AIRBORNE PHASED ARRAY RADAR (APAR)

Jorge Salazar, Eric Loew, J. Vivekanandan, Wen Chau Lee and V. Chandrasekar
EARTH OBSERVATORY LABORATORY, NATIONAL CENTER FOR ARMOSPHERIC RESEARCH
Boulder, Colorado 80307 US

I. Introduction

Airborne radar systems have been used successfully to study air motion and microphysical characteristics in storms where ground-based radars are ineffective. Studies of tropical convection, lake-effect snow, and hurricane eye walls, and rain bands are examples of atmospheric phenomena studied by the Electra Doppler Radar (ELDORA) system. Retirement of Naval Research Lab P-3 aircraft beginning 2013 effectively terminates future deployment of ELDORA in the current configuration. Continuation of airborne radar capabilities necessitated NCAR's Earth Observing Laboratory to investigate possible development of active electronic scanned phased array radar mounted on the fuselage of the NSF/NCAR C-130 turboprop aircraft. Electronic scanning capability offers more accurate and higher temporal resolution meteorological observations in a shorter dwell time when compared to a mechanically scanned beam. Recent advances in monolithic microwave integrated circuits in the commercial manufacturing area show potential for building robust phased array radar. This poster describes preliminary design concept, development timeline and cost.

II. Background

Due to the large surface area of the C-130 fuselage, the radar system can be either C- or X-band. Sensitivity of the X-band radar system is about 5 dB better than C-band in the absence of any significant attenuation due to precipitation. Signal attenuation at X-band is about a factor of five to seven times larger. As a result, an X-band radar fails to penetrate a heavier precipitation region when compared to C-band radar. Figure 1 shows ELDORA X-band radar's limitation for detecting inner rainband as a result of attenuation.

EOL is in the process of developing automatic data quality control of ELDORA data and estimating real-time dual-Doppler winds. This package will be adopted for an e-scan system. One of the significant enhancements to the proposed airborne radar is polarization capability for estimating precipitation and cloud microphysics. A number of simulation studies suggest high quality polarimetric measurements could be collected over limited scan coverage.

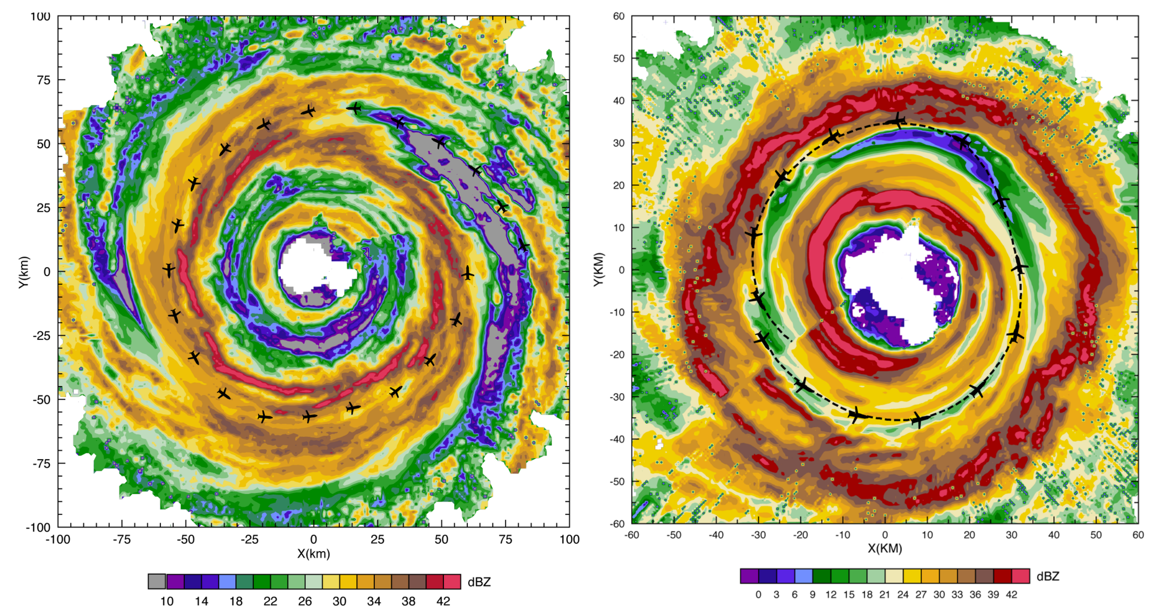


Fig. 1. Hurricane Rita Reflectivity from ELDORA at 2 km MSL, 22 September 2005. Attenuation at X-band limited detection of inner rainband.

Comparison Between ELDORA and the Proposed C-band Phased Array radar

ELDORA	Proposed C-band Phased Array radar
•Mechanically scanned – inflexible, least reliable part of radar •Operates at X band – subject to large attenuation •Transmits high peak power at low duty cycle – single point failure, lifetime < 10,000 hrs •Fixed antenna beamwidth and gain •Limited to single polarization •Calibration is straightforward	•Electronically scanned – fast, flexible, reliable • Operates at C band – less effected by attenuation •Transmits moderate peak power at moderate duty cycle – fault tolerant, lifetime > 40,000 hrs • Antenna beamwidth and gain varies with scan angle •Doppler and dual-polarization measurements (Z_{DR}, K_{DP}, LDR, ρ_{HV}) •Calibration is complex

III. Airborne Phased Array Radar (APAR) Concept

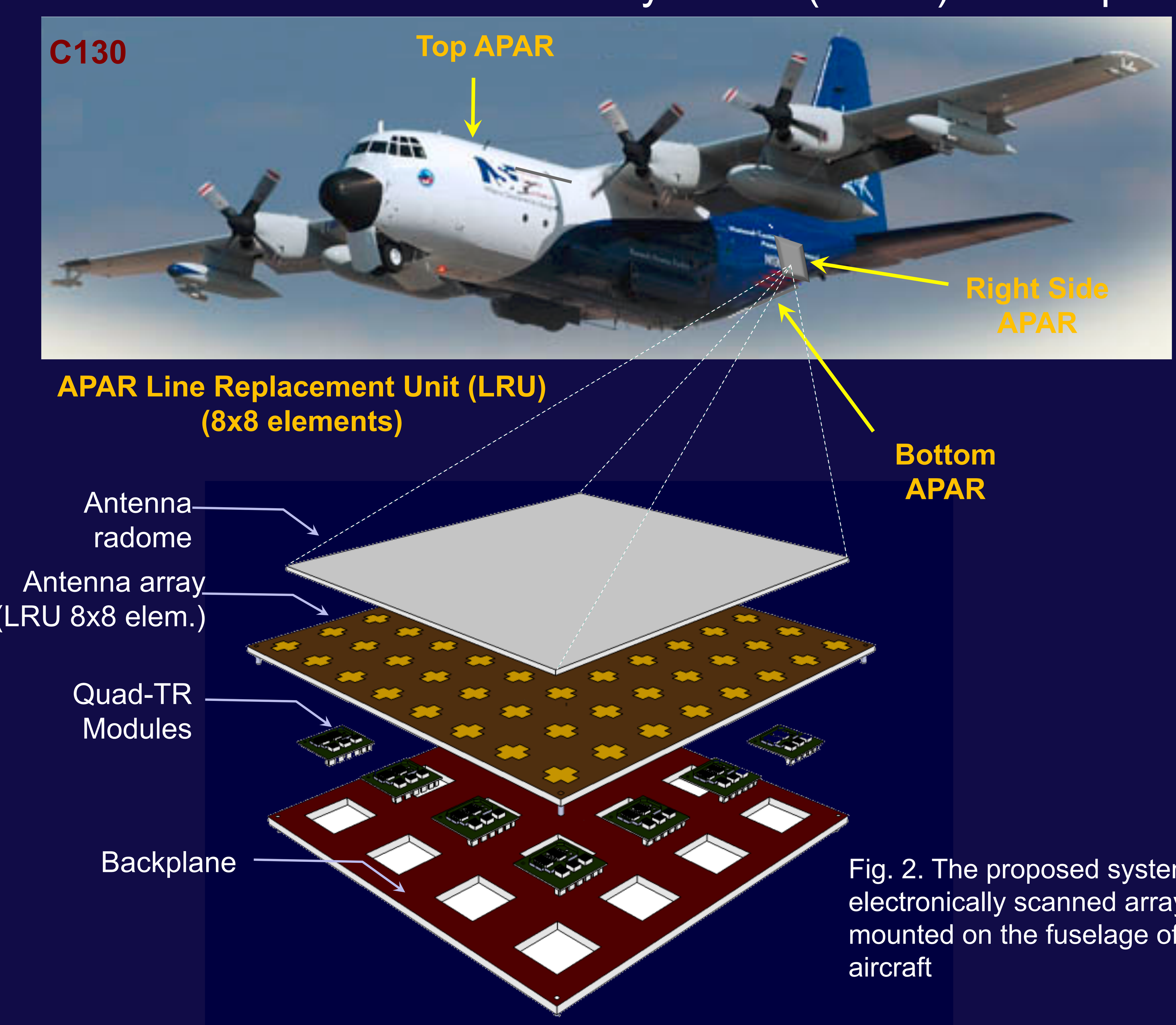


Fig. 2. The proposed system consists of four, C-band active electronically scanned array antennas (AESAs) strategically mounted on the fuselage of the NSF/NCAR C130 turboprop aircraft

APAR Technical Characteristics

Parameter	Specification
Frequency	5.4 GHZ
Wavelength	5.55 cm
Element spacing (0.5 lambda)	2.78 cm
Number of Elements (#Nx, #Ny)	56, 64 (3584)
#LRUx, #LRUy	7, 8
Tx Beamwidth (Uniform)	θ_0: 1.8°, 1.6° θ_{45}: 2.1°, 1.8°
Rx Beamwidth (Taylor -25dB, n=4)	θ_0: 1.9°, 2.2° θ_{45}: 2.2°, 2.5°
Tx Gain Rx Gain	40dB 39dB
Xpol isolation (ATSR)	<-25dB
Spatial Resolution at 10 km	~350m
Tx Power (4W per TR mod.)	14.3kW
Sensitivity @10km (include attenuation at 10 mm h^{-1})	-12dBZ

APAR Architecture

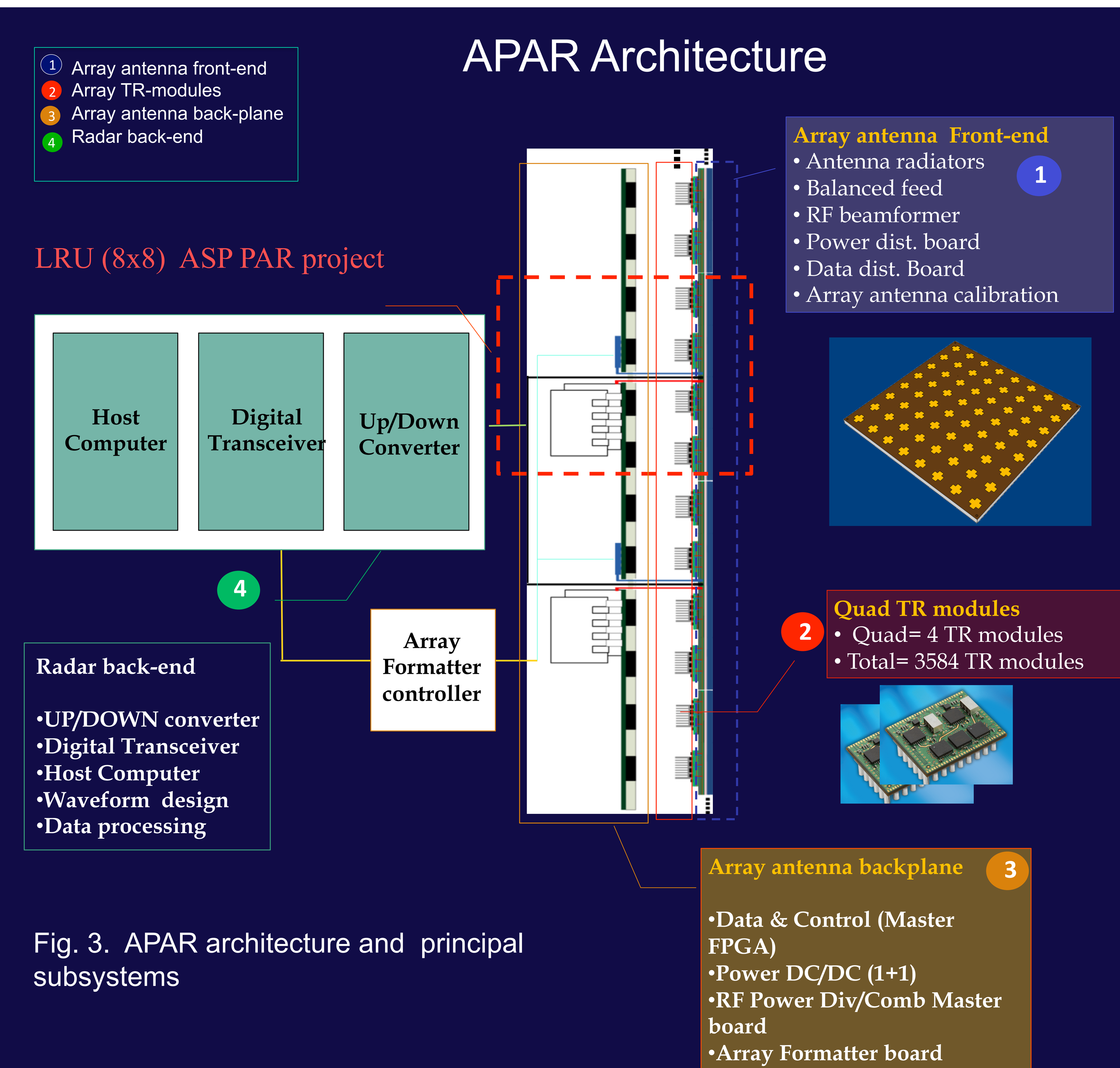


Fig. 3. APAR architecture and principal subsystems

IV. APAR Transmit and receive (TR) module and micro strip patch antenna

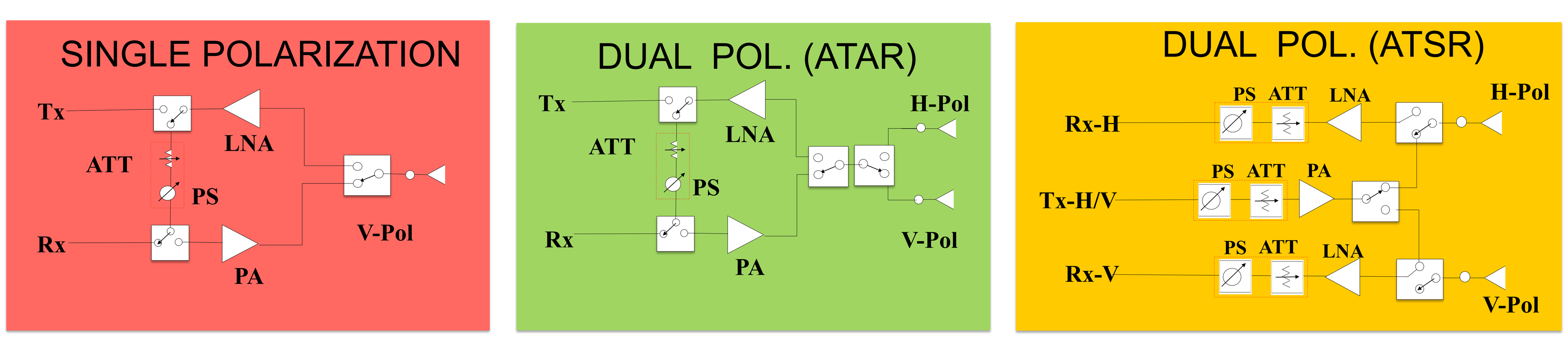


Fig. 4. TR-Module architecture options for APAR: a) Single Polarization, b) dual-polarization for alternate transmit and alternate receive (ATAR) and, c) dual-polarization alternate transmit and simultaneous receive (ATSR)

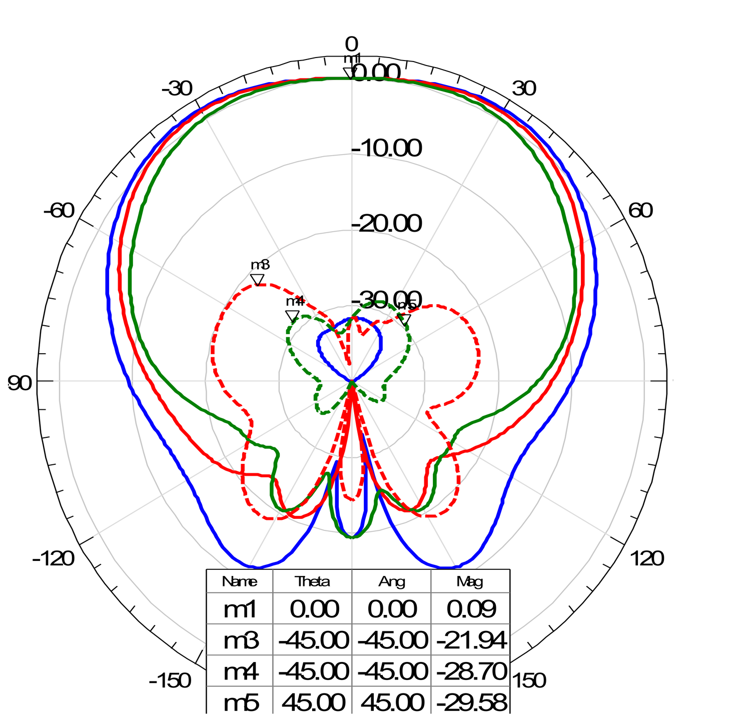
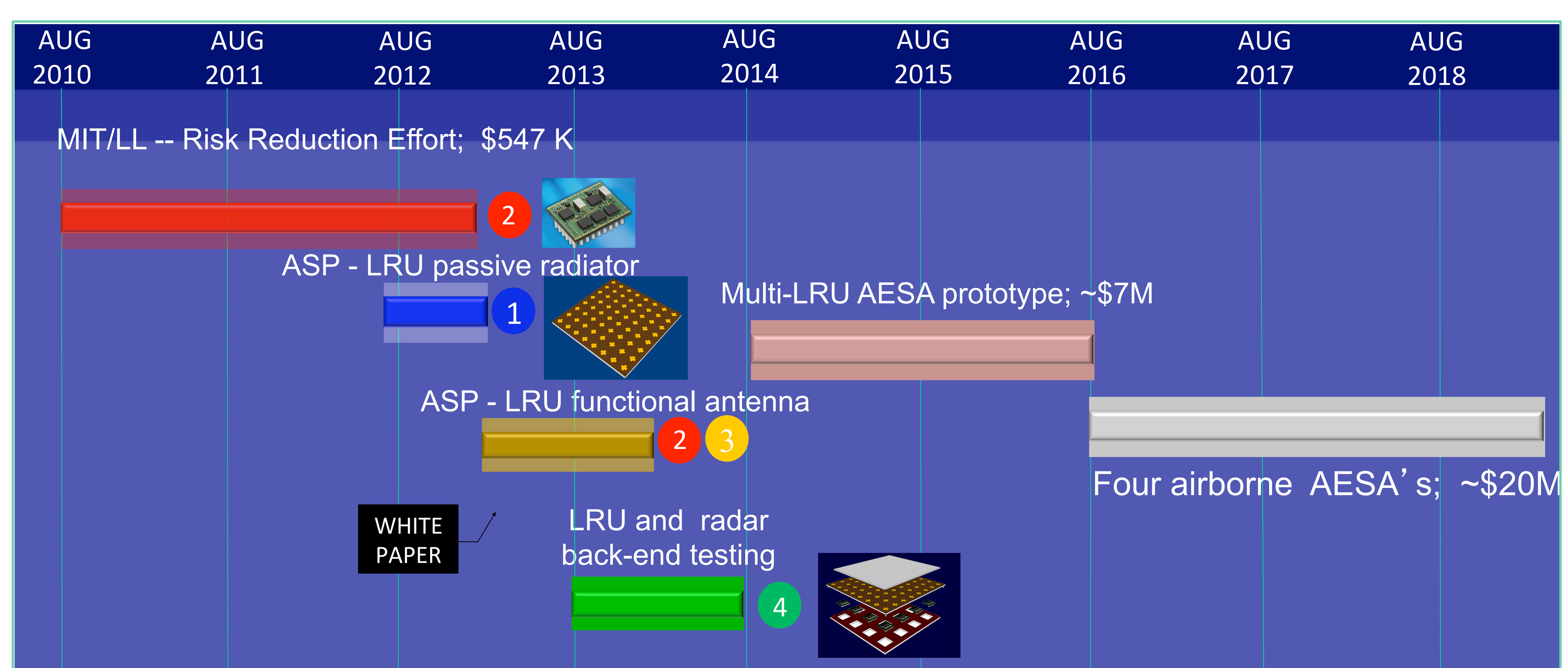
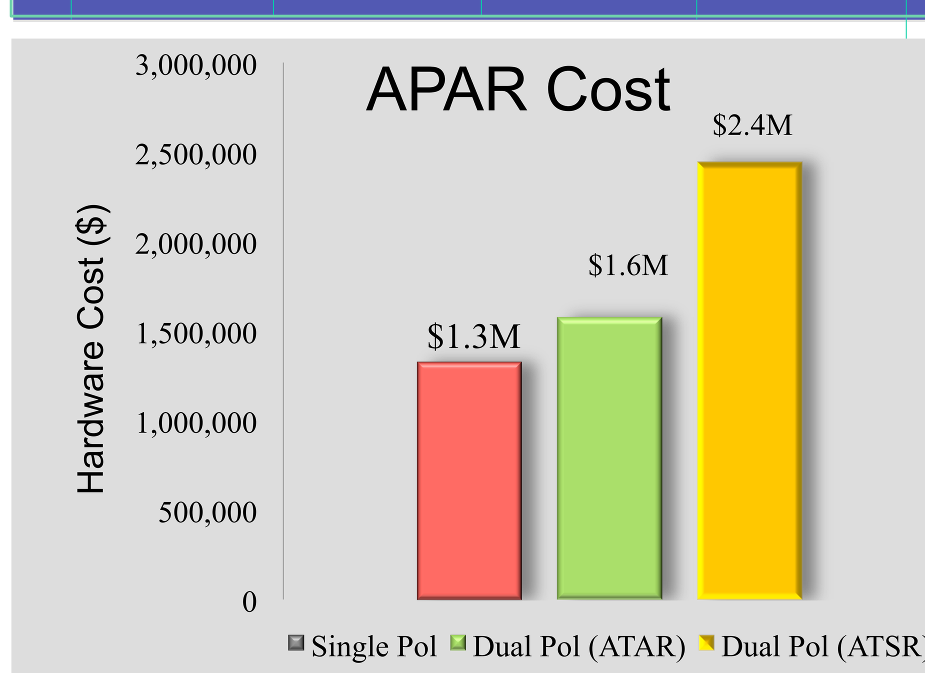


Fig.5. A new radiating micro strip patch antenna element using a Defected Ground Structure has been designed for achieving high polarization performance at scan angles away from boresight. A cross-polarization below -25dB is obtained in the diagonal plane using HFSS simulation software

V. APAR Development timeline and hardware cost estimate





NCAR/EOL
P.O. Box 3000
Boulder, CO 80307
303.497.8801 ph
303.497.8770 fax
www.eol.ucar.edu

EOL is managed by the National Center for Atmospheric Research and sponsored by the National Science Foundation. Any opinions, findings and conclusions or recommendations expressed in this publications are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.