NCAR

Aviation Multi-function Phased Array Radar

Overview

Radar is the primary instrument for remote sensing of the atmosphere for aviation needs. The FAA utilizes several radar networks for such purposes: TDWR, WSR–88D, ARSR and ASR, which continues to be a critical tool for tracking of aircraft. Weather radar has traditionally been used to estimate precipitation location and intensity. However within the past 30 years, technology has advanced and Doppler dual polarization radar is the current standard weather radar configuration. Doppler radar estimates motion associated with the detected precipitation and other scatterers. Recently the National Weather Service upgraded the WSR–88D radar network to polarimetric capability that now allows enhanced discrimination of standard aviation hazards such as hail, heavy rain or snow and in-flight icing conditions. To provide higher update rates of both aircraft surveillance and hazardous weather an electronically steered beam Multi-function Phased Array Radar (MPAR) is considered for future implementation.

Aviation Weather Contributions

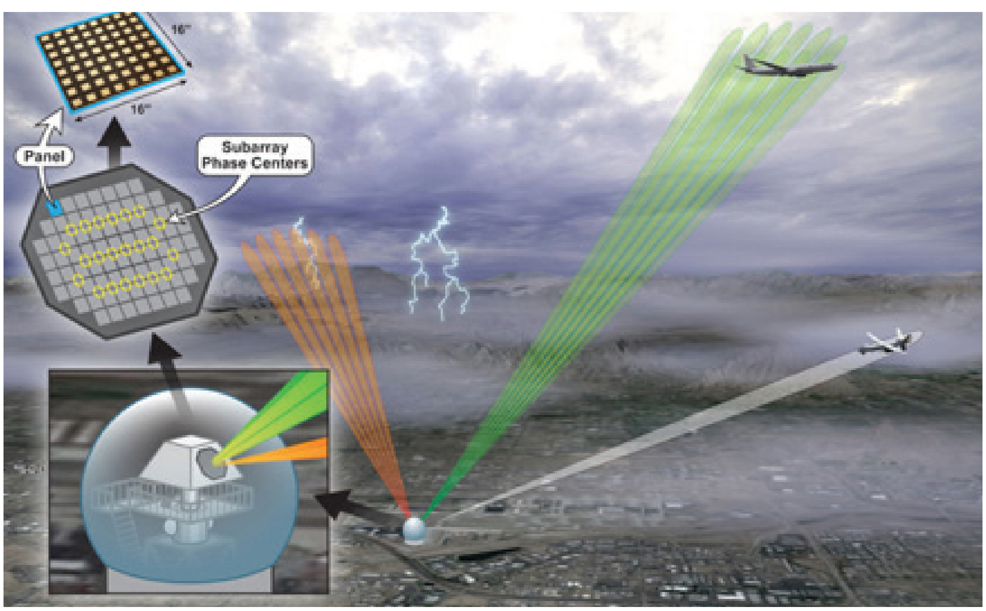
Aviation weather became a key applied research activity in the early 1980s at NCAR and has significantly grown since then. Current aviation weather research areas include: in-flight icing, snowfall and freezing precipitation, convective storm nowcasting and forecasting, atmospheric turbulence, numerical weather prediction, data assimilation, precipitation physics, ceiling and visibility, oceanic weather, verification methods, and advanced dissemination technology to users on the ground and in the air. Development of useful aviation applications requires a strong connection between our work and the needs of aviators. End-user requirements are considered at each step along the development path. Understanding weather sensitivity of aviation and integration of short-term weather prediction with specific stakeholder applications (i.e., decision support guidance) is a high priority. Our work tends to be heavily oriented toward real-time operational systems and this focus leads to an emphasis on algorithm development, specialized graphical displays, systems engineering, operational demonstrations with the associated scientific validations and user-oriented evaluations.

CONVECTIVE STORMS

NCAR's research and development on convective weather for aviation are geared towards very short-term forecasting of high-impact weather. The objective is to facilitate monitoring (i.e., analysis), nowcasting (under two hours), and forecasting (beyond two hours) of weather-related conditions that pose a threat to, or otherwise impact, air transportation. Advances build on a basic understanding of dynamic, thermodynamic, and micro-physical processes related to severe weather, including the initiation of storms and their subsequent evolution, and make use of in-situ and remotely-sensed observations, data assimilation, numerical modeling, forecasting, and diagnostic evaluation. Radar plays a key role in all of that. TITAN is a widely used radar-based algorithm for storm detection and tracking.

TURBULENCE DETECTION

Making use of the wind variability data provided by Doppler weather radars, NCAR scientists have developed and tested the NCAR Turbulence Detection Algorithm (NTDA), designed for use on the nation's network of WSR–88D radars. The NTDA utilizes reflectivity, radial velocity, and spectrum width to assess data quality and produce atmospheric turbulence intensity (Eddy Dissipation Rate) measures of "in-cloud" turbulence. By providing a direct detection of turbulence, NTDA provides an important addition to radar reflectivity as an indication of in-cloud aviation hazards.



Aviation MPAR concept of operations with tilted four face fixed array (Courtesy of Lincoln Labs)

continued on reverse side

AIRCRAFT ICING

Research is in progress to utilize the dual-polarimetric WSR–88D radar network for remote detection of in-flight aircraft icing. The high-resolution dual polarimetric radar signatures of super-cooled liquid water and ice crystals overlap, complicating the identification of icing conditions using individual radar measurements. NCAR has determined that the aggregate characteristics of dual-polarimetric radar measurements over areas of several square miles show distinguishing features between those regions containing super-cooled liquid and those with ice only. NCAR's new Radar Icing Algorithm (RadIA) generates an accurate and reliable icing threat product that can then be combined with existing icing detection systems to improve their performance.

MPAR Essential Components

There are 3 critical elements of an operational multi-function radar system: 1) An electronically scanned phased array likely using active TR elements is necessary for the rapid and flexible beam movements necessary to detect and track multiple aviation hazards, 2) Pulse compression waveforms and novel pulsing schemes are necessary to rapidly collect enough independent samples of the same spatial phenomena to yield accurate measurements of precipitation intensity, motion and phase and 3) Dual polarization is necessary to determine its physical phase (ice, snow, hail, super-cooled liquid water, etc.) that determines the aviation hazard level.

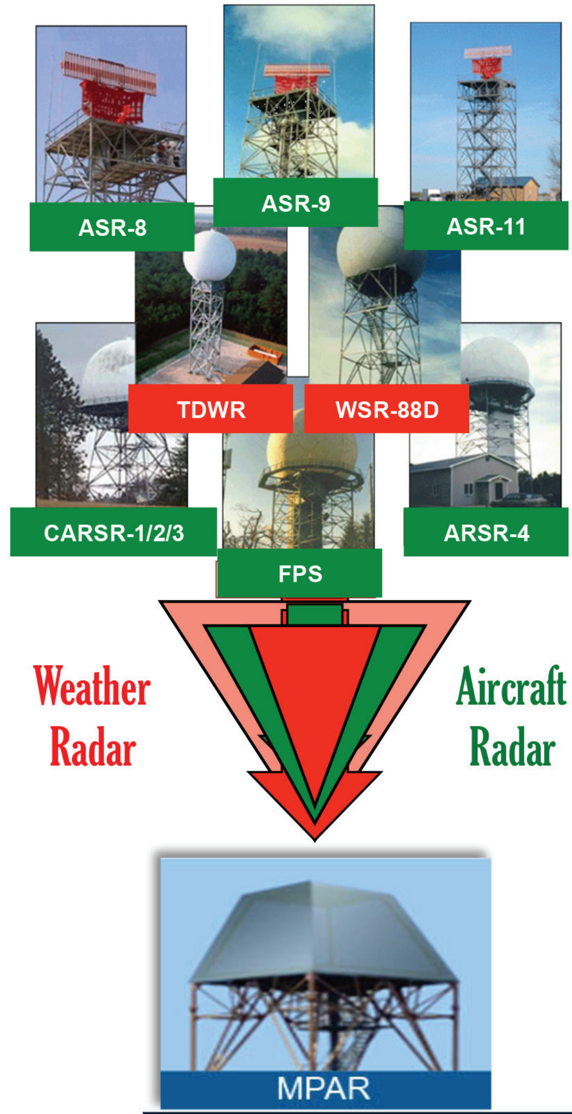
MPAR CONFIGURATIONS

Various antenna and scanning configurations have been proposed and studied over the last few decades. The simplest antenna configuration is a single face flat plate phased array using either passive slotted waveguide technology or active TR elements. A simple extension is to use a double-faced array or two single arrays on one pedestal which would double the update rate. The most frequently studied configuration is a fixed tilted 4-face array that allows full hemispheric coverage at a very rapid update. Another commonly cited configuration is the cylindrical array. All these MPAR antennas suffer from polarization distortion when scanning off their principal axes that must be corrected; correcting this distortion is an active area of research.

Radar Acquisition

NCAR has been a key participant in both the WSR–88D development and test activities since 1993, defining and developing the polarimetric Radar Echo Classifier and automated calibration techniques. NCAR has also played a key role in TDWR requirements development, prototyping, testing and algorithm development during a variety of demonstration and improvement programs.

NCAR is currently designing and building a dual polarimetric Airborne Phased Array Radar (APAR) that will use Digital Beam Forming technology to improve sensitivity and minimize polarimetric distortion over "conventional" dual-pol PAR systems. NCAR has closely collaborated on many radar activities for over 35 years, including the Joint Airport Weather Study that mitigated aviation microburst fatalities, dual polarization radar validation for aircraft icing studies and convective storms nowcasting. NCAR staff has participated in National Research Council panels for defining the next generation weather radar requirements. Furthermore, NCAR continues an active MPAR collaboration with MIT Lincoln Labs on dual pol TR module development, testing and application for APAR plus a collaboration with the University of Oklahoma's Advanced Radar Research Center and the co-located NOAA National Severe Storms Laboratory, both of which have a long history of MPAR research and applications with NCAR.



MPAR concepts from MPAR Joint Working Group
(Courtesy of NOAA/NSSL)

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