Industry Day:

BAA# 04-016

Cost Reduction and Affordability in Advanced Multifunction Radio Frequency Electronics for Fleet Force Protection

April 23, 2004

Dr. Dan Purdy
ONR Code 312
703-588-1920
purdyd@onr.navy.mil

Industry Day Meeting Agenda

- 8:00 – 9:00 Check in
- PART 1 – Government Presentations (MIC, 9th floor)
- 9:00 -- 9:10 Welcome Junker / Lawrence / Purdy
- 9:10 – 9:25 Purdy: Electronics Program summary
- 9:25 – 9:40 Tavik: AMRFC Program summary
- 9:40 – 9:55 Krapels: AMRFC Goals / Transition Plans
- 9:55 – 10:10 Purdy: BAA Philosophy and Highlights

- 10:10 -- 10:25 Break (Fran Rothwell Room, 9th floor)

- PART 2 – Questions and Answers (Panel, Chair-Purdy)
- 10:25 – 11:00 Panel: Answers to written questions
- 11:00 – Noon: Open to questions, discussion, clarifications
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Presentation Data Classification

- UNCLASSIFIED meeting
- DO NOT discuss classified numbers!

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Opening comments for Q&A sessions

- Oral Questions OK as time permits (during presentations)
- NOTE: Please submit any written questions to D. Purdy at beginning of the break
- Contributors and participants:
  - Code 31: Junker
  - Code 312: Purdy, Mack, VanVechtion, Dietrich, Hathaway
  - Code 313: Lawrence, Kraples, Pollock, Monsma, McGreggor (Johnson)
  - NRL: Tavik, Webb, Rao, Alter
  - Q&A Panel members

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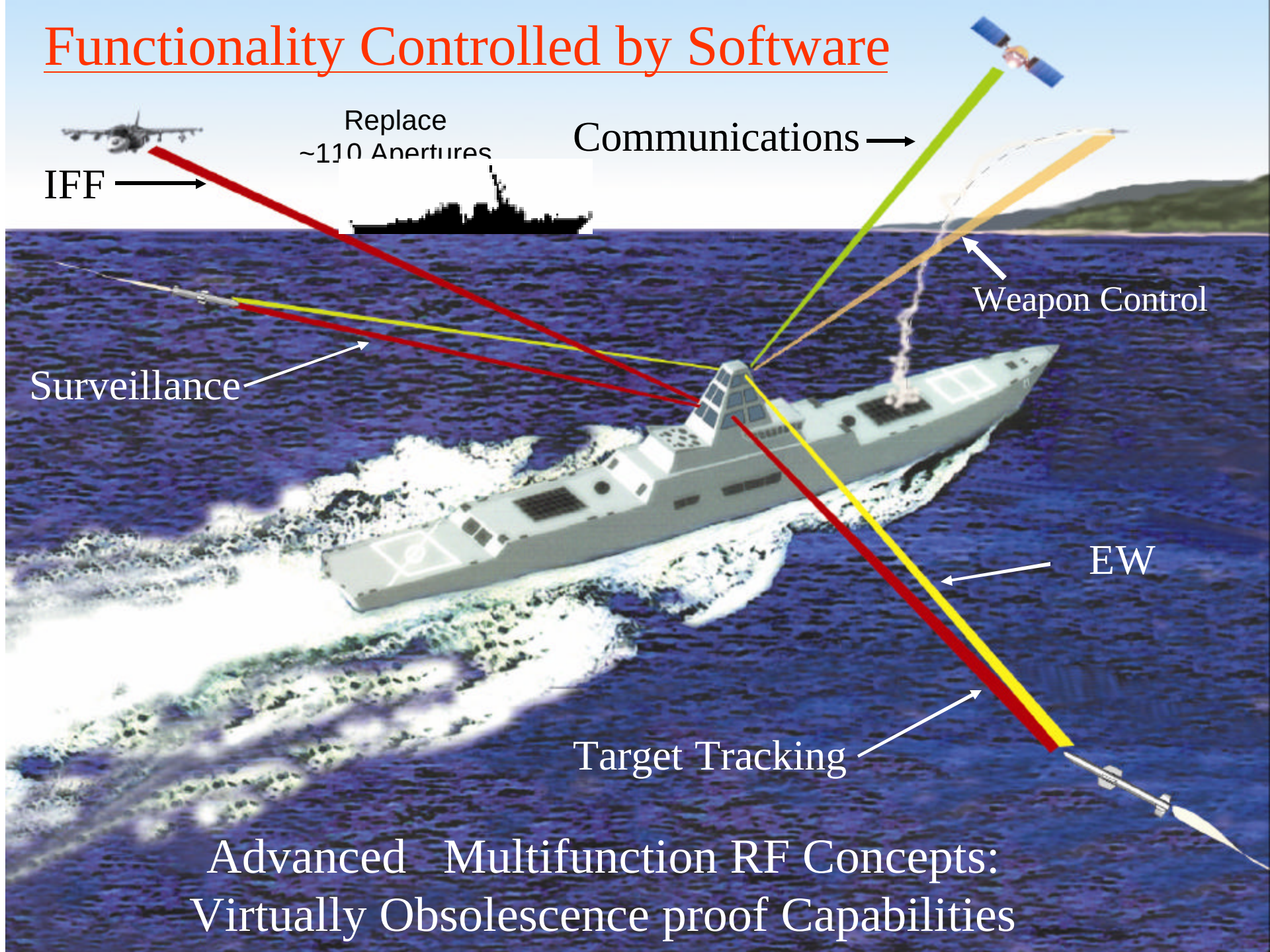
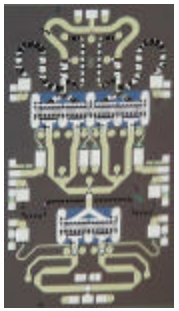
Functionality Controlled by Software

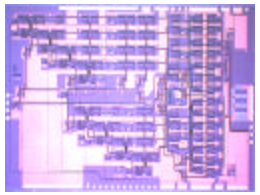


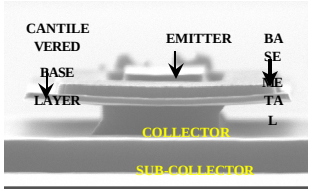
Advanced Multifunction RF Concepts:
Virtually Obsolescence proof Capabilities

Enabling Capability (EC) 2
Electronics Technology Demo

OBJECTIVE: To perform research and development of advanced electronic components which enable new RF architectures for multifunction electronically scanned arrays. These new electronically scanned arrays support the AMRF-C and other programs and are capable of generation of multiple simultaneous beams.







APPROACH / TECHNOLOGY AREAS:

- High Power Solid State Amplifiers: Si,GaN, HV-GaAs
- Extremely low noise, robust amplifiers
- 100+ GHz Logic based on InP at room temperature
- Direct Digital Synthesizers (DDS); μ–wave frequencies
- High Power DACs; multi-octave bandwidth
- Advanced New RF Architectures
- Low phase noise clocks and techniques
- Bandpass ADC's; sampling at RF frequencies
- Wide bandwidth, high power isolators and channelizers
- Thermal management techniques; ultra dense high power
- Amplifier chain linearizers, multi-GHz Bandwidth

Achievements / Projected Benefits:

- **High Power Solid State Amplifiers**
  - Improved efficiencies and multi-octave bandwidths.
  - Achieved factor of 5 increase in power levels over GaAs
- **Direct Digital Beamforming at Microwave Frequencies**
  - Demonstrated word record DDS at 4.6 GHz RF
  - Projected DDS to 20 GHz frequency
  - Multiple simultaneous beam capacity
- **80+ GHz Flip-Flops achieved @ (120GHz projected)**
- **100 GHz sources with 120dBc @ 1Khz (projected)**
- **5GHz Center Frequency, up to 500 MHz programmable bandwidth ADC's (projected)**
- **New Software Definable RF Apertures and Architectures**

Transitional Opportunities:

AMRF-C Version 2 Test Bed, Digital Array Radar
SEWIC EA transmitter, IDEKM, NULKA upgrade, HESS, Low Cost Radar

Projected System Impacts:

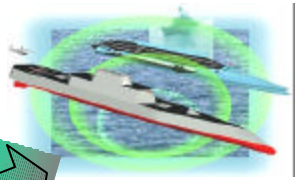
Increased bandwidth, high power, multi-functional electronics for Naval systems.

ONR POC:

Dr. Dan Purdy, ONR Code 312, purdyd@onr.navy.mil
703-588-1920

Systems that Directly Benefit from the Electronics Components Demo Program

AMRFC

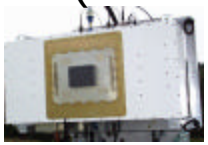


Near term

Next Generation

IDECM

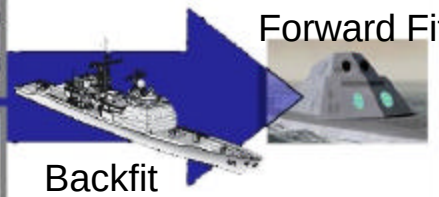
(SEWIP) EA Transmitter



S-Band

DAR

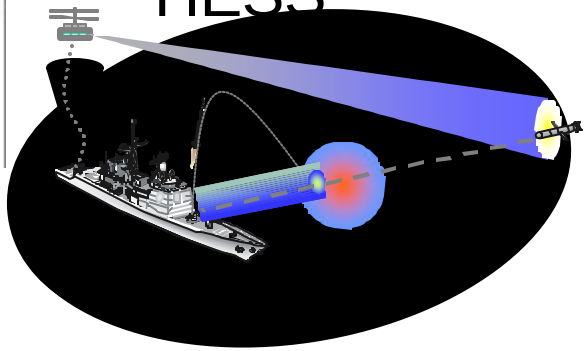
Forward Fit



Backfit

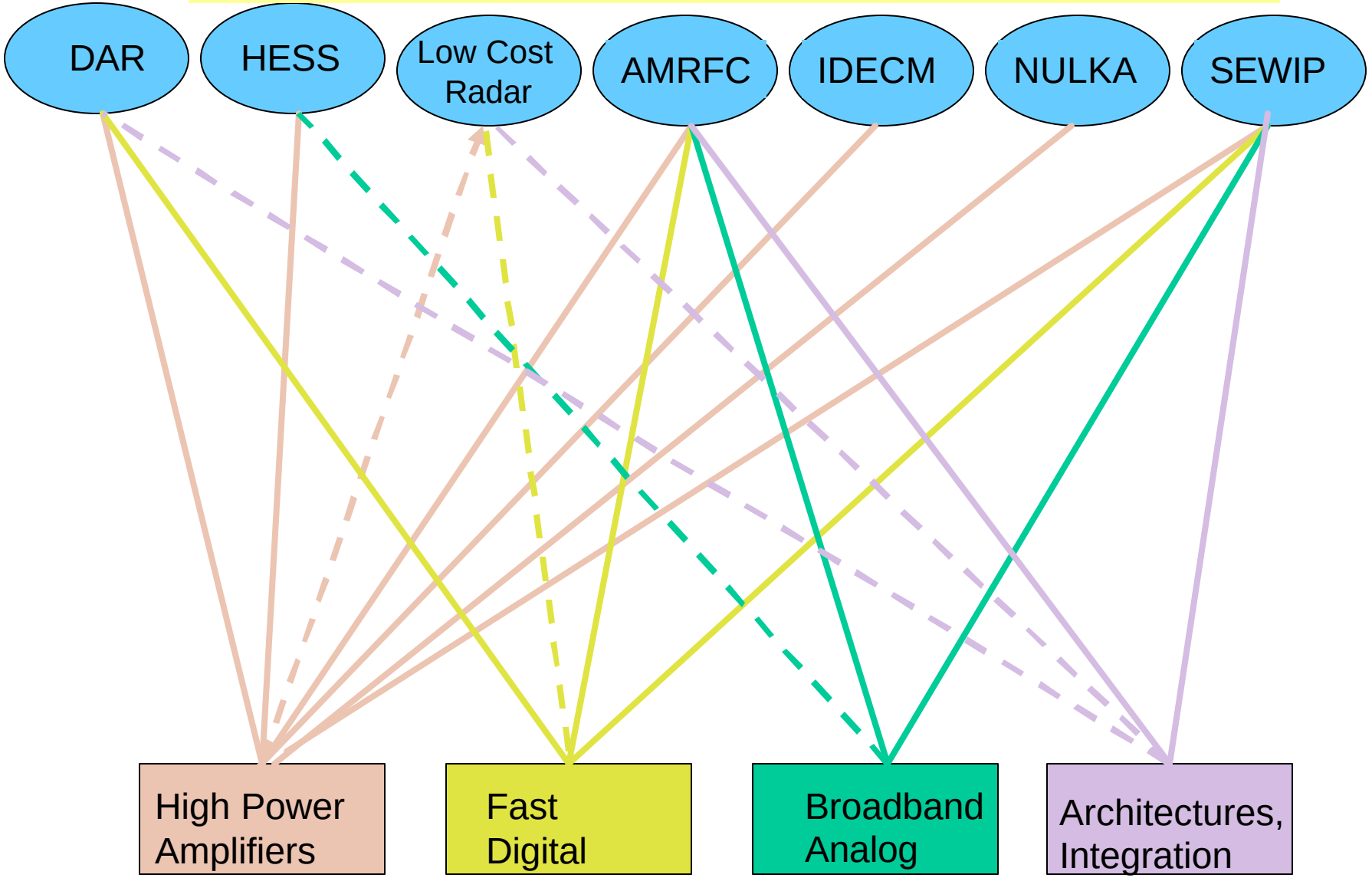
X-Band

HESS



NULKA

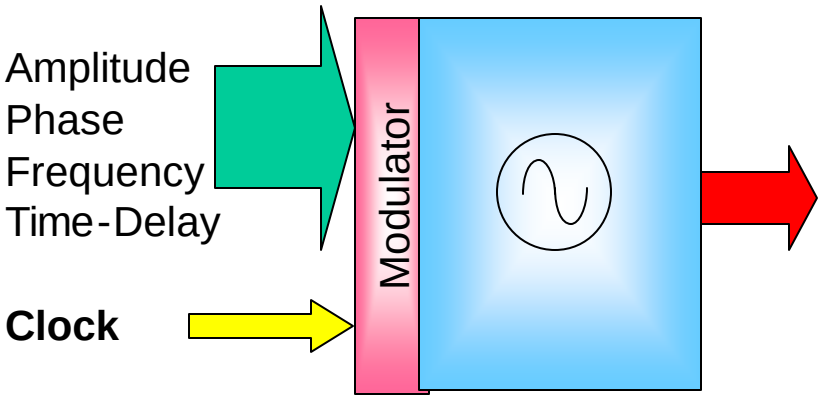
Systems that Directly Benefit from the Electronics Components Demo Program



Some historically funded projects under ONR this program

Direct Digital Synthesis

Digital Inputs: **RF Output:**



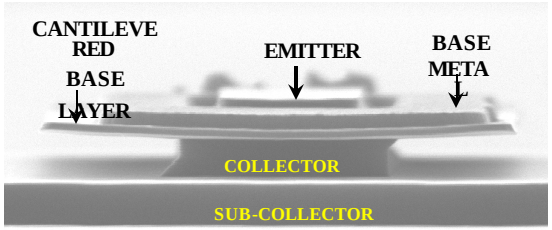
POC: Dr. Dan Purdy, ONR

Objectives:

- RF outputs to 20 GHz
- -160 dBc phase stability derived from clock
- Multi-GHz bandwidths
- Complex waveform generation
- True time delay for beamsteering

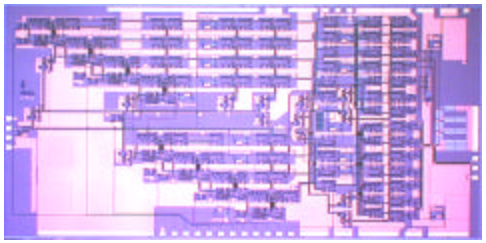
Approach:

- Monolithic mixed signal
- Sub-micron scaling of InP HBT's
- Multi-bit Sine-ROM lookup table
- 1-bit delta-sigma



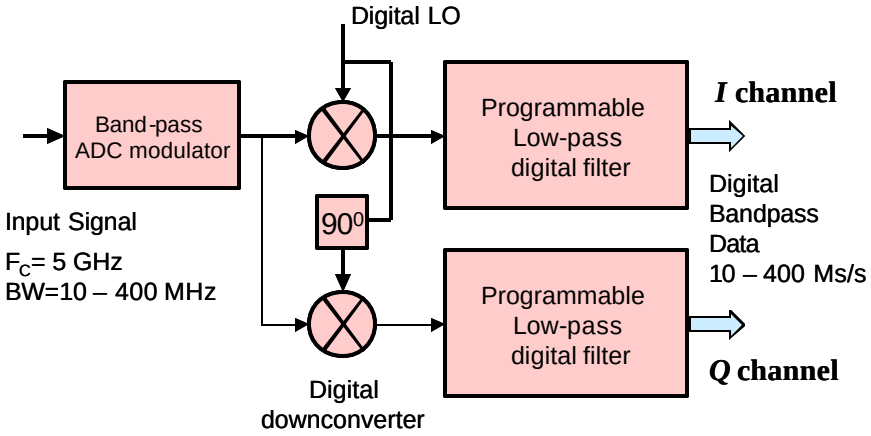
Recent Accomplishments:

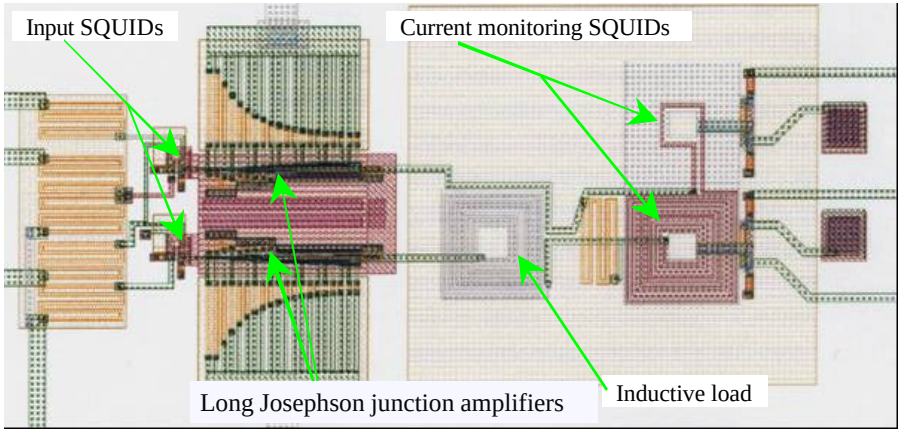
- Record 3300 InP Transistors on chip
- Record 4.56 GHz RF output
- Clock frequencies to 9.2 GHz
- Novel architectures



5 GHz Superconducting ADC Development

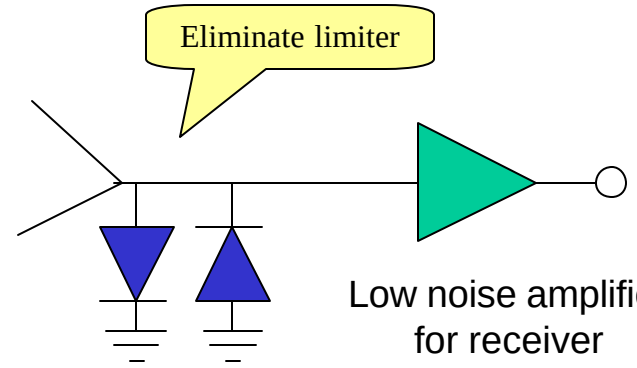
- SCE digital logic necessary for performance > 20 GHz
- 300 GHz T Flip-Flop demonstrated- allows wideband ADC directly at RF
- Completed design & fabrication





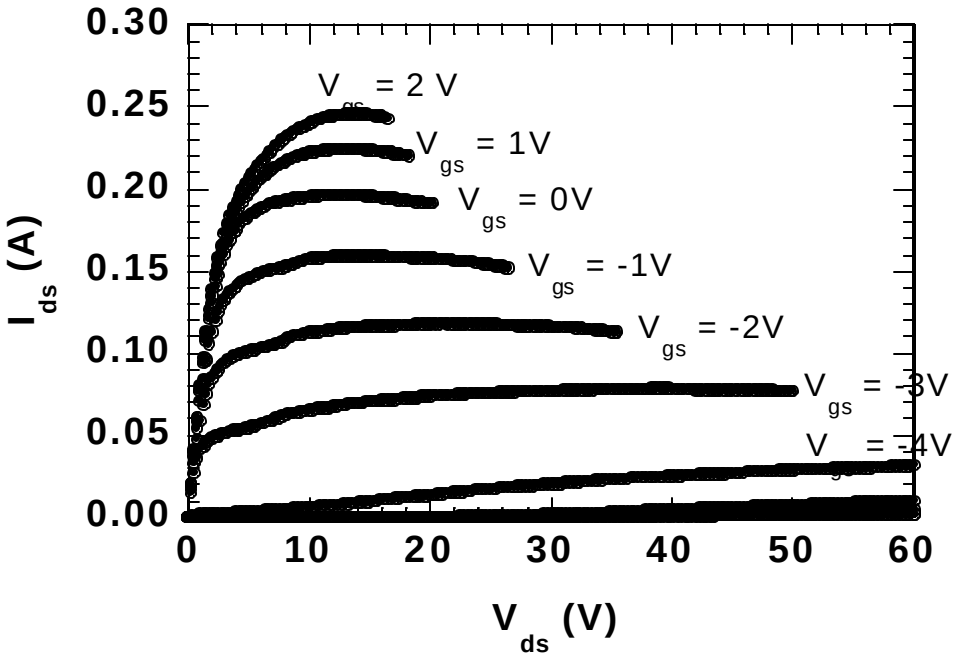
Hypress

High Dynamic Range Robust LNA



Limiter
0.5 to 2.0 dB loss
==>> NF

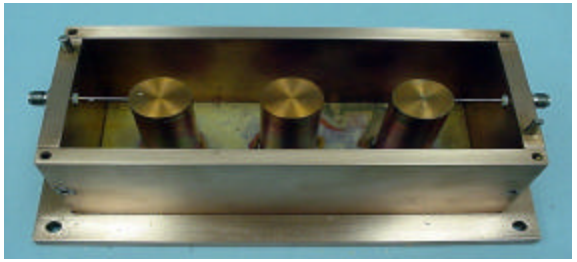
AlGaN HEMT DC characteristics



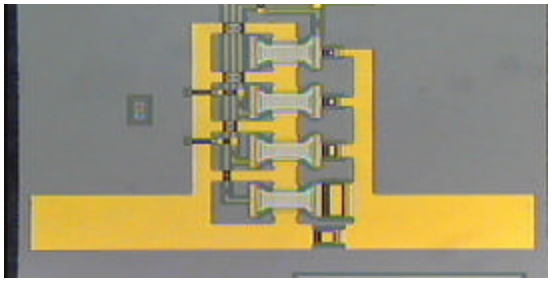
Metric	GaAs pHEMT	InP HEMT	GaN HFET
Minimum NF @ 10GHz	~ 0.5 dB	< 0.3 dB	0.4 dB
Associated Gain	14 dB	18 dB	14 dB
Breakdown Voltage	~ 4 V	~ 3 V	>80 V

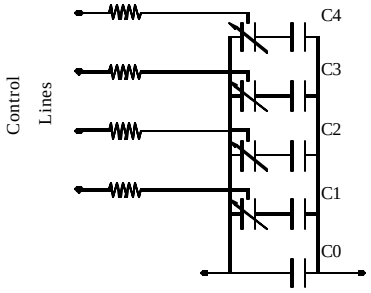
Tunable Filters

High Power

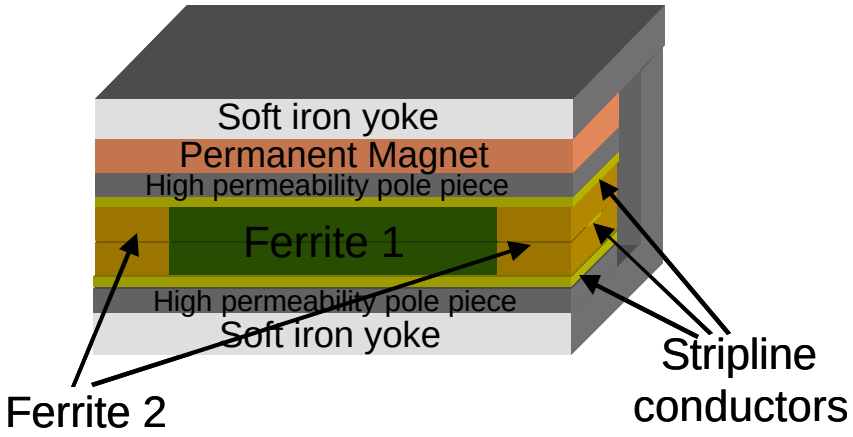


Low Power

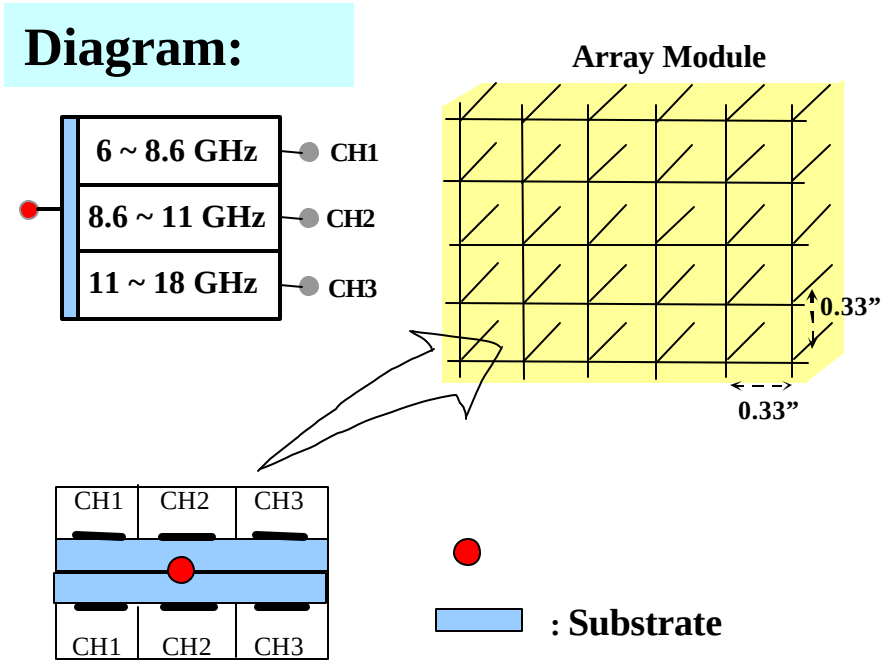




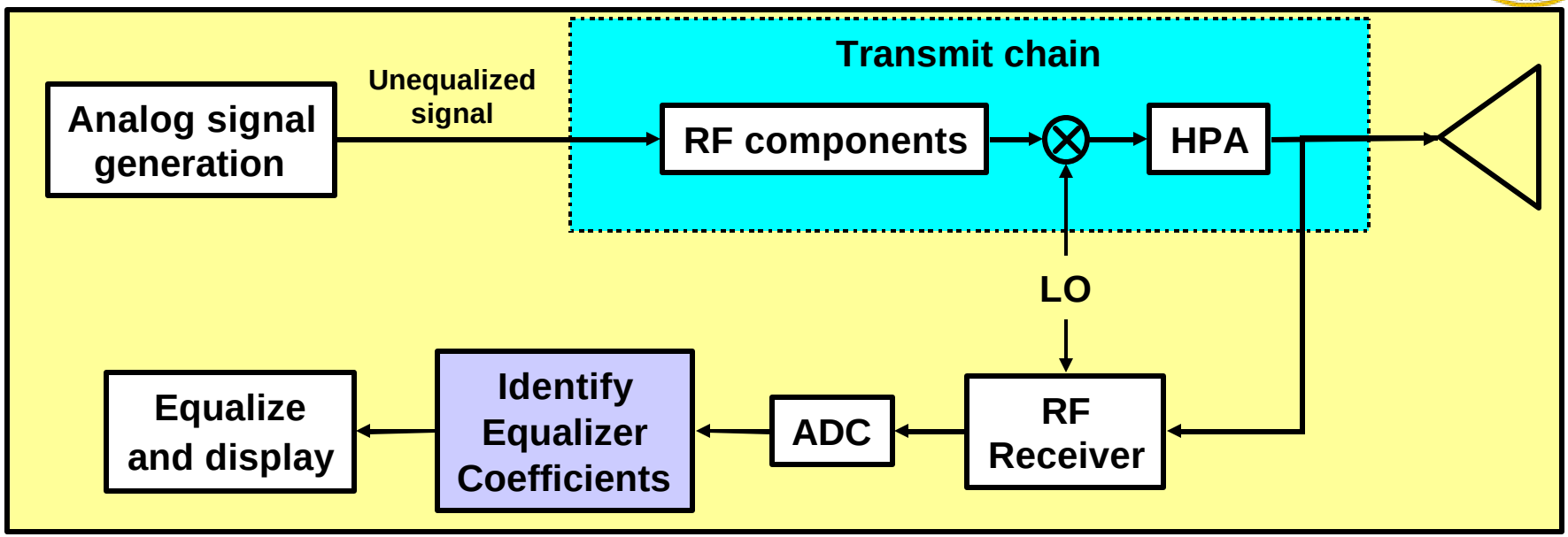
High Power, wideband Isolators



High Power (TX) Channelizers

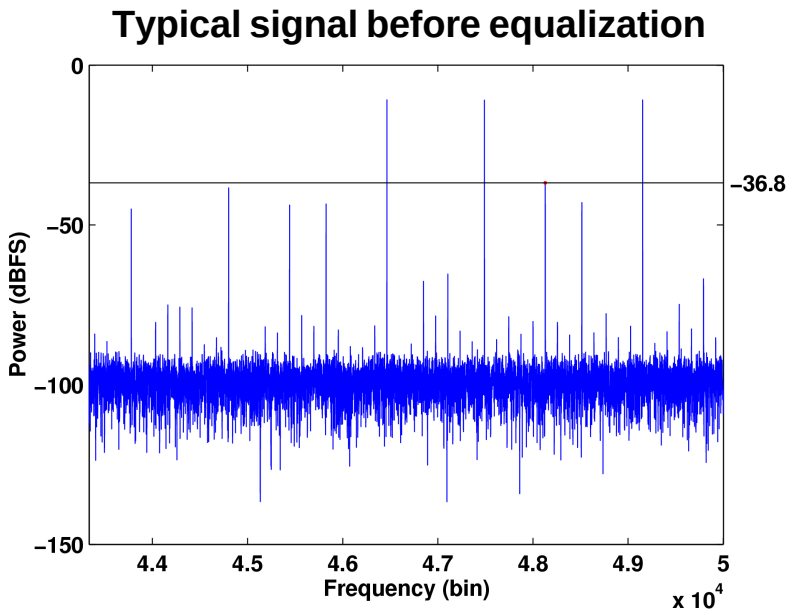


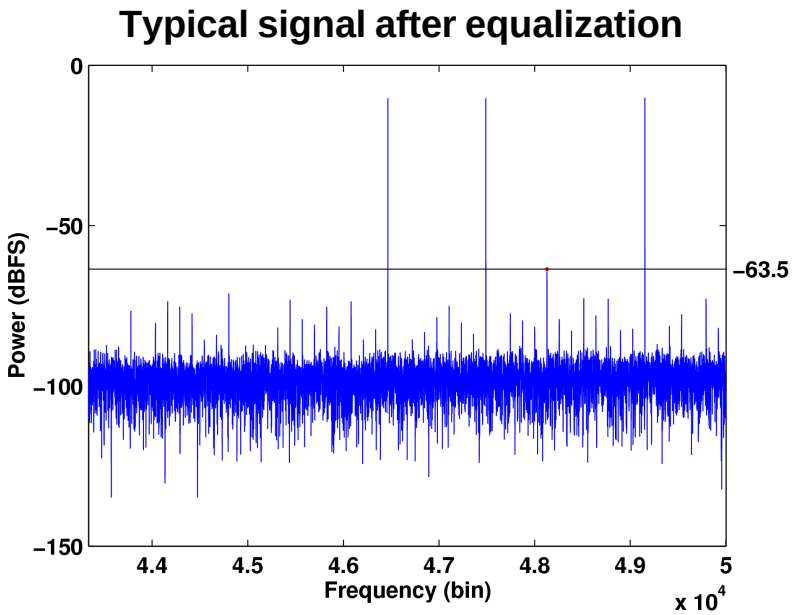
Equalization Experiment Setup (FY02)



- One-, two-, and three-tone input signals
- Variable input power allows saturation levels from very linear (70 dB+ SFDR) through 3 dB compression point
- Receiver has linearity in excess of transmit chain's linearity
- Current setup allows bandwidth up to 200 MHz
- Sample rate 1GSps (Maxim 104 ADC)

Typical High Power Amplifier Equalization Results





- HPA operating at 1 dB compression point
- Achieved a 27 dB improvement in SFDR

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* *William Gottwald will present for Keith Krapels and Greg Tavik*

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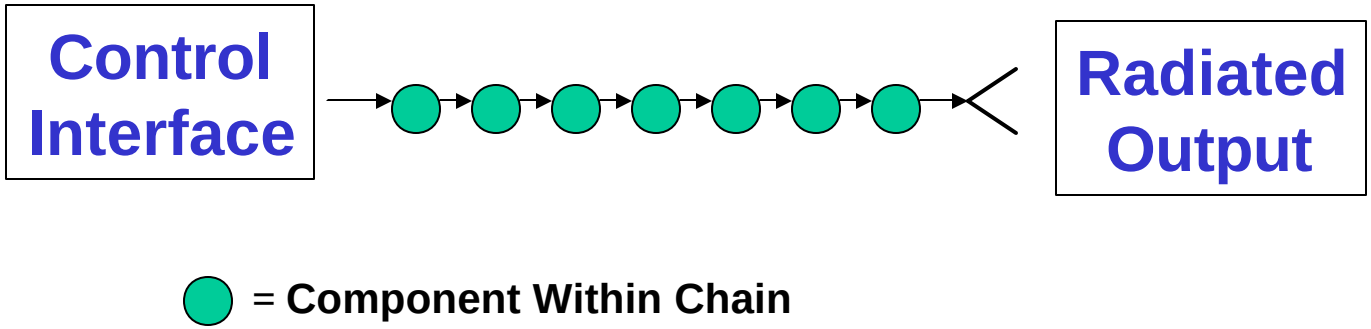
Basic Philosophy of Program

- FY05-FY07 (…maybe beyond? Future Array Demo?)
- Fill-in Gaps
- Demo whole optimized RF element chain for ESA
  - End to end solutions
- **Cost** and performance improvement
- Deliverables:
  - See BAA
  - Complete functional circuits TRL5 (or greater preferred)
  - RX and TX both needed (see BAA and Q&A's)
  - Clear path to modules, lower cost
- Contractors may team as makes best sense
- Find solutions that are readily scaleable
- Plug-and-play?
- Highly integrated solutions where makes best sense?
- Standardized interfaces?
- See BAA for Details

TX RF Element Chain Demonstration
(for example)



Component Functions:

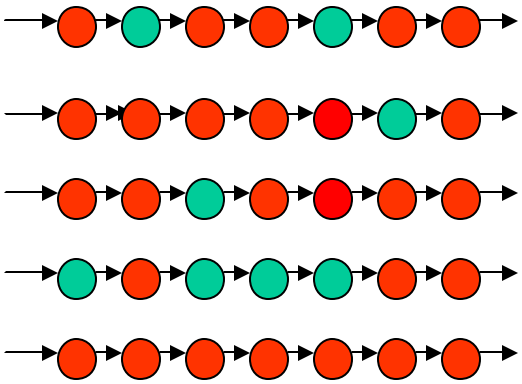
1. Signal generation / synthesis / modulation
2. Signal Combining
3. Beamforming
4. RF power
5. Isolation and filtering
6. Radiation
7. "House keeping" functions

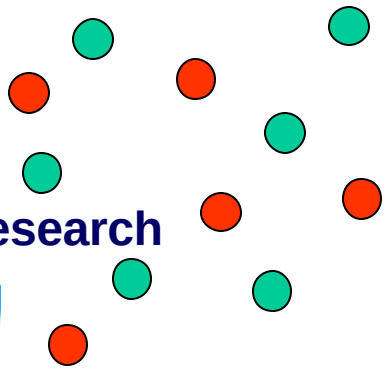
Ideas → Electronics Components → Array

= Fund / Demo (e.g., to prove-out, already proven; "Obtainium")

= Not yet funded or not technically viable; "NON-Obtainium"

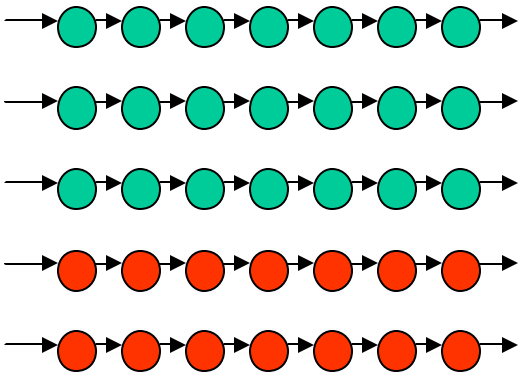
Discovery and invention:

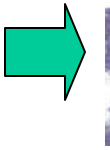


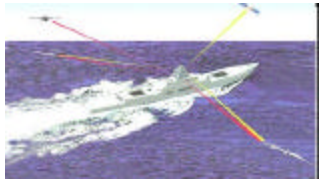


Basic Research

Exploitation and Development (FNC) strategy:





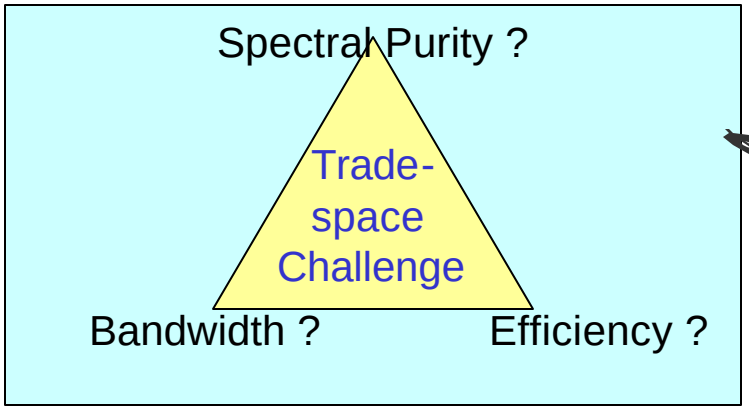


- Develop, demo, or prove ***whole RF element chain***
- (Note that in some cases 'GREEN' might include prior or existing components as well, so we are filling the 'RED' wholes where it makes best sense.

… It takes many years to get from ideas (FY98) → arrays (FY07)

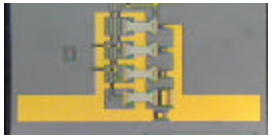
Some Significant Challenges:

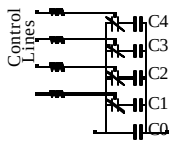
(Examples of RE: AMRFC electronics)



$ COST $!

?? Tunable Filters ??

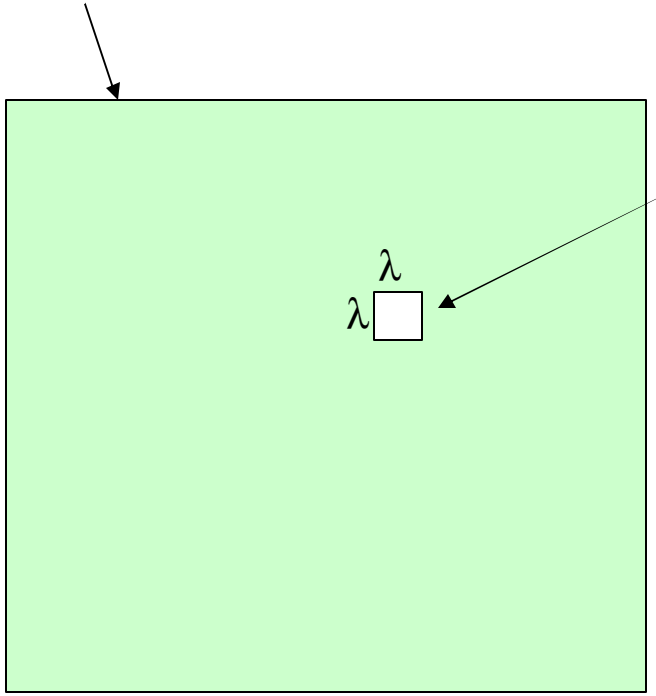




- Amplifier bias and back off?
- Arrays are built from 1000's of elements (not one element)
- Maturation and TRL (need sufficient maturity for array use)
- Significant issues with tunable filters?
  - Not yet clear this is the best technical solution
- Spectrum and isolation (e.g., EMI, EMC)
- How to cohere multiple elements?
  - (maintain calibration over time, power, temperature, simultaneity, and etc…
- Affordability: How to achieve?
  - Highly integrated solutions for element chains
- Where can we "re-use" components if at all possible
  - e.g., must be truly multifunctional

Format for Providing Metrics

Large Electronically Scanned Multifunction RF Array (100's - 1000's of elements)



- Consider element chain (circuit) including components, circuits, etc.. Per BAA guidance:
- What are the important performance capabilities and limitations of a λ x λ section of the large array?
- Provide specifics per BAA guidance
- Indicate where results are be scalable
- Must represent under conditions and mode of use

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Q&A session

- **What is the relationship of this BAA (#04-016) to a recent ONR RFP listed in FEDBIZOPS?**

  - Both are under the FFP FNC and support advanced multifunction RF Concepts.

  - ONR uses best judgment to maximize synergy among different programs.

  - ONR will not fund redundant technical efforts.

  - The specific RFP details are not to be discussed in this meeting.

  - Contractors may choose to respond to either, both or none of the announcements (entirely the contractors choice)

Q&A session

- **Could ONR provide clarification cost ?**

  - Contractors must consider cost in the proposed effort and will be evaluated accordingly. Cost is one of the key evaluation criteria.

  - Historically, within the program ONR and contractors have evaluated costs of associated electronics systems; however ONR can not provide details of studies due to proprietary nature of cost estimates. Costs are dependent on system under consideration.

  - Suggested guidance is to consider technical approaches that may have a dramatic improvement in cost (1/3 goal)

  - A possible example might include, increase in capacity or functionality so as to reduce cost per function unit of a given array. In other words, adding simultaneity and/or functionality to an ESA for minimal cost.

Q&A session

- **Could ONR provide clarification cost (Cont'd)?**
  - Another innovative approach might be: 'plug and play' modules. Is this a possible approach for MFRF and ESA technology?
  - High level of integration, scalable designs, are all possible approaches the contractor may wish to consider
  - Other innovative approaches and 'out of the box' ideas are encouraged.
  - Technical approaches / proposals MUST have a sound plan to reach TRL per BAA.

Q&A session

- **Are photonics, …, InP, SiGe, GaAs, GaN,…., etc… specific technologies, architectures, etc… of any interest?**

  - Yes.

  - In Section 6, the BAA states examples of technologies, components, and material systems which have historically been funded under the program. However it also states "**Other innovative components and technologies not listed are highly encouraged**.....". Do not misconstrue examples as only interested technologies.

  - The Government is not directly specifying which type of material, components, architecture, etc.. must be used.

  - Proposals must addresses the overall objectives of the BAA.

Q&A session

- **Does RX or TX have priority??**

  - The BAA solicits proposals for both RX and TX

  - The Government has a slightly nearer-term priority for RX
    - › Demo Array planned for FY05-FY07 → transition to fleet

  - The Government has a slightly longer-term priority for TX
    - › Demo array is planned for FY08-FY11

  - Contractors may submit proposals for TX, RX, either or both. It is entire the up to the contractor to choose which are to be addressed.

Q&A session

- **Clarification of Interface definitions?**

  - Contractor must consider interface definitions.

  - The Government plans to pursue an open system architecture approach
    - › Black box interface for chain must be define within program execution
    - › Top level interfaces to be published to allow for competitive approaches
    - › Plug-and-play highly desirable

  - Open message format highly preferable

  - Commercial interfaces highly desirable (e.g., Ethernet, COTs, etc)

  - Future: Industry working group is possibility (industry to define)

Q&A session

- Is there an unclassified or classified requirement specification with more definitive metrics than what appears in the BAA?
  - Government persons / BAA have presented a somewhat generic overview of the requirements. No classified requirements will be presented / discussed, since it is open to public.
  - A potential suggestion might be: work the problem sets as best as possible and address fundamental issues. Provide a scalable solution that can be easily adapted to specific systems requirements.
- Can specific numbers be given for RF power versus application, receiver protection level, and tuning speed?
  - Assume numbers that are most constant with EW, Communications, and radar.

Industry Day Meeting Agenda

- 8:00 – 9:00 Check in
- PART 1 – Government Presentations (MIC, 9th floor)
- 9:00 -- 9:10 Welcome Junker / Lawrence / Purdy
- 9:10 – 9:25 Purdy: Electronics Program summary
- 9:25 – 9:40 Tavik: AMRFC Program summary
- 9:40 – 9:55 Krapels: AMRFC Goals / Transition Plans
- 9:55 – 10:10 Purdy: BAA Philosophy and Highlights

- 10:10 -- 10:25 Break (Fran Rothwell Room, 9th floor)

- PART 2 – Questions and Answers (Panel, Chair-Purdy)
- 10:25 – 11:00 Panel: Answers to written questions
- **11:00 – Noon: Open to questions, discussion, clarifications**
- Noon -- Meeting Adjourn
- 12:30 – Doors close


The End