



SPEAR: Scalable Panels for Efficient, Affordable Radar

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Report Documentation Page

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Outline

- 👉 Low Power Density Radar System Considerations
- ◆ The SPEAR Program
- ◆ Low Cost Panel Technologies
- ◆ Summary

SPEAR is a prime example of an application of low-cost manufacturing technologies in a next-generation military system

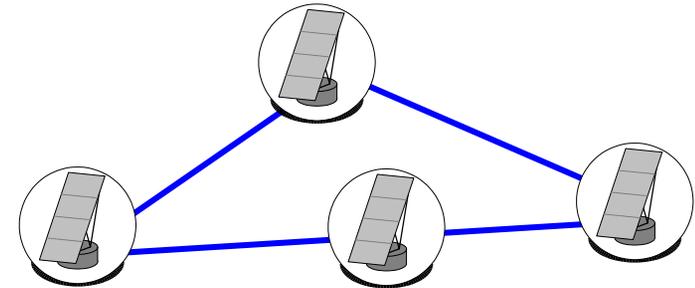
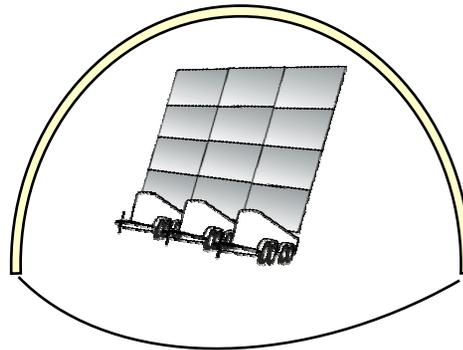
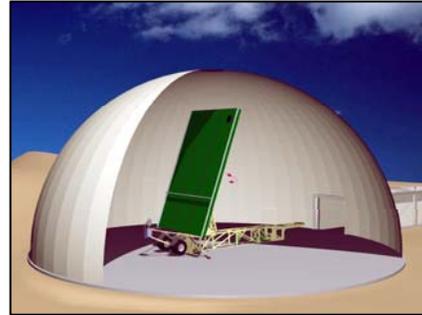


Next Generation Radar for BMDS

2000



2010

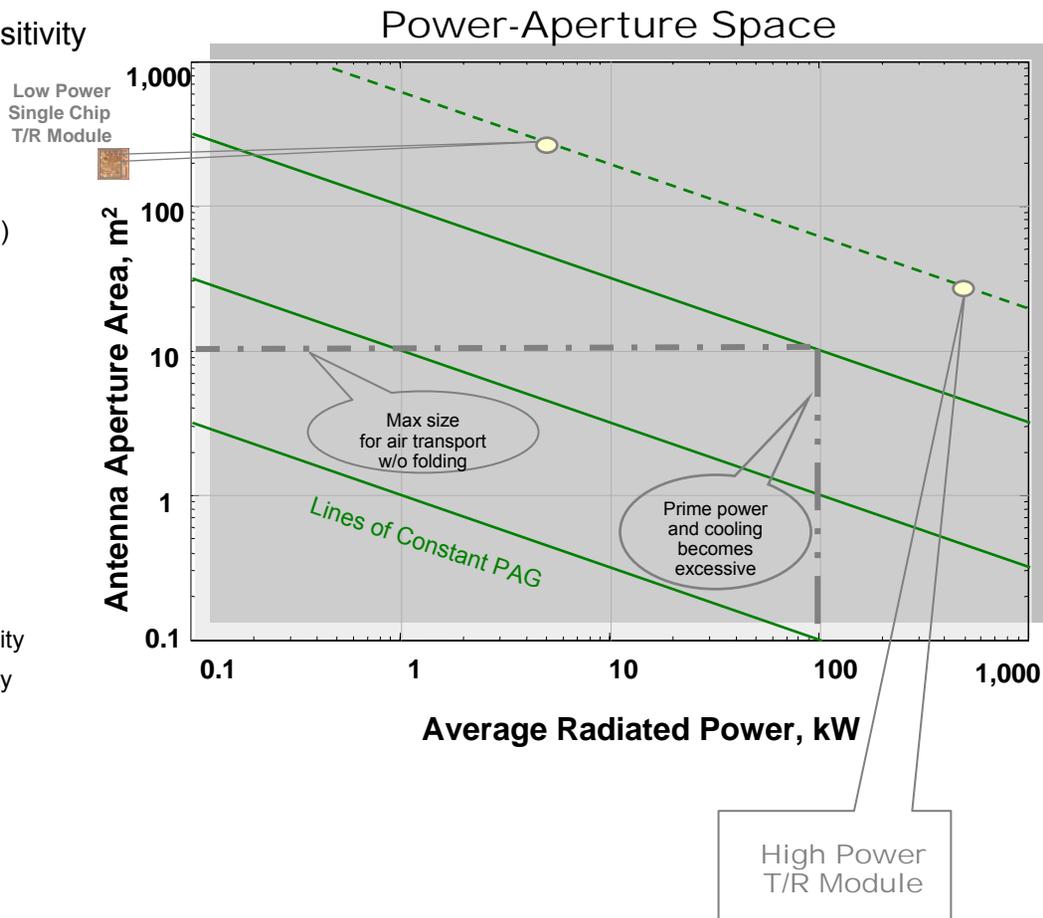


Next Generation Radar (NGR) to provide objective BMDS capabilities



How can we achieve future needs for affordable, transportable radars?

- ◆ Driving performance is tracking/discrimination sensitivity
- ◆ Radar figure of merit is PAG (power · aperture · gain)
- ◆ For solid state (active) arrays:
 - P = Power per element (P_e) x number of elements (N)
 - A = Area per element (A_e) x number of elements (N)
 - $G = 4\pi A_e N / \lambda^2$
- ◆ So $PAG = 4\pi(A_e)^2 N^3 P_e / \lambda^2$
- ◆ To improve performance, grow one of these:
 - A_e = area of one element (GBR-P)
 - ❖ LFOV
 - ❖ Too large to transport
 - P_e = power per element (GaN, SiC approach)
 - ❖ Cooling becomes serious problem for transportability
 - ❖ Prime power becomes excessive for transportability
 - ❖ T/R module cost is excessive
- ◆ Or, LPD Approach → Break out of the box by:
 - Grow A by increasing N (third power payoff)
 - ❖ FFOV
 - Reduce P_e (P_e goes as $1/N^3$)
 - ❖ Reduced cost per element (<\$10)
 - ❖ Cooling and prime power requirement decrease significantly
 - ❖ Aperture will not be as mechanically rigid
 - ❖ **But**, large aperture can be folded for stowage

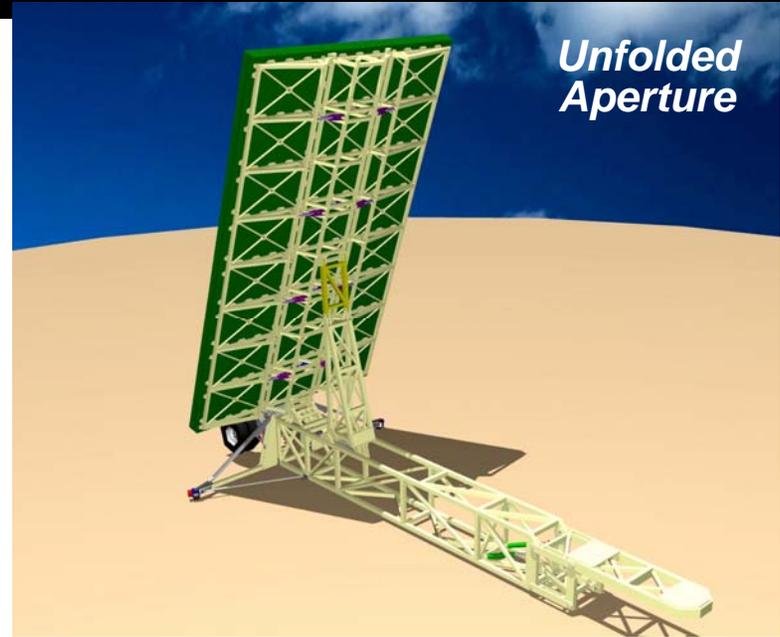


Example of Deployable Structure

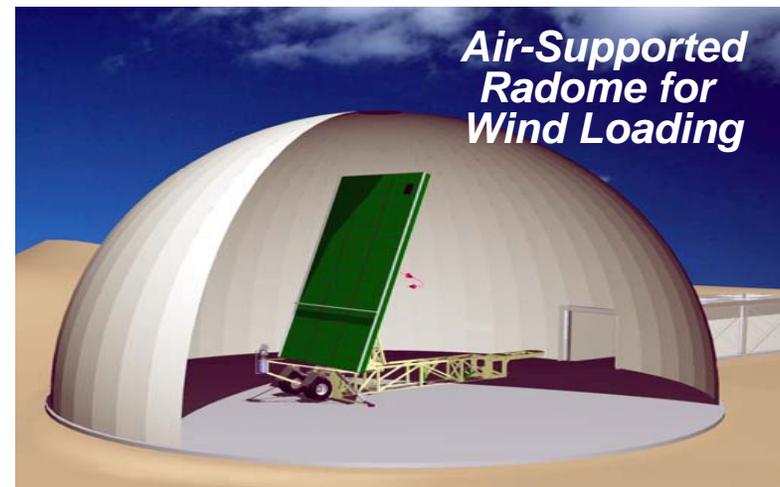
Transportation Mode



Unfolded Aperture

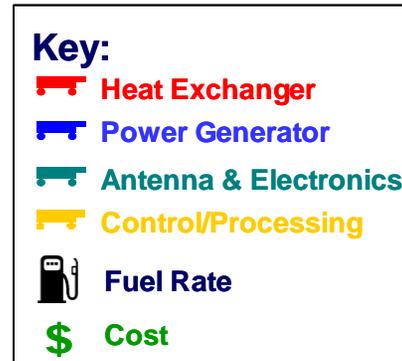
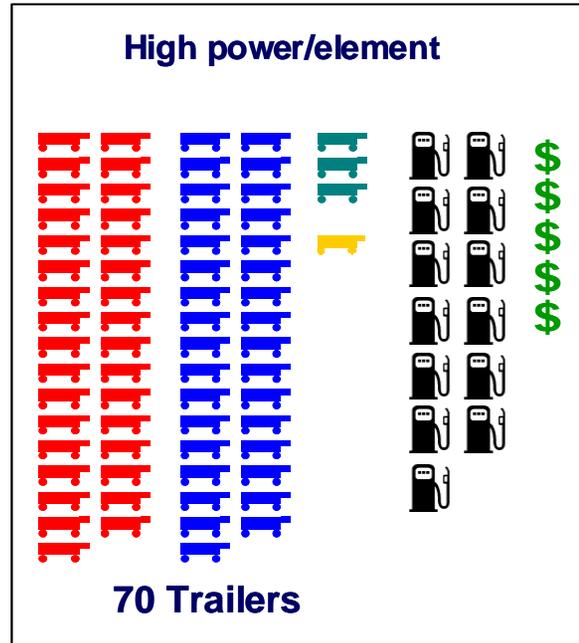
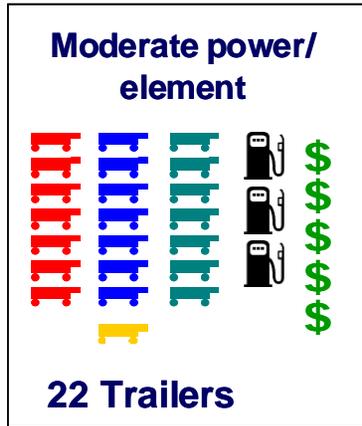


Air-Supported Radome for Wind Loading





Benefits of LPD Antenna Technology

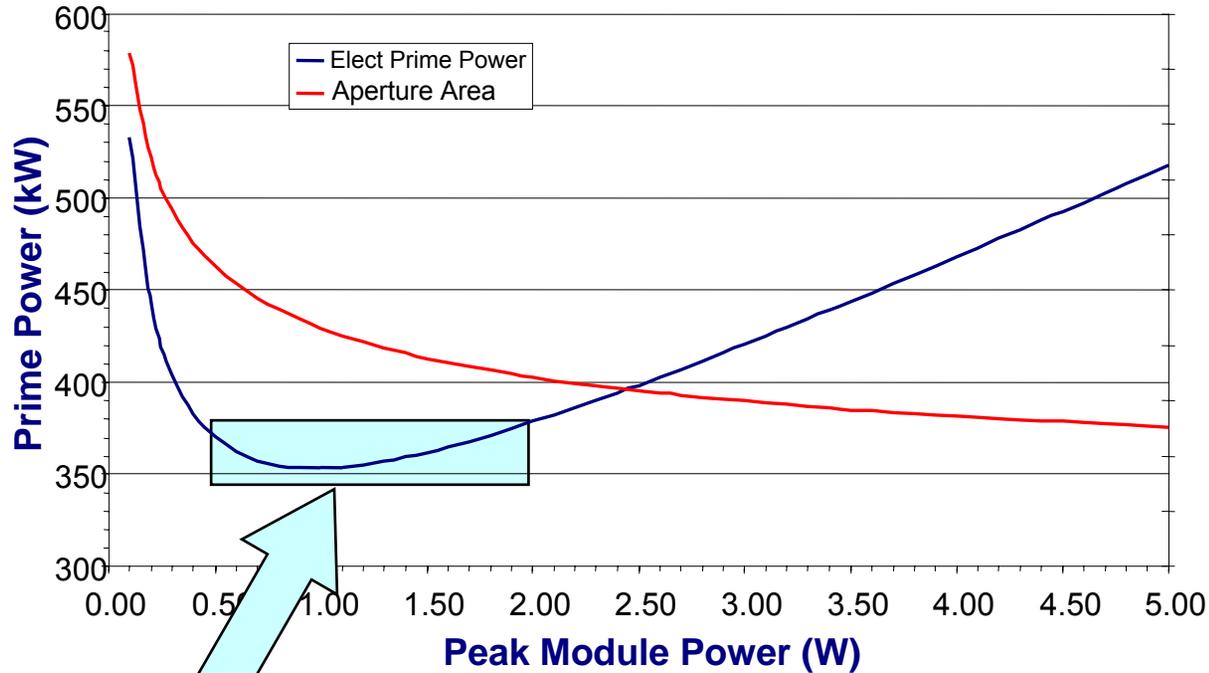


Large LPD antennas reduce cost and system footprint

What is the optimum power density?



Electronics Prime Power vs Module Power for Base Unit Fixed PAG



Region of interest for SPEAR IPT



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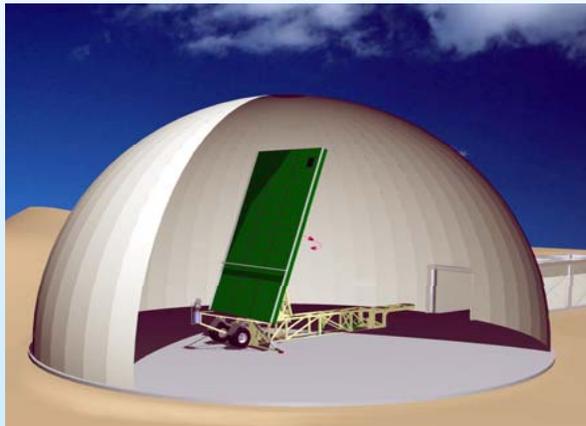
SPEAR Vision

Scalable Panels for Efficient, Affordable Radars for BMDS

Single Chip
T/R

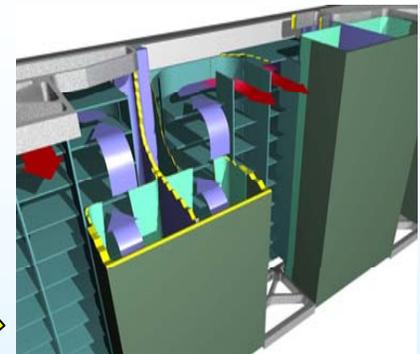


AFRL Scalable Panel



Transportable, Deployable Structure

Efficient Cooling



Alignment and Calibration

Risks

- Transportable, Lightweight, Deployable Structure
- Alignment and Calibration of Deployed Structure
- Wind Loading of Large Aperture
- Cost of Low Power Panels
- Efficient, Reliable Cooling

Benefits

- Full Field-of-View
- Affordable
- 30-day Relocation
- Low Power Density
- Efficient
- Enhanced Bandwidth



SPEAR IPT

Missile Defense Agency
Advanced Systems (AS)

Radar System Technology (RST)
Army, Navy, Air Force



SPEAR OSA
Working Group

SPEAR IPT Lead
USASMDC

SPEAR Technical Director
GTRI

AFRL
Scalable Panels

MIT/LL
Open System Architecture

USASMDC / GTRI
Array Implementation

Industry Partners

- Multi-Service
- Air Force
- Army
- GTRI, MIT/LL
- SPEAR Contractors

MDA/AS RST tri-service panel established IPT to leverage space, airborne (AFRL) and ground based radar (USASMDC/GTRI) expertise to develop affordable scalable panels with a government owned interface standard (MIT/LL OSA)



SPEAR Spiral Development

2002	2003	2004	2005	2006	2007	2008	2009	2010
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Scalable Array Scalable Radar

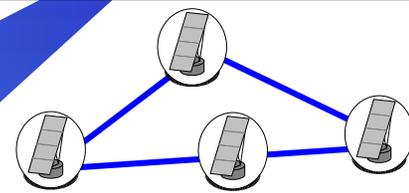
Gov't & Industry IPT

- Leads Development
- System Engineering
- Open Standards

Specification Development

Tech Dev For Spiral 2

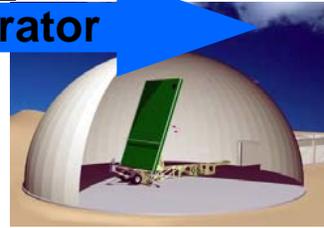
- Distributed Array Techniques
- WB Rx/Tx on a chip
- WB DBF Panel (AF \$ support)



Spiral 2 FY 07

Spiral 2 Demonstrator

- Radar
- Digital panels
 - Distributed



Radar Demonstrator

Tech Dev For Spiral 1

- Distributed Processing
- Alignment/Calibration
- Coherency
- Affordability
- Thermal
- Sub-array Fab.

Solicitation 4Q FY04

Contracts Jan 2005

Spiral 1 FY05/06

Spiral 1 Testbed

- Antenna
- Analog panels
 - Digital receivers

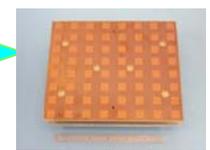


Antenna Testbed

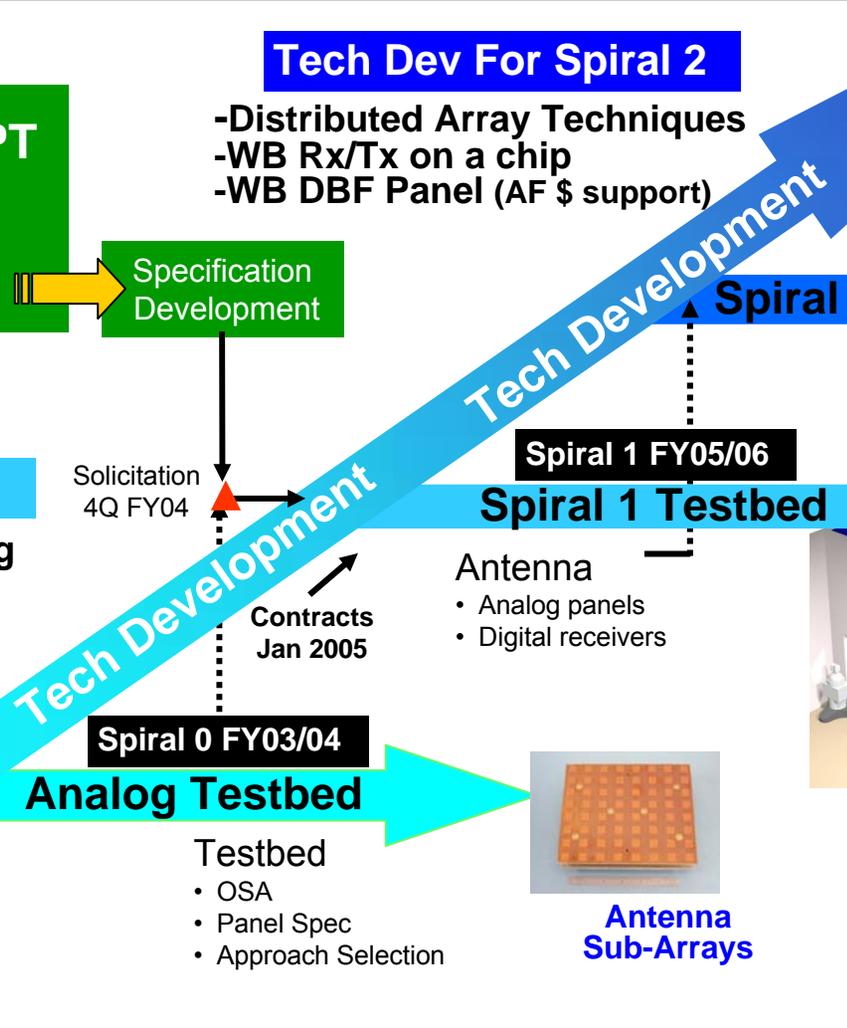
Spiral 0 FY03/04

Analog Testbed

- Testbed
- OSA
 - Panel Spec
 - Approach Selection



Antenna Sub-Arrays





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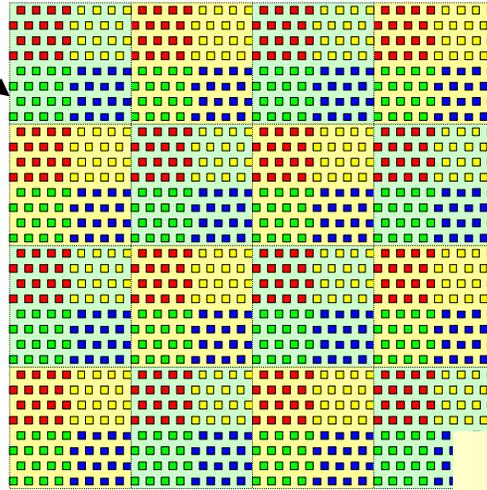


NGR/SPEAR Study Results: Base Unit Antenna Notional Designs

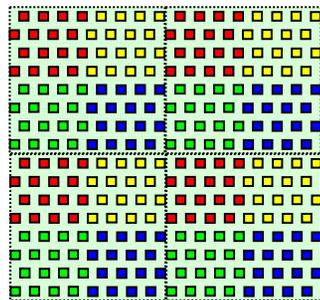
Approach



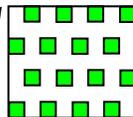
Autonomous Panel
2x2 Digital Sub-Arrays
0.5m x 0.5m



Digital Sub-Array (DSA)
4x4 analog sub-arrays
0.25m x 0.25 m

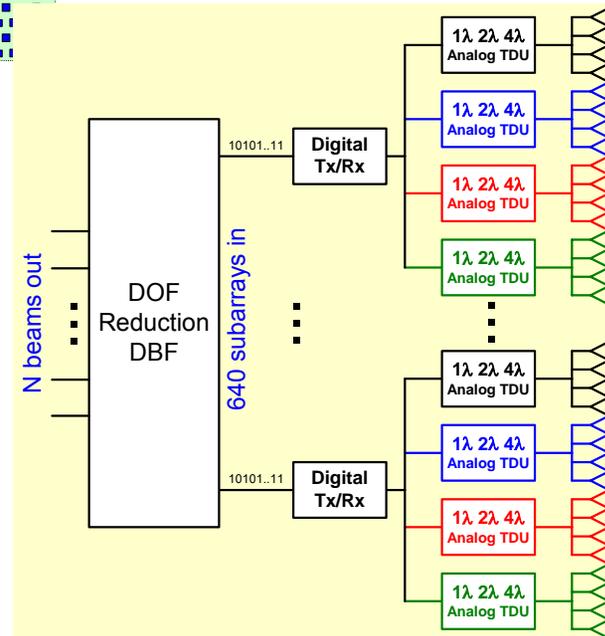


Analog Sub-Array (ASA)
4x4 Elements



Baseline Design

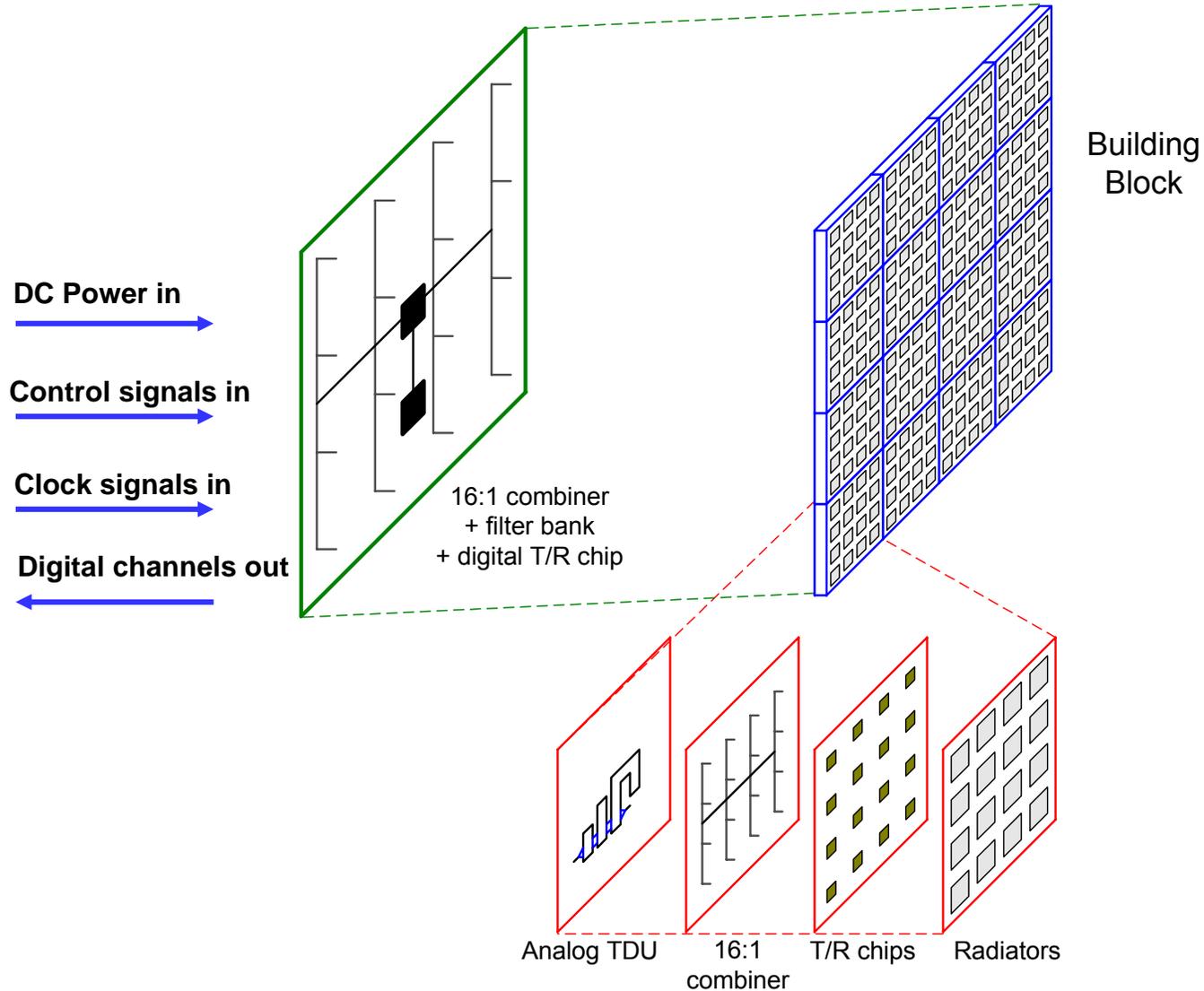
- 4 x 4 element Analog Subarray (ASA)
- 16 x 16 element Digital Subarray (DSA)
- 1024 elements per panel (4 DSAs)
- Wide Operating Bandwidth
 - ❖ Analog time delay for short bits (1λ , 2λ , 4λ)
 - ❖ Digital time delay for longer bits
- Full Field-of-View
- DOF Reduction beamformer from 100's of DSAs to 10's of beams





Building Block

(= 1 Digital Subarray - 16X16 Elements)





Low Cost Panel Technologies

- ◆ Emphasis on using established industry processes
 - Circuit board based signal and power distribution
 - Use of flex materials and HDI for higher density and lower mass
 - Maximizing automation over hand assembly
 - Possible use of plastic or non-hermetic packaging approaches
- ◆ Better understanding of packaging tradeoffs and how they affect cost
 - Greater single chip integration vs multiple chips
 - Single chip vs multichip modules
 - Including more routing on modules vs on the circuit board

Ceramic Package Option

Panel Cross Section with Ceramic Packaged MMICs



- ◆ Printed Circuit Board (PCB) Technology for RF Distribution and DC Bias Networks
- ◆ Hermetic Cavity Package for MMICs (Mature Technology)
- ◆ Single or Multichip modules
- ◆ Most Routing in PCB Reduces Number of Layers in Ceramic (Lower Cost)
- ◆ Multiple Ceramic Module Attach Approaches (pins, fuzz button, BGA)
 - Can be Automated
 - Lower Cost

Plastic Package Approach

Panel Cross Section with Plastic Packaged MMICs



- ◆ Plastic Molded Packages Offer a Very Low Cost Option for Some Applications
- ◆ Some Materials Compatible with X-Band Frequency Range
- ◆ Non-Hermetic
- ◆ Coatings Such as BCB or Parylene Provide Chip Protection
- ◆ Direct or BGA Attach
- ◆ Additional PCB Layers Required for Signal Routing
- ◆ Liquid Crystal Polymers (LCP) Can Provide Hermeticity but are Less Mature



Packageless Approach

Panel Cross Section with MMICs Mounted to PCB in a Packageless Approach



- ◆ MMICs Mounted Directly to the PCB Surface
 - Flip Chip Mount (requires underfill)
 - Adhesive Mount w/ Wire Bonding (chip face up)
 - Both Approaches Require Chip Protection Method (to be developed)
- ◆ All RF and DC Routing are in the PCB
- ◆ High Density Interconnect (HDI) Process Could Accommodate High Trace and Component Density
 - Increases PCB cost
 - Used to Reduce Number of PCB Layers and Overall Panel Mass
- ◆ Control and Passive Components Mounted Directly to the Surface of the PCB
- ◆ Approach Offers Potential for Lowest Cost and Mass
- ◆ Technical Challenges Still to be Overcome



SUMMARY

- ◆ Affordability
 - Higher level of manufacturing integration
 - New low power density panel paradigm
- ◆ Efficiency
 - Single chip T/R, minimum combining and interconnect loss
 - Efficient cooling techniques
- ◆ Scalability
 - Highly digital architecture
 - Build arrays to arbitrary size with minimal changes
- ◆ Ground-based application for MDA is a first step towards space, airship, and airborne platforms