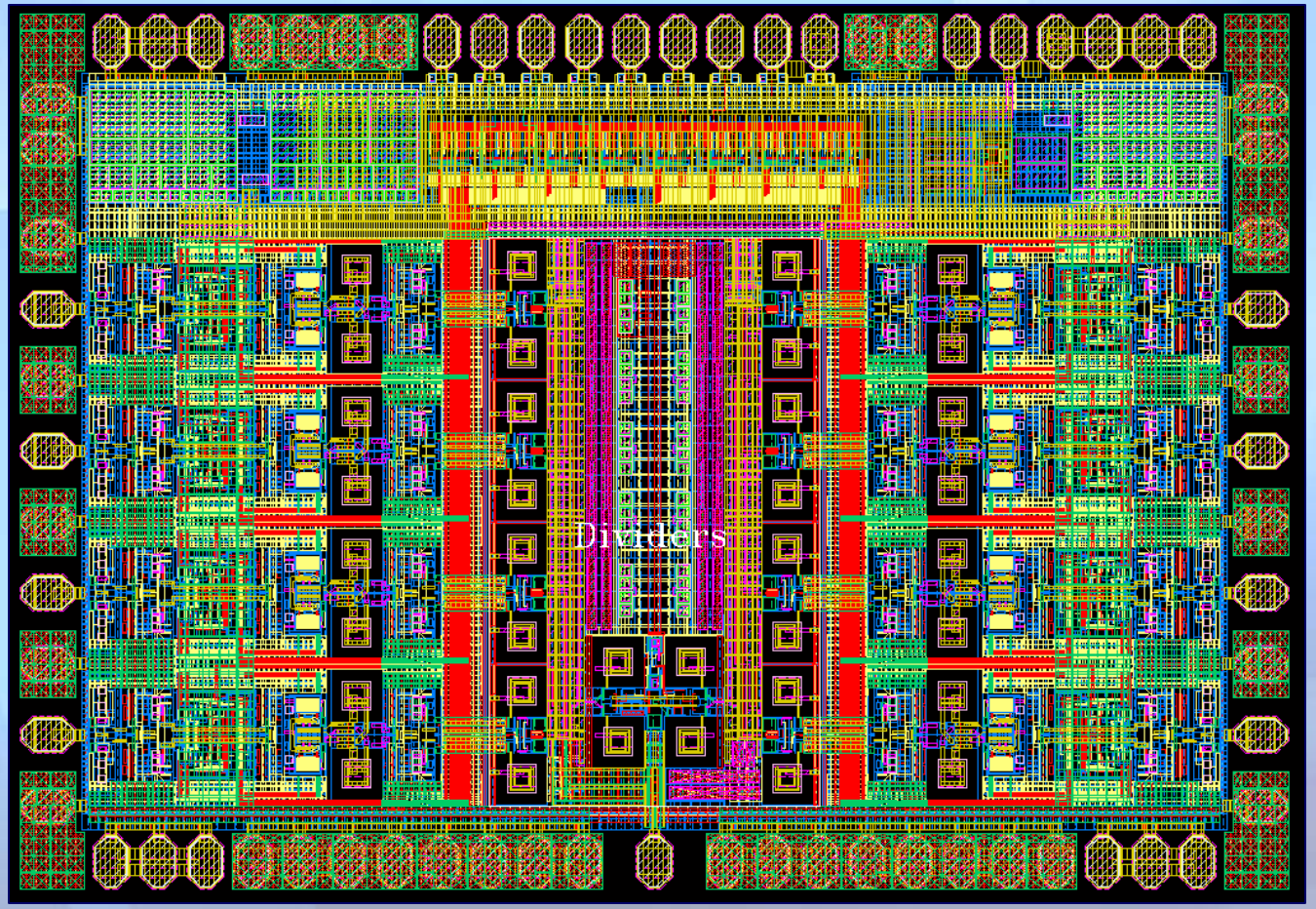
For large GaN devices, we are still a long way from the material limit

The Ideal Power Amplifier



The ideal PA demands a new focus on thermal management

Complete Beamformer-on-a-Chip



- 44GHz
- 8 channels
- All beamforming functions
  - RF amplifiers
  - 4-bit phase shifters
  - Amplitude controllers
  - Summing network
  - Power control
  - Latches for phase state
  - Address decoders
  - Digital-to-analog converters

→ 2.2x2.4 mm ←

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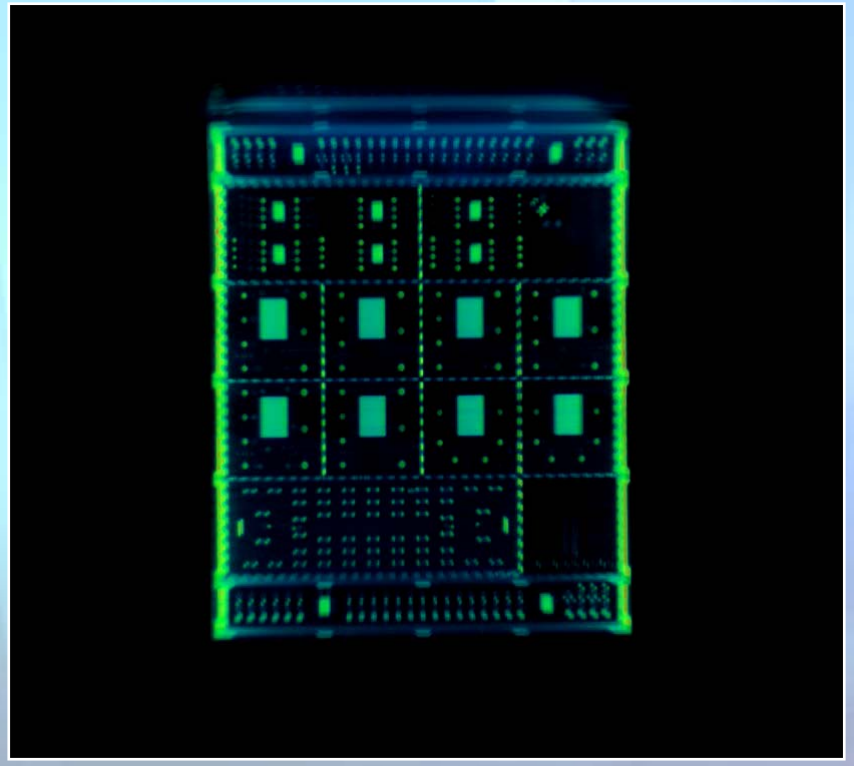
3D Integration of an RF Array



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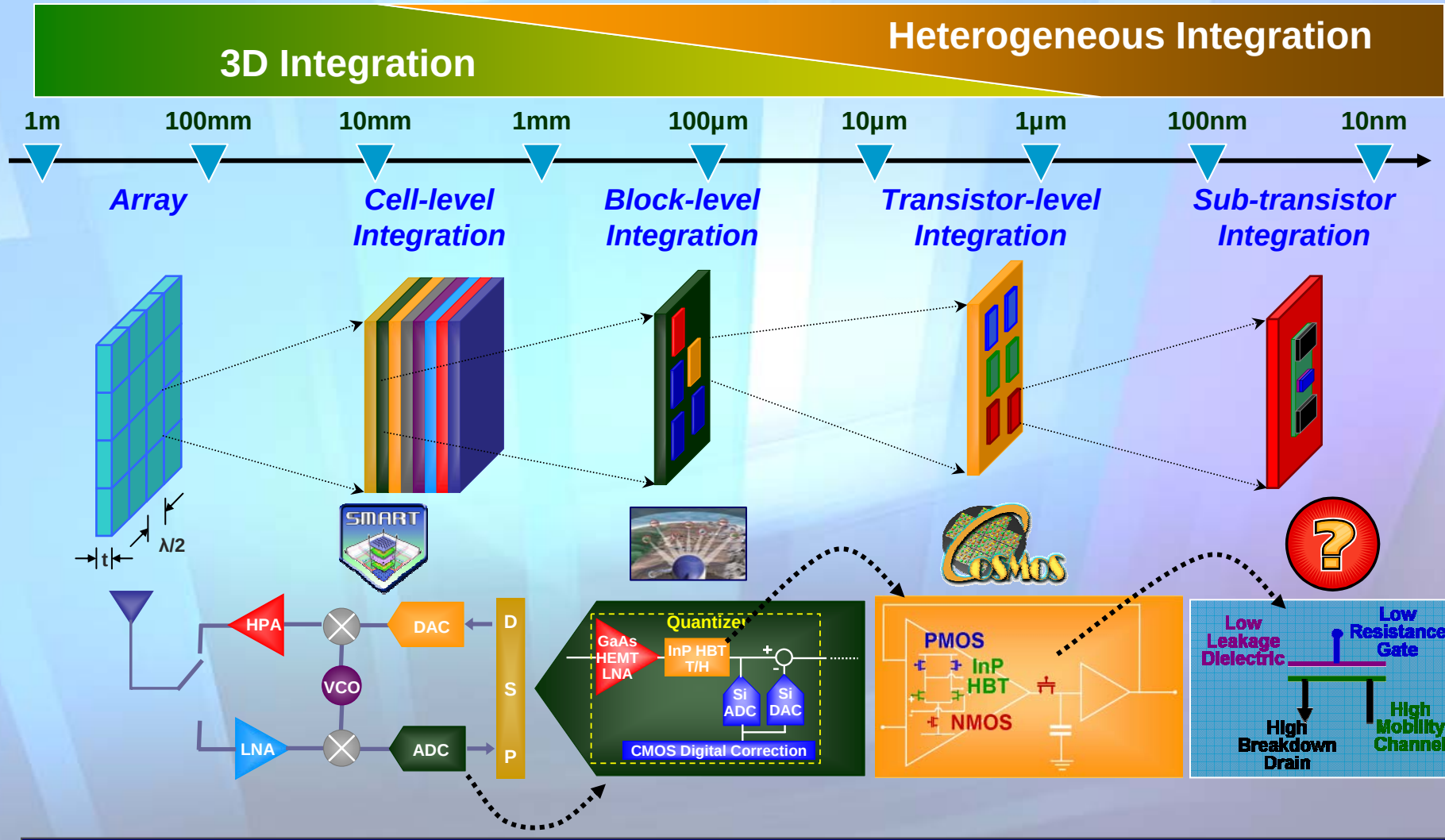
Space Technology

Today: integrated circuits; Tomorrow: integrated arrays

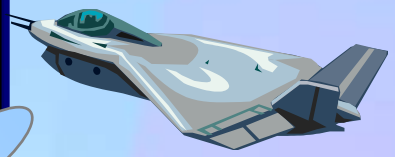
Constructing the Ideal Array



Integration occurring on all length scales

The Challenge

Range



Massive capacity (> coax cable)

Integrated

Highly directional; low probability of intercept

What could be cooler than this?

Array no larger than display

Highly efficient

Your 200GHz MTO-Phone…

…made possible by DARPA & the ideal array