Deployment Considerations and Hardware Technologies for Realizing X-Band Radar Networks

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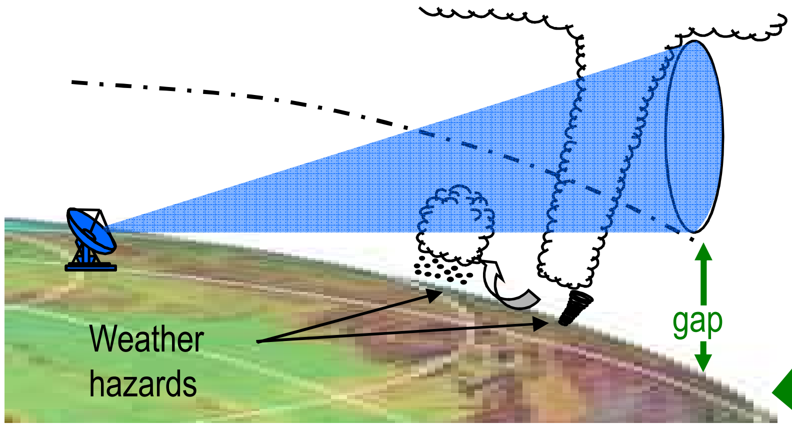
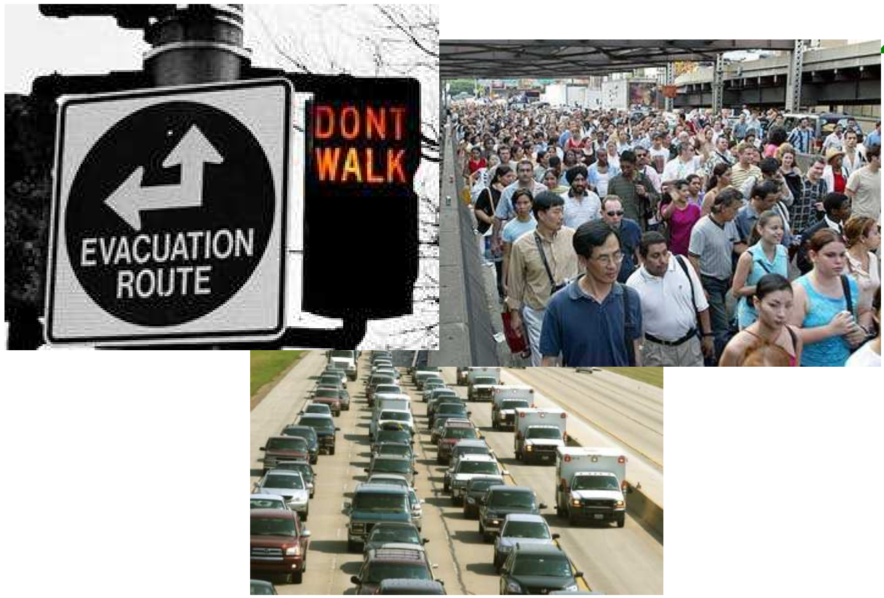
Outline

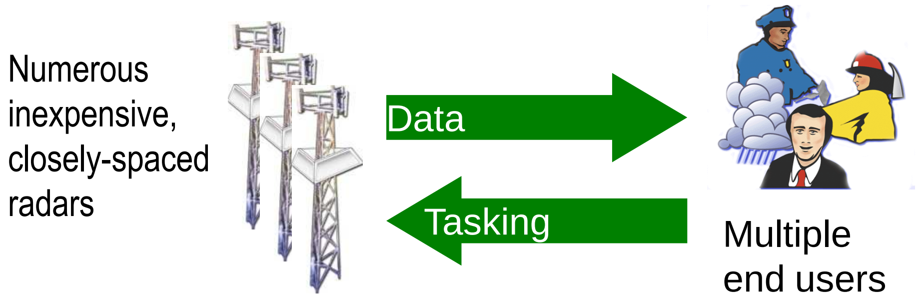
- CASA Overview
  - Why radar networks?
- Network Performance Considerations
- Why Phased Arrays?
- Latest Hardware Technology Development:
  - CASA Phase-Tilt Weather Radar System

Collaborative Adaptive Sensing of the Atmosphere (CASA) Engineering Research Center





Solution



Observe, understand, predict and respond to hazardous weather events

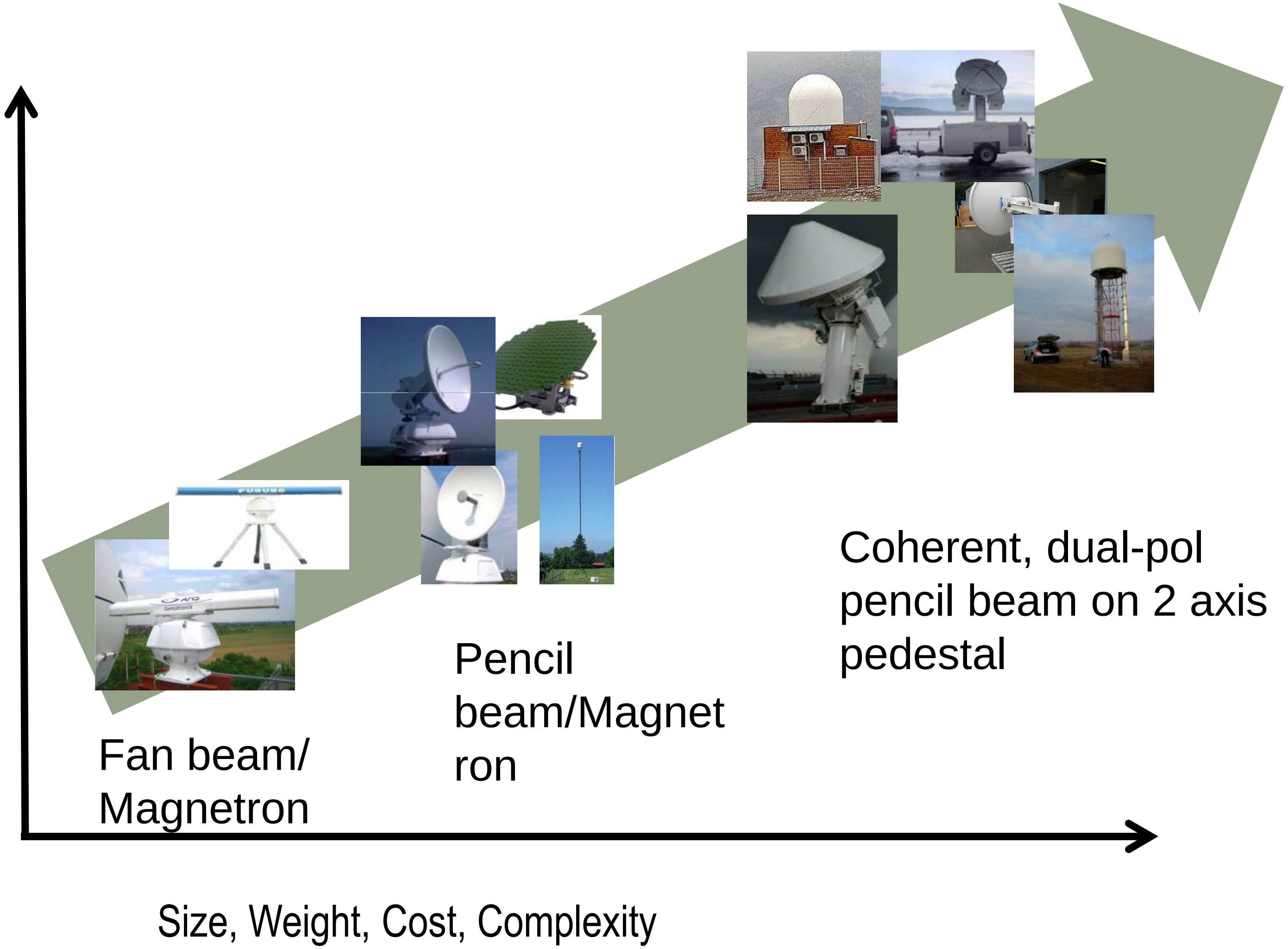
Some theoretical numbers
Assumes regular grid 230km (S), 150km (C), 30 km (X)

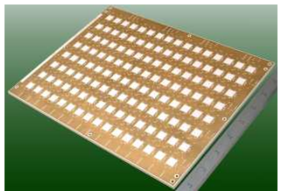
	"Blanket Coverage"		15% Coverage*
	Large Radar (S/C-Bands)	Small Radar (X-Band)	Small Radar (X-Band)
USA / CONUS	145	8,511	1,277
Europe / OPERA	217	5,416	812
France	28	712	107
UK	11	270	41
Belgium	2	42	6

*Critical infrastructure, population centers, borders, etc…

Large numbers of small radars –must be inexpensive, easy to deploy

X-Band Weather Radar Technologies Deployed Over Past Decade





Radar nodes must be a balance between Size/Weight/Cost and Performance

Performance Considerations for X-Band Radar Networks

- Need to establish a performance baseline for X-Band radar systems to be realized in a network:
  - These numbers are derived from the validated performance of the CASA IP1 radar network

Attribute	Top-Level System Requirement	Derived Requirement
Low Profile	$1m^2$	X-Band (9.3 – 9.5 GHz); < 200lb
Scan Volume	100m to 10's of km altitude	Azimuth: 360° Elevation: ~0° to 60° Range ~ 30km
Radar Sensitivity	< 10dBZ at 30km	100W (w/ Pulse Compression)
Spatial Resolution	< 1.3km at 30km	2° x 2° antenna beamwidths
Dual Polarization	Bias in Zdr < 0.2dB	Alternate T/R (ATAR): ICPR > 20dB Simultaneous T/R (STSR): ICPR > 40dB

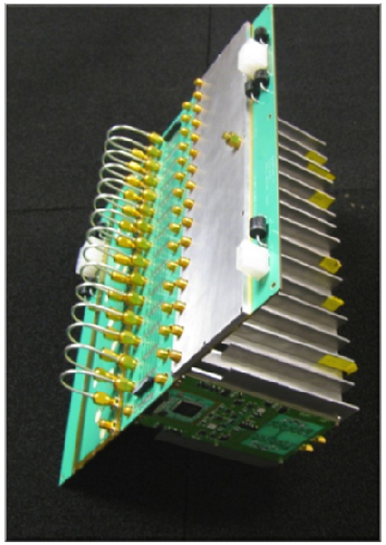
Phased Array Radars have the capability to meet these performance baselines

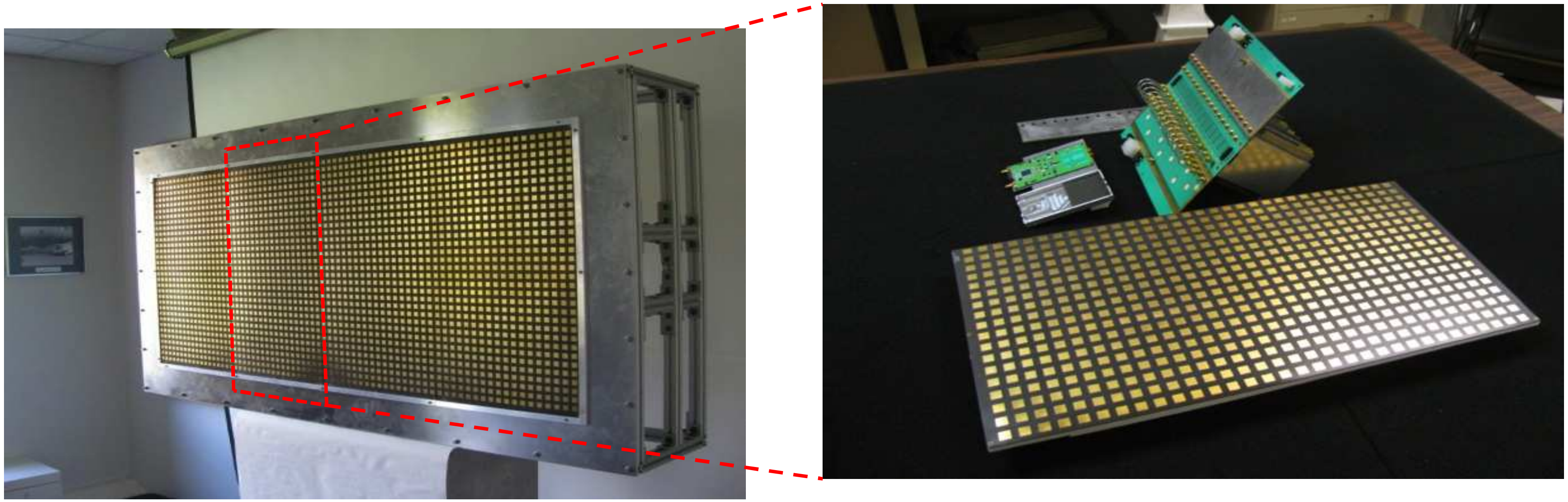
Why *Dense Networks* of Phased Arrays

1. **Capability of Low Level Situational Awareness**
   - "Mind the Gap"
2. **Ease of Installation**
   - Easily installed on the sides of buildings, existing infrastructure
   - Low weight / low power, no large pedestals requiring dedicated land
3. Low maintenance cost
   - No moving parts
4. Enhanced reliability
   - Solid state, active arrays over magnetron/klystron systems
5. Multi-Mode Operation
   - Can support multiple missions simultaneously

Phased Array Radars as the Next Generation Technology

- CASA has successfully demonstrated the feasibility of a phase-tilt antenna as a low-cost technology for future weather radars
  - University of Massachusetts' research prototype shown below, parts cost ~$50K (US) per antenna
  - Demonstrated better than 20dB cross-pol over +/- 45°





Phase-Tilt Weather Radar

- CASA Phase-tilt antenna concept developed as a commercialized product by First RF Corp., Colorado, USA
- Radar backend (software and transceiver) developed at UMass Amherst

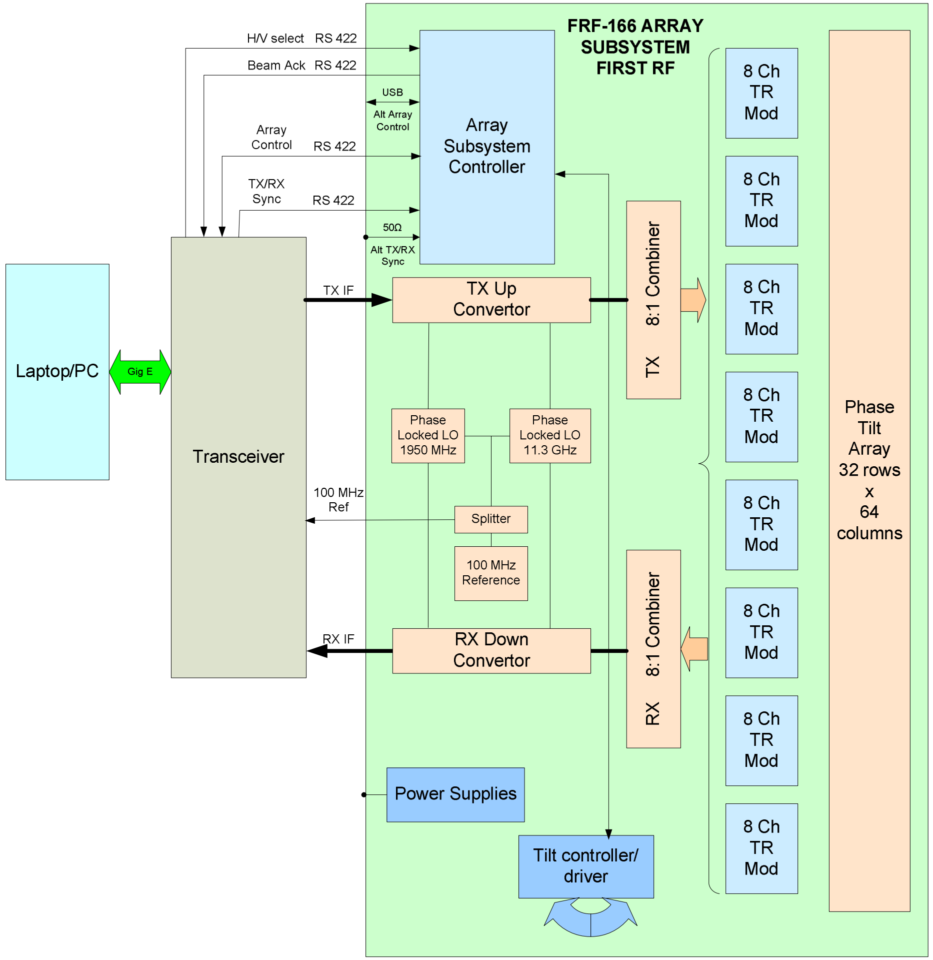
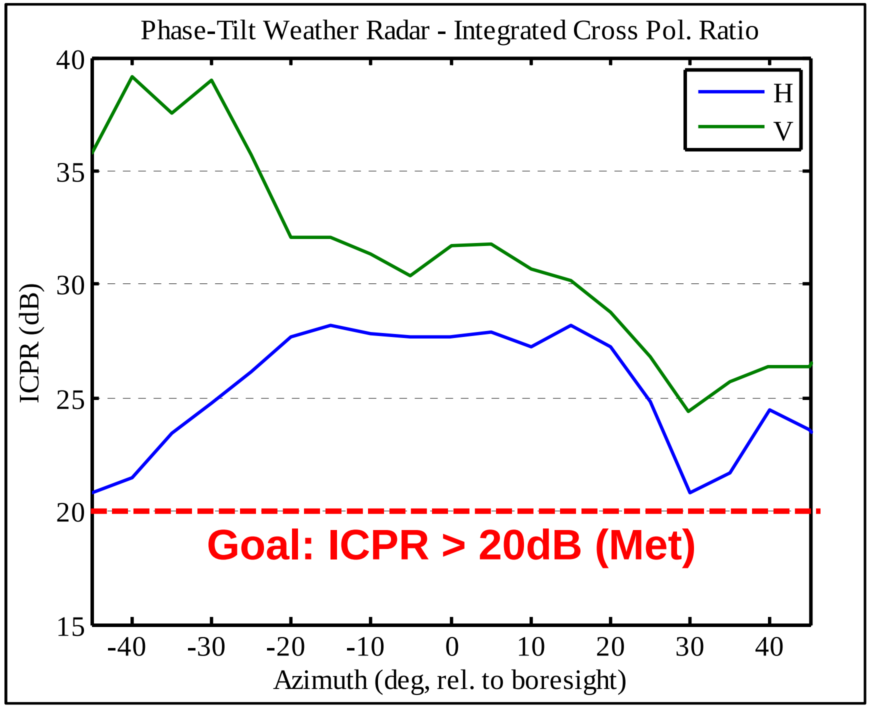


Table 1: Phase-Tilt Weather Radar system parameters.

Performance Specifications

Parameter	Units	PTWR
Frequency Range	GHz	9.3 – 9.5
Transmit Power (Peak)	W	70
Pulse Length	µS	.6 - 60
Pulse Compression Gain	dB	Up to 20
Duty Cycle (max)		30%
Unambiguous range @ max PRF	km	31
Unambiguous Velocity @ single PRF	m/s	up to 38
Unambiguous Velocity @ Dual PRF	m/s	57 @ (2:3)
Sensitivity @ 30km (@Boresight)	dBZ	16
Elevation Beamwidth	deg	2.8
Azimuth Beamwidth	deg	1.8 -2.4
Polarization Mode		Alternating
Integrated Cross Pol Ratio (max)	dB	-20
Power Consumption		600W (average)

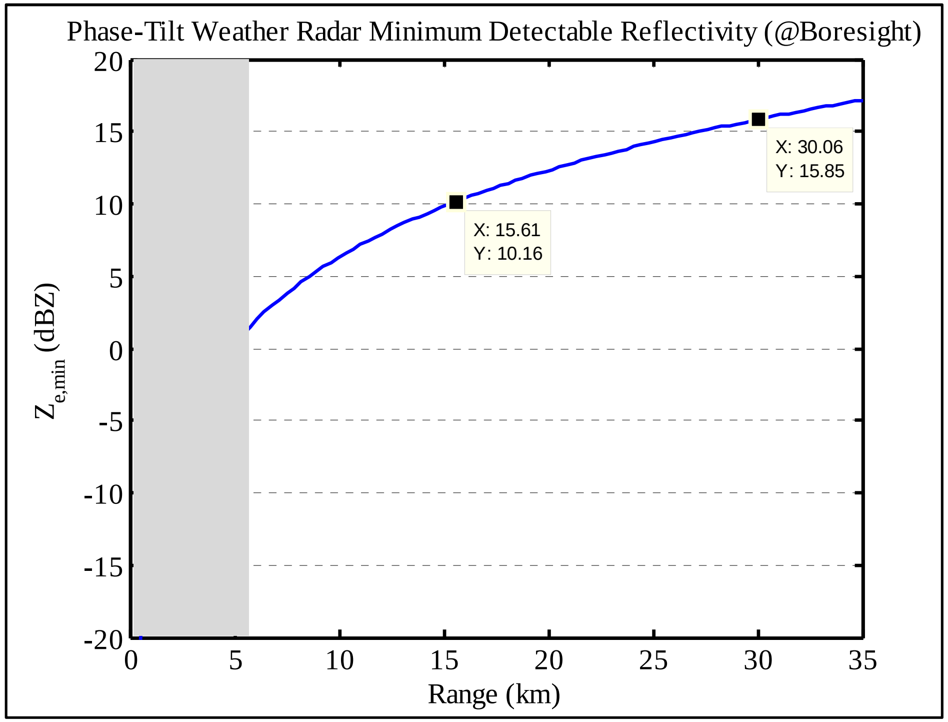


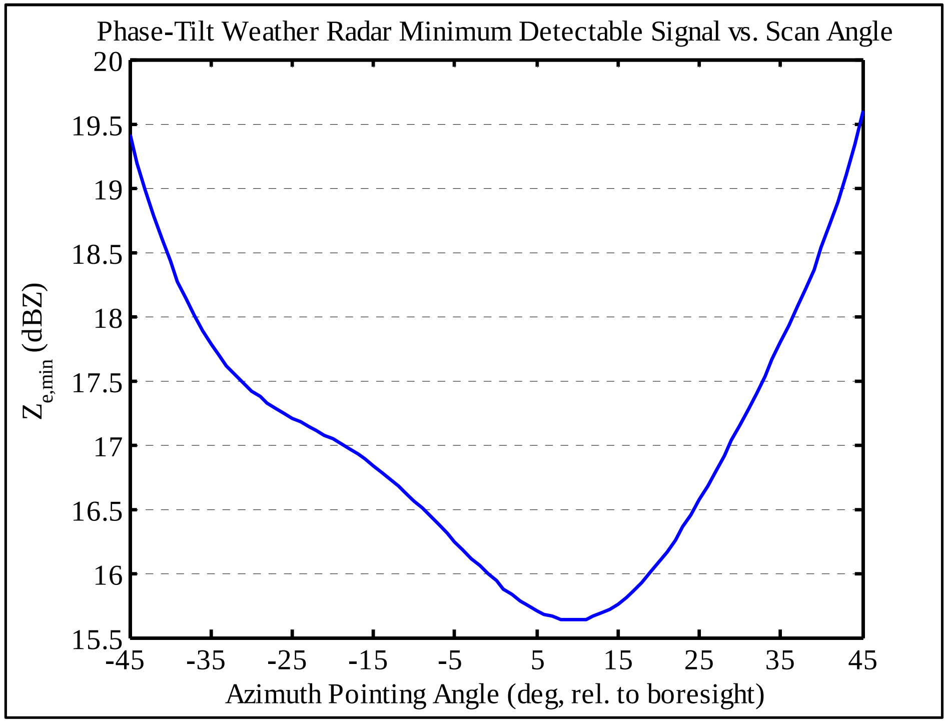
Phase-Tilt Weather Radar meets key performance needs

Effect of Scan Loss on Radar Sensitivity

- Scan loss in a phased array degrades radar sensitivity off boresight:
  - At Boresight: **16dBZ at 30km**
  - At +/- 45°: **19.5dBZ at 30km**

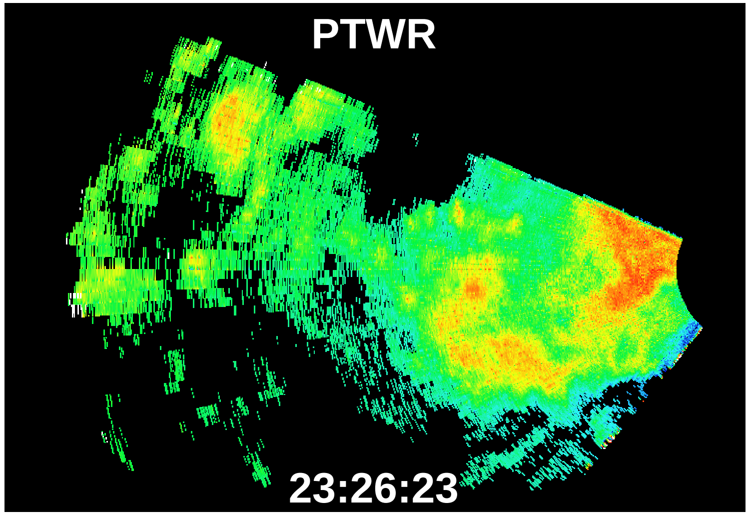
- **Sensitivity is enhanced through X-Band network signal processing**



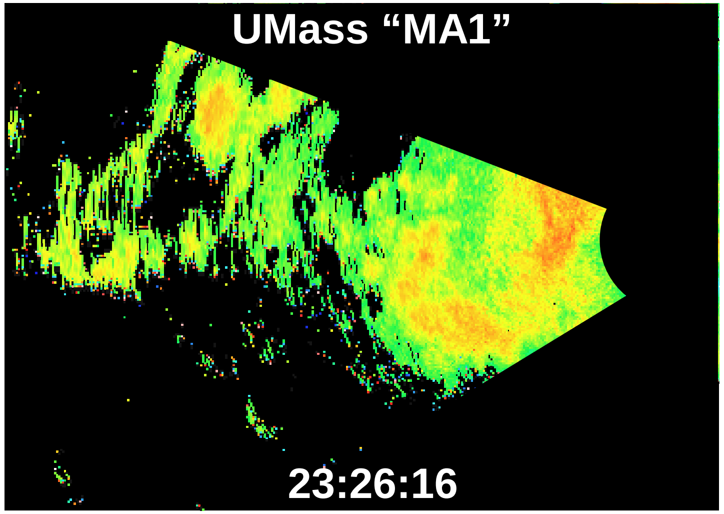


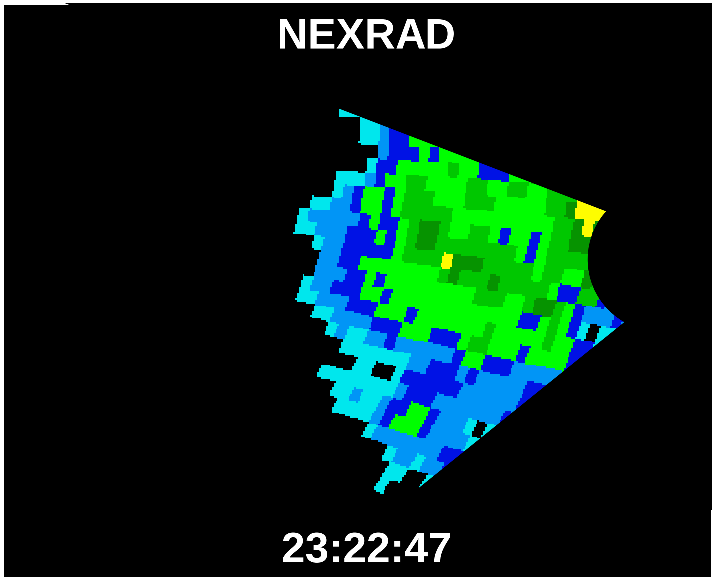
*Assuming 40usec, 3MHz LFM Chirp

Performance Comparison
Event on May 30, 2012 – Amherst, MA



*No attenuation correction





Performance Comparison (movie)

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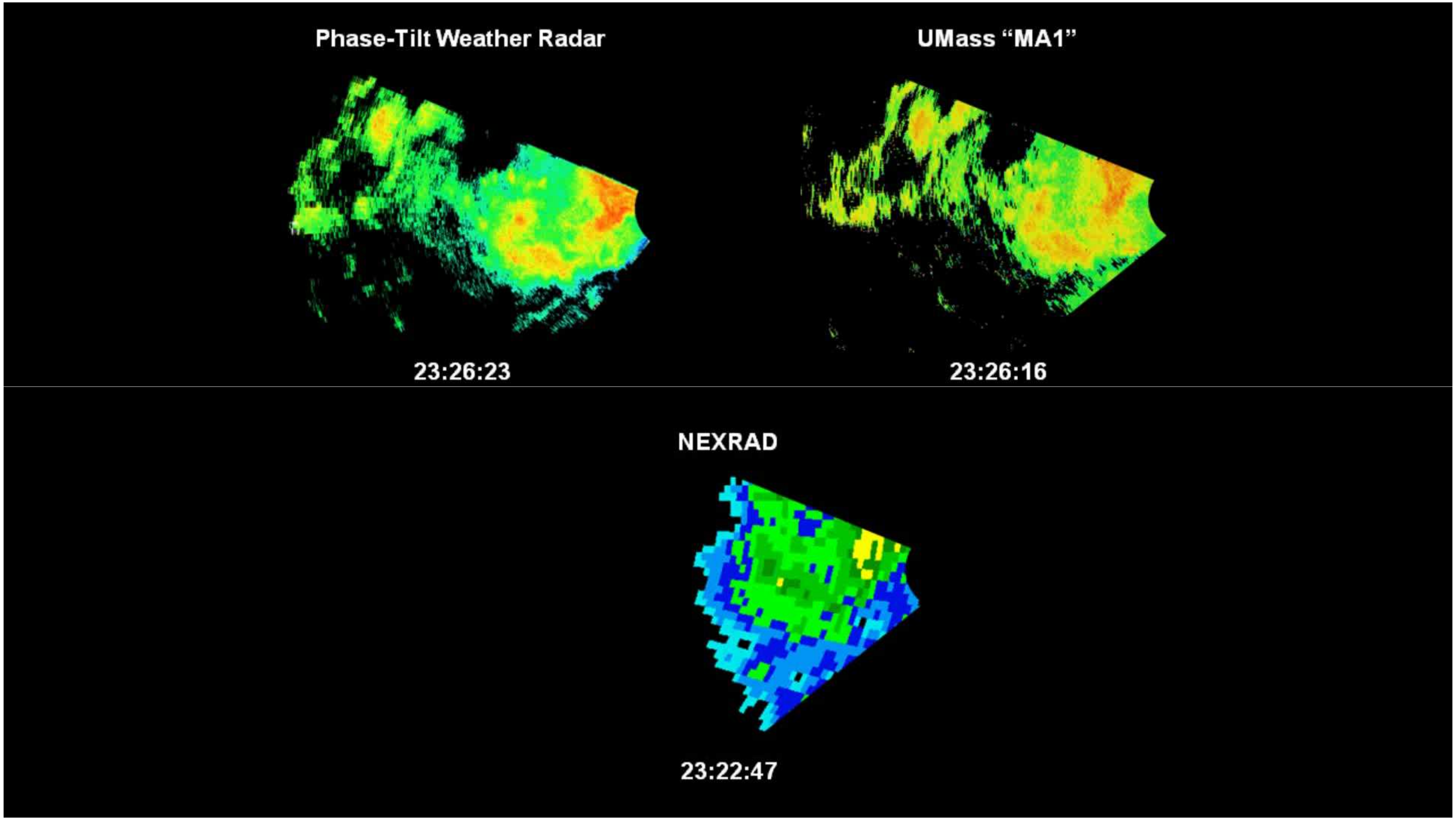

No moving parts were used in the making of this video!

Conclusion

- X-Band Radar networks fulfill a critical need in many government and municipality weather applications
  – However, development of these networks will only happen if the initial and recurring costs of the technology is low
  – Phase-Tilt technology represents a key step towards driving down the recurring cost of such networks without sacrificing performance

- Have successfully demonstrated the realization of a commercial-grade phase-tilt radar system
  – Continuing to collect data and study effects of phased array technology on weather products

Questions?

Backup

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Low transmit power supports the feasibility of switches capable of supporting Integrated Cross Pol Ratio requirements