Next Generation Sensors Employing Wideband, Agile, Multi-Function Capabilities and Technologies

2018 Military Radar Summit

Jerald Nespor

LM Senior Fellow

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Agenda and Key Messages

Agenda

- **The Challenge**
  - Global Landscape
  - Sensor Convergence
  - Demand Pull
- **Historical Overview**
- **Current and Future Trends**
  - Architectures
  - Reconfigurable Parameters
  - Technologies
- **Summary**

Key Messages

- **Existing military primary mission sensors provide significant capability**
- **Evolving technologies are enabling new multi-mission architectures**
- **Future sensors will be smaller, distributed, cohered and converged**

The Challenge

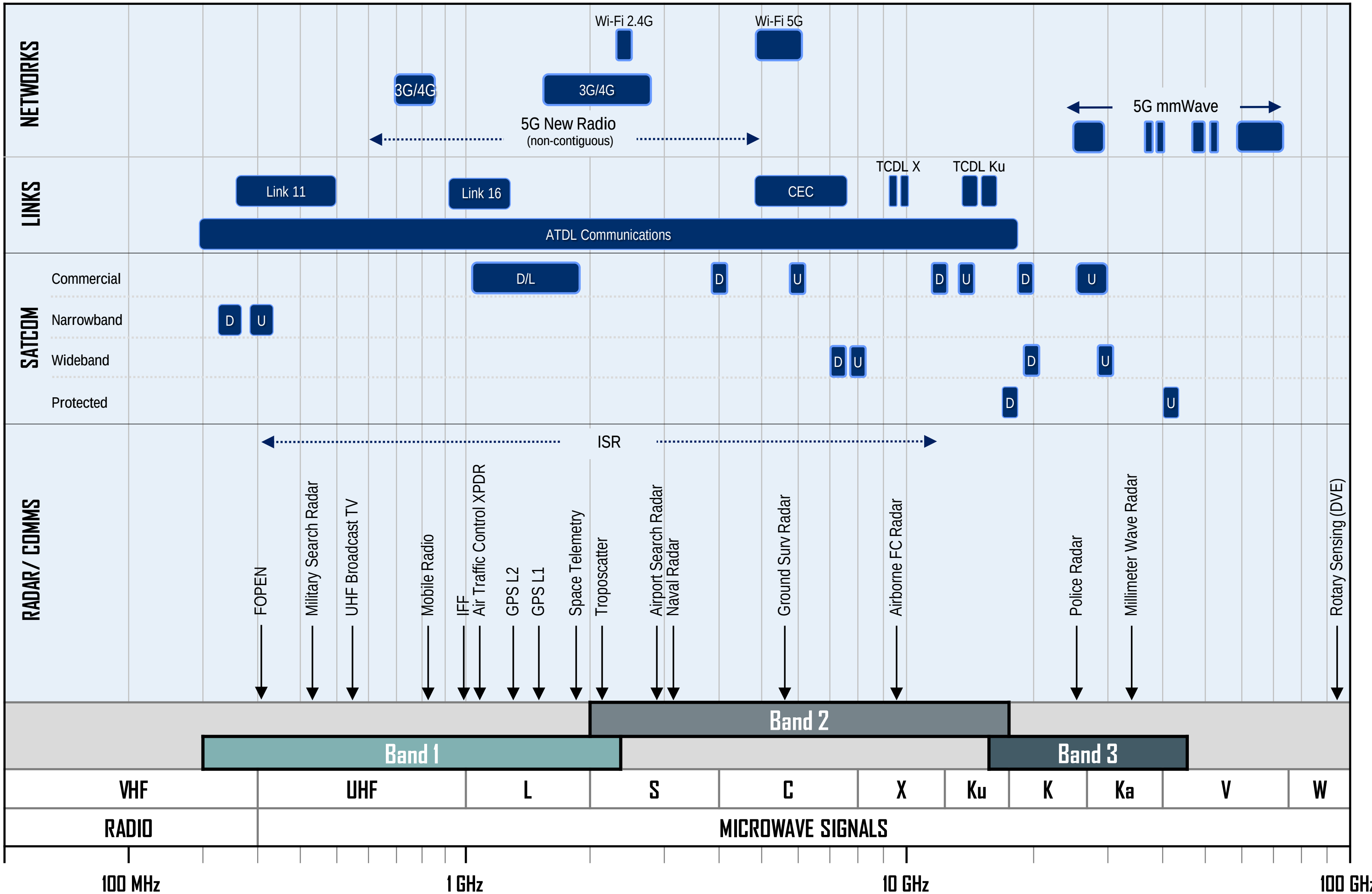
A Contested, Disordered World

We live in a dangerous world, and the fact that our military is the finest fighting force the world has ever known is not a birthright. It's not a guarantee. We have to earn it again and again.

Secretary of Defense Ashton Carter, 2015

Aviation Week & Space Technology: December 26, 2016
Politics, Terrorism, and Refugee Crises Change World Security Outlook

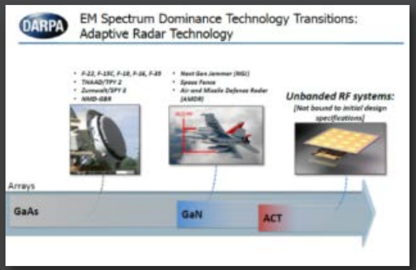
Spectrum Utilization



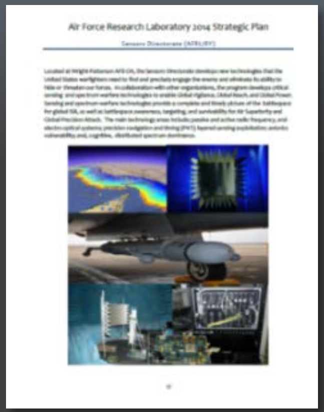
Demand Pull

Focus Areas:
- Ultra-wide-band apertures and electronics
- Techniques for anti-jamming/spectral efficiency
- Machine learning for automated response
- Management and control algorithms for spectral management across battle force, systems and components

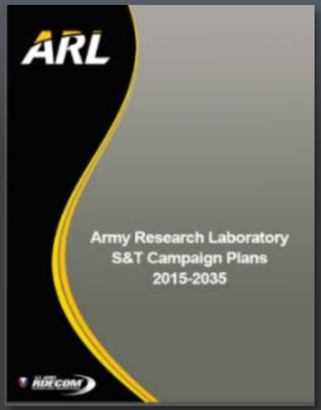
Focus Areas:
- Full and Dynamic control of the EM spectrum for communications, sensing and imaging
- Un-Banded RF Systems



Focus Areas:
- Passive and active RF and EO/IR systems
- Layered sensing exploitation
- Cognitive, distributed spectrum dominance



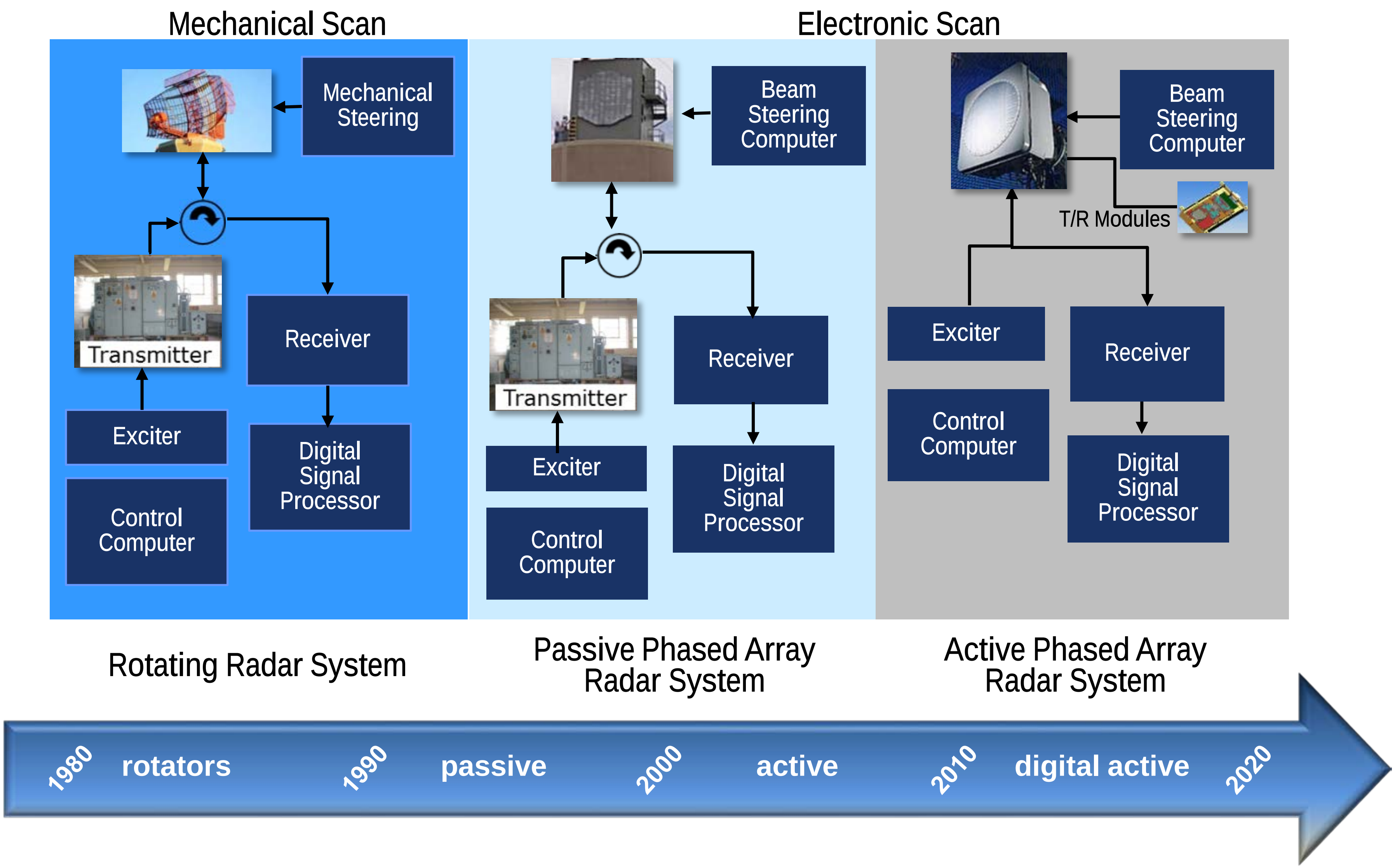
Focus Areas:
- Novel active and passive devices and components with improved dynamic range, linearity, bandwidth and loss performance



Military Seeking Ultra-Wideband, Converged, Spectrum Reconfigurable Sensor Solutions

Historical Overview

Evolution of Military and Commercial Radar



Aegis SPY-1 Radar Evolution

1983
AN/SPY-1A

- *First Shipboard Multi-function Phased Array Radar*
- *Blue Water Mission Focus*

1987
AN/SPY-1B

- *Improved ECM Performance*
- *Increased Average Power*

1991
AN/SPY-1D

- *Adaptation for Single Deckhouse Destroyer Configuration*
- *Automatic Environmental Adaptation*
- *Faster Search Rates*
- *Improved Clutter Rejection*

2004
AN/SPY-1D(V)

- *Pulse Doppler*
- *Improved Clutter Rejection*
- *Dual Beam Search*
- *Integrated Track Initiation Processor (TIP)*
- *Increased Transmitter Power*
- *Additional MTI Waveforms*

Lockheed Martin’s AESA Radar Evolution

1999 | 2007 | Today

1st Generation AESAs

- COTS Technology
- Analog Beamforming

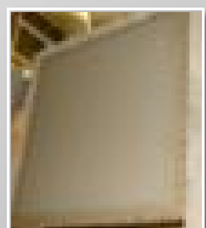
SBAR MSRD

TPQ-53

2nd Generation AESAs

- Scalable System Architectures
- COTS Technology
- Digital Beamforming

VSR



S4R / ARTIST

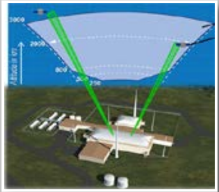
3rd Generation AESAs

- Increased Sensitivity
- Modular/Scalable Architectures
- COTS Technology
- Digital Beamforming

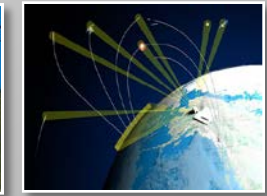
Solid State SPY

MEADS

Space Fence



LRDR



- ***Improved Packaging Optimized for*** *Scalability*
- ***High Levels of Integration***
- ***Significantly Reduced Cost per Element***

The Case for Sensor Convergence

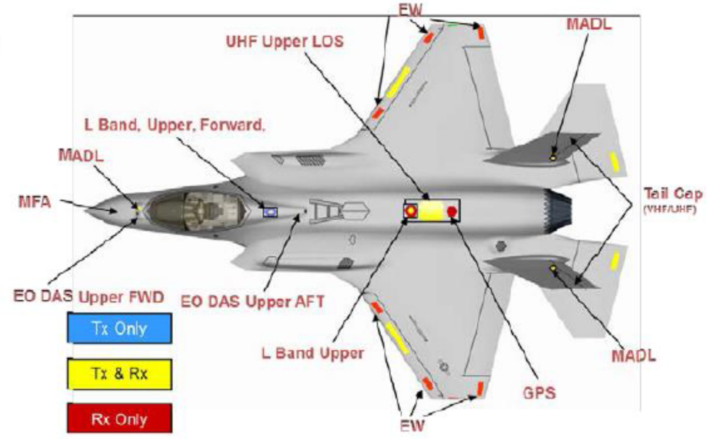
DARPA

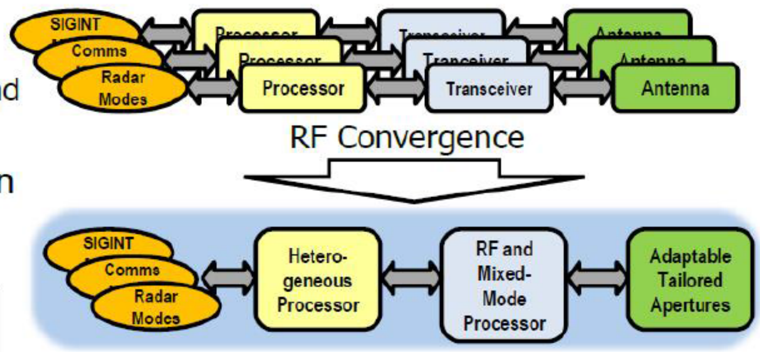
RF Convergence Challenge / Opportunity

STO Strategic Technology Office

- Challenges: Apertures and systems
  - Costly to develop, expensive and time consuming to upgrade
  - Apertures expensive and difficult to integrate onto platforms
- Unsustainable against growing threats and shrinking budgets
- Opportunities
  - Powerful digital processing
  - Emerging flexible wideband distribution to the aperture
  - Flexible wide-band apertures
  - Low cost manufacturing assembly and integration technology
- Enables any function on any band on any aperture at any time

F-35 has many apertures (topside shown here)





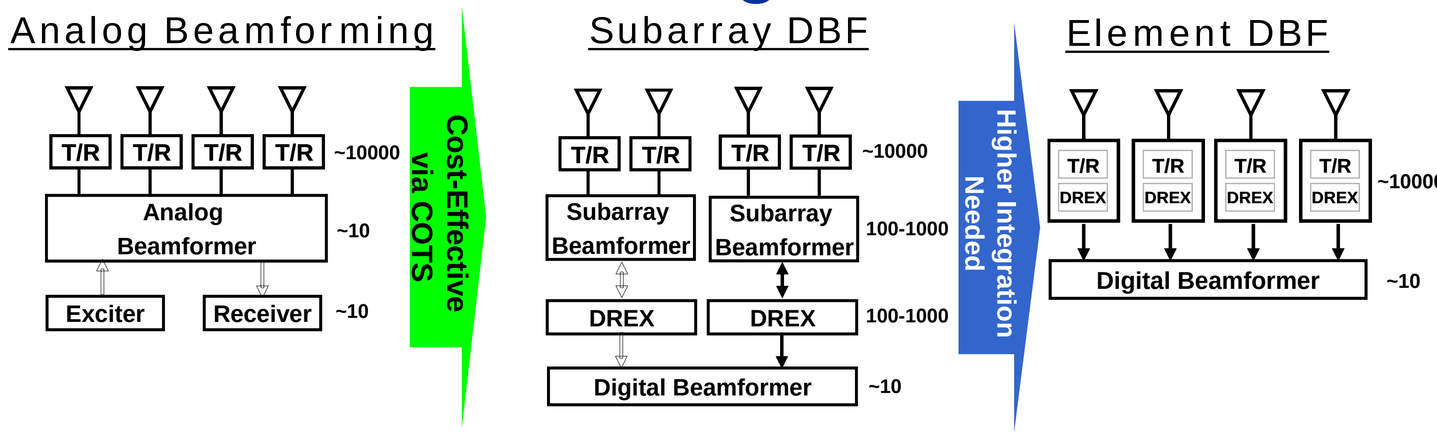
DAS= Distributed Aperture System	EO=Electro-Optical
EW = Electronic Warfare	LOS=Line Of Sight
MADL = Multi-function Advanced Data Link	VHF: Very High Frequency
MFA=Multi-Function Array	UHF: Ultra High Frequency

Excerpt From: “Maritime Radar Trends & Initiatives: A Look into DARPA STO & More”, September 17, 2015, Dr. Tim Grayson, Fortitude Mission Research LLC; DARPA SETA

Current and Future Trends

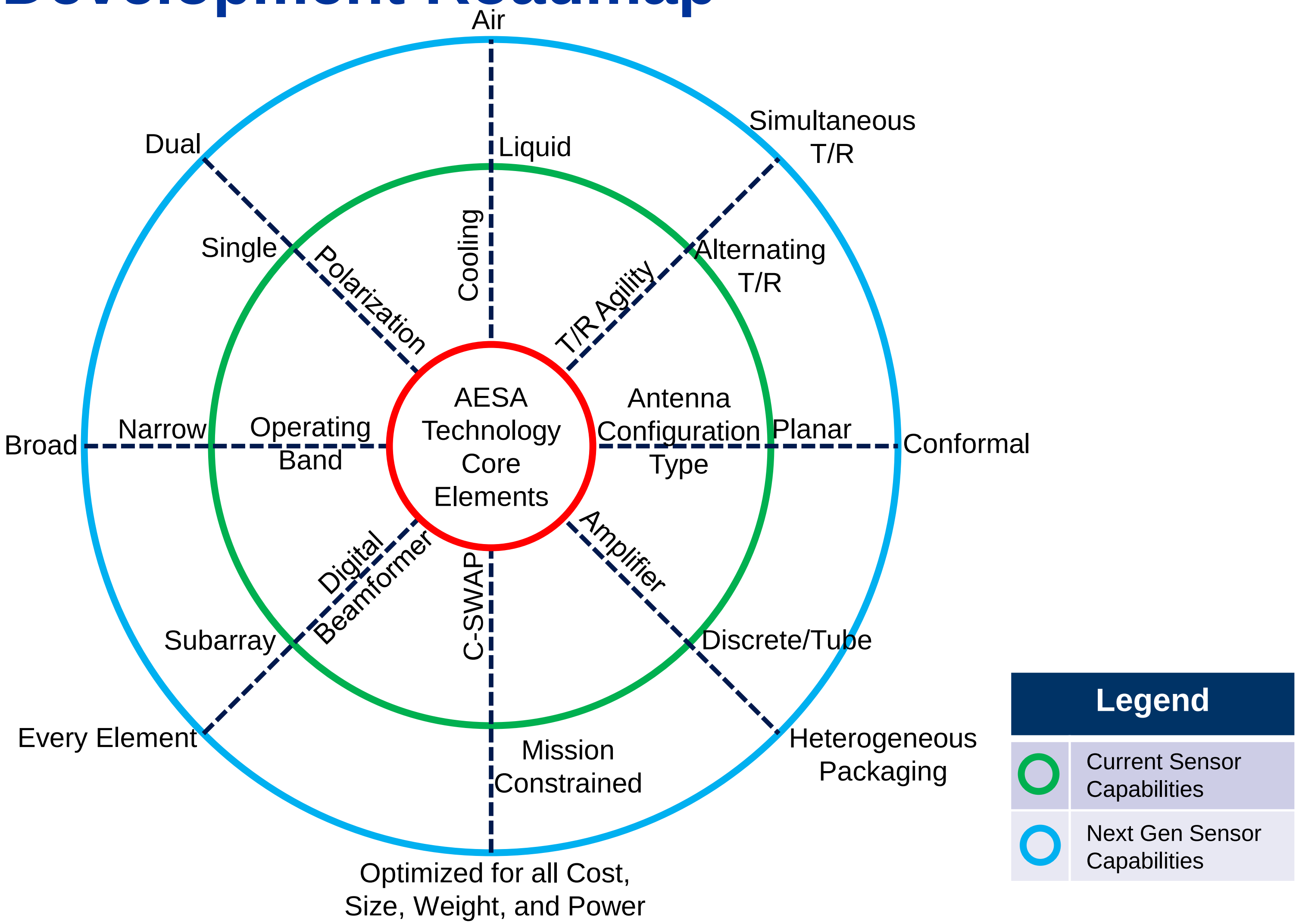
The Benefits of Element Digitization

- Exceptional (blue)
- Good (green)
- Marginal (yellow)
- Unacceptable (red)



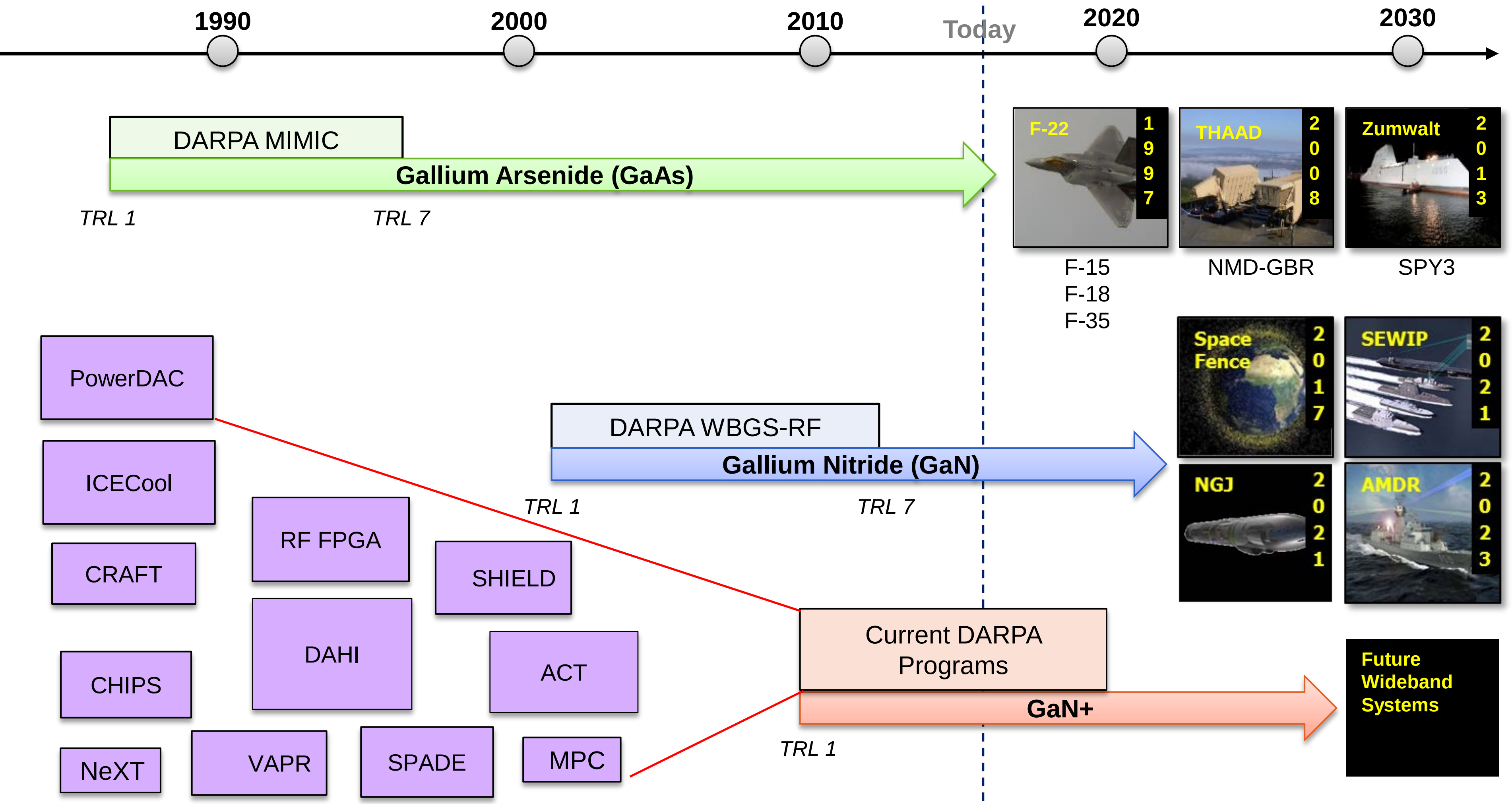
Radar System Performance Metrics	Analog Beamforming	Subarray DBF	Element DBF
Frame Time	Unacceptable	Good	Exceptional
Clutter Rejection	Unacceptable	Good	Exceptional
Instantaneous Dynamic Range	Unacceptable	Good	Exceptional
Adaptive EMI Rejection	Marginal	Good	Exceptional
Adaptive Angle SL	Marginal	Good	Exceptional
TOI Dynamic Range	Marginal	Good	Exceptional
Large Array Packaging			
Packaging Density	Exceptional	Good	Good
Digital Distribution	Exceptional	Good	Good
RF Distribution	Exceptional	Good	Good
Power Consumption	Exceptional	Good	Marginal
Thermal Management	Exceptional	Good	Good

Sensor Development Roadmap



Next Generation Sensor Emphasis is on Multi-Mission Capabilities, with Adaptable Electronics

DARPA IC Technology Investments

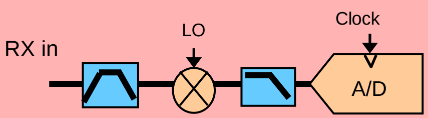


DoD Technology Investments that Are Creating Enabling Technologies

Ultra-Wideband Receiver Options

Mixer Based

Maturity: High



Approach
- Downconversion to IF Frequency
- A/D Sampling at IF

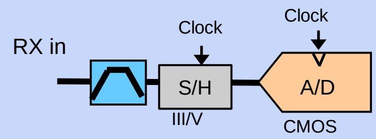
Pros
- Well Understood
- Best Dynamic Range

Cons
- Agile LO Required

Challenges / Tradeoffs
- Power
- Mixer Spurious / Filtering

Sample and Hold Based

Maturity: Emerging



Approach
- Sampling at RF
- A/D Operation in Upper Nyquist Zone
- Fold to First Nyquist

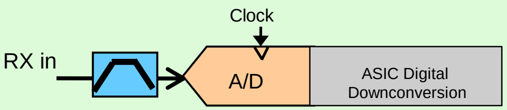
Pros
- Eliminates Mixer
- Easy for a COTS proof of Concept Demo

Cons
- Gaps in coverage at Nyquist Edges
  - Options: Tunable Clock,
    Dual A/D with Nyquist Unwrap
- Noise Folding

Challenges / Tradeoffs
- Power
- Noise / Filtering

Direct Sampling

Maturity: Future



Approach
- Sampling at RF
- Fast A/D Clock
- A/D Operation in 1^{st} and 2^{nd} Nyquist Zone

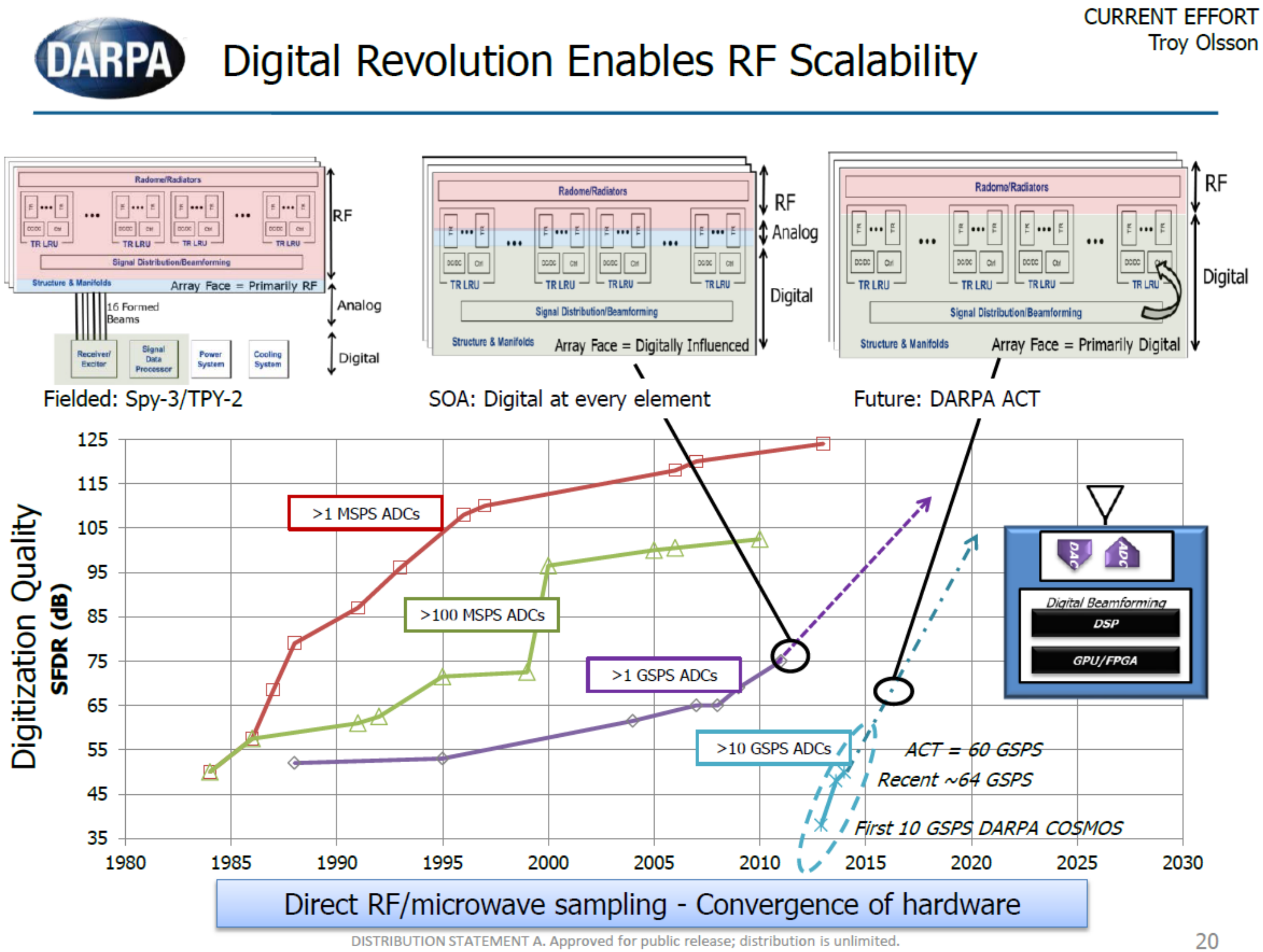
Pros
- Instantaneous Full Operating Band Sampling

Cons
- Technology Maturity
- Instantaneous BW lost at System Level with Digital Down Conversion

Challenges / Tradeoffs
- Power
- Volume of Digital Data
- High Speed Timing

Emerging Requirements are Driving System Solutions to Direct Sampling

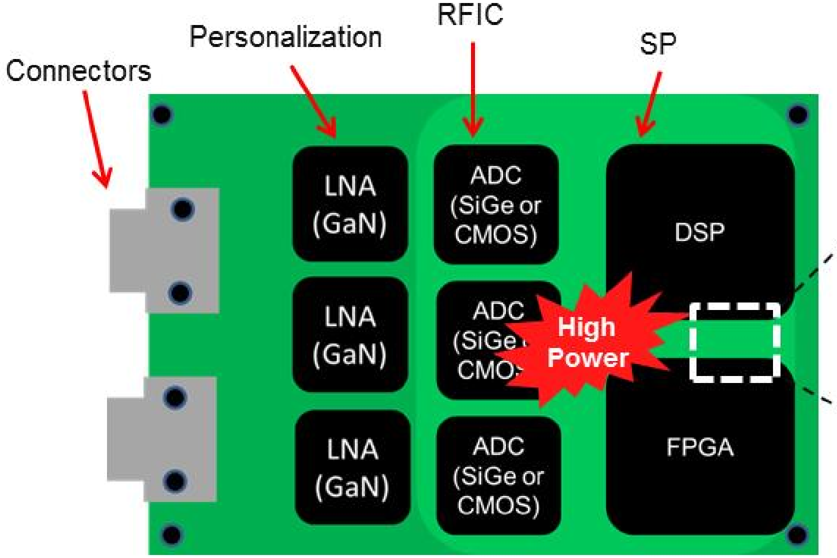
DARPA Focus on RF Sampling

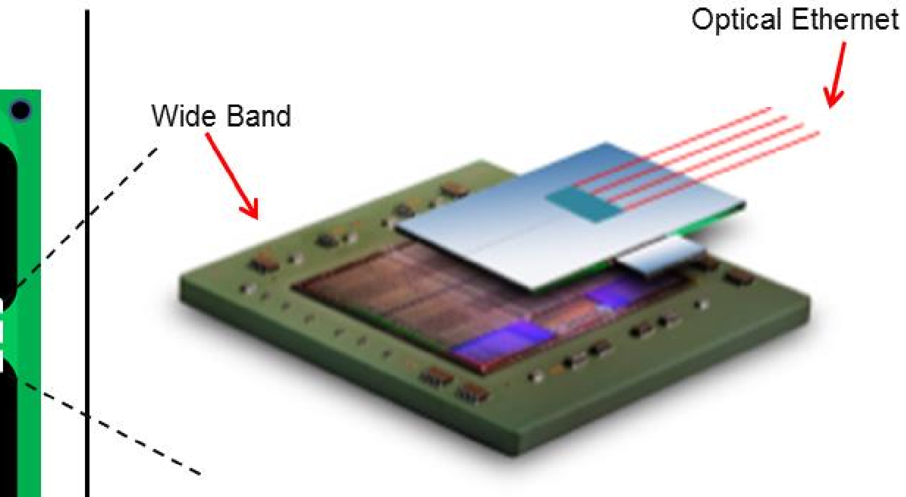


Excerpt From: "Microsystems Technology Office Exposition", February, 2016, Dr. Troy Olsson, PM DARPA MTO

Putting it all Together

State of the Art → **Next Gen HIT** → System-in-Package (HIT)





	Board Based Design	System-in-Package	Benefits
Recurring	~$50K	~$100	↓ Cost
Business Model	Component Purchasing	Commercial Foundries	↓ Cost
Substrates	Printed Wiring Boards	Liquid Crystal Polymer (LCP)	↑ Performance
Interconnects	Cable Harness	Fiber Optic	↓ Weight, Cost
System Test	Cabinet Level	ICLevel	↓ Cost
Life Cycle	EOL Management of COTS	Managing IC IP	↓ Cost
Reliability	Low (large number of interconnects)	High (minimal interconnects)	↓ Cost

Key Enabling Technologies

Technology	Why is this Important?	Major Suppliers / Innovators
 FPGA	• High Speed Serial Communication • Embedded On-array Control • Critical Enabler of Distributed Digital Beam Forming for Digital Array Radar Systems	ALTERA XILINX Microsemi
 Embedded Accelerators	• High Density Algorithmic Computing Resources to Meet Demands of Adaptive Beam Forming • Enable Radar Processing and Control • Meets Size Constraints of Shipboard Applications	NVIDIA AMD ATI intel
 High Speed Networking	• High Speed Serial Communication • Embedded On-array Control • Critical Enabler of Distributed Digital Beam Forming for Digital Array Radar Systems	Mellanox Technologies ARISTA CISCO

Embedded Processing and High Performance Computing Technology for Sensors

Custom/Accelerated Hardware Solutions

- **Custom FPGA-based Hardware Leverages Latest Generation FPGA Technology to meet high throughput requirements of modern AESA**
  - **Digital Beamforming**
  - **Beam Steering Control**
  - **Digital Filtering for Bandwidth Limiting and Equalization**

- **COTS Embedded Accelerator Hardware Employed in Highly Parallel, High Throughput Digital Signal Processing Applications**
  - **GPGPUs applied to Digital Beamforming and Cancellation**
  - **Embedded FPGAs to perform Digital Filtering and very low latency ECM and Sensitivity Control**

Custom FPGA-Based Designs

- Higher Density (50%) and Lower Power (33%) A
  - Moved from 90 nm to 28 nm Technology
  - FPGA Count Reduction (3 to 1)
- 75% Increase in High Speed SERDES Bandwidth from generation to generation

COTS Embedded Accelerators

COTS FPGA/GPP Boards

COTS Graphics Processing Unit

- Accelerators have been assimilated into Radar Signal Processing
- Cray Embedded GPU Platform
- IBM HS23 GPP/NVIDIA GPU
- Intel PHI

Custom Processing and COTS Embedded Acceleration Increases Processing Capability

Summary

- **Existing military primary mission sensors provide significant capability**

- **Evolving technologies are enabling new multi-mission architectures**

- **Future sensors will be smaller, distributed, cohered and converged**

12th Annual

Military Radar Summit

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