

All Weather Wind Monitoring with Integrated Radar and Lidar

Sensors for Wind Monitoring in All Weather Conditions

WakeNet3 - Greenwake

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Sensing & Exploration Systems

Lockheed Martin Coherent Technologies (LMCT)

Overview



- **Motivation**
- **Existing all weather implementations**
- **Combined performance for Lidar + Radar**
- **Making it happen in Europe – the DWD ITWS/LLWAS project**
- **Summary**

Motivation



- **“All” Weather**
 - Often interpreted as “adverse” weather
 - But “All” = “Fine” + “Adverse”
- **Goal: robust, cost-effective terminal area wind monitoring all the time**
 - Select the right sensor combination to optimize Aerodrome Monitoring and Airport CDM

Airport Wind Monitoring



- Recent terminal area wind sensing operations have added Lidar to address alerting deficiencies
 - Hong Kong: TDWR + Lidar
 - Japan: DRAW + Lidar (2 airports and counting)
 - USFAA/LAS: TDWR + Lidar
- However, these have all coupled Lidar with expensive, large dish radars at C-band (5 cm) wavelengths

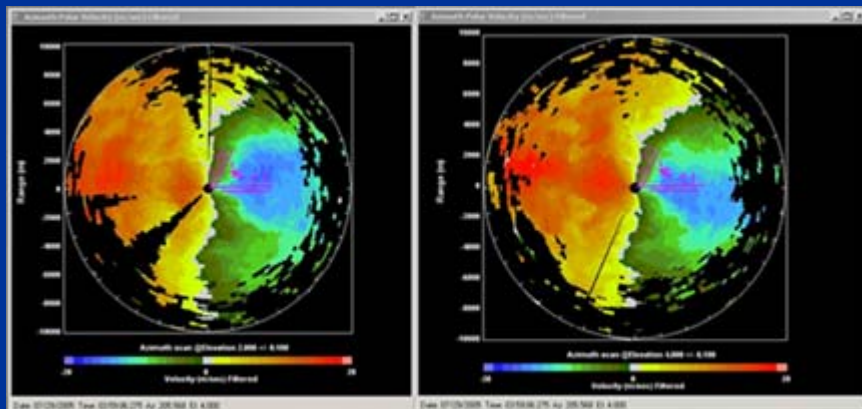


FAA Evaluation Success

McCarran International Airport (Las Vegas)



- **35%/25% (POD/PFA) → 91%/10% with TDWR+Lidar**
 - TDWR deficiencies detecting dry microburst and winds ahead of gust fronts
- **FAA procured unit in 2008 after completing Operational Test & Evaluation**
- **System moved to permanent location in 2009**



WindTracer Terminal Doppler Solution

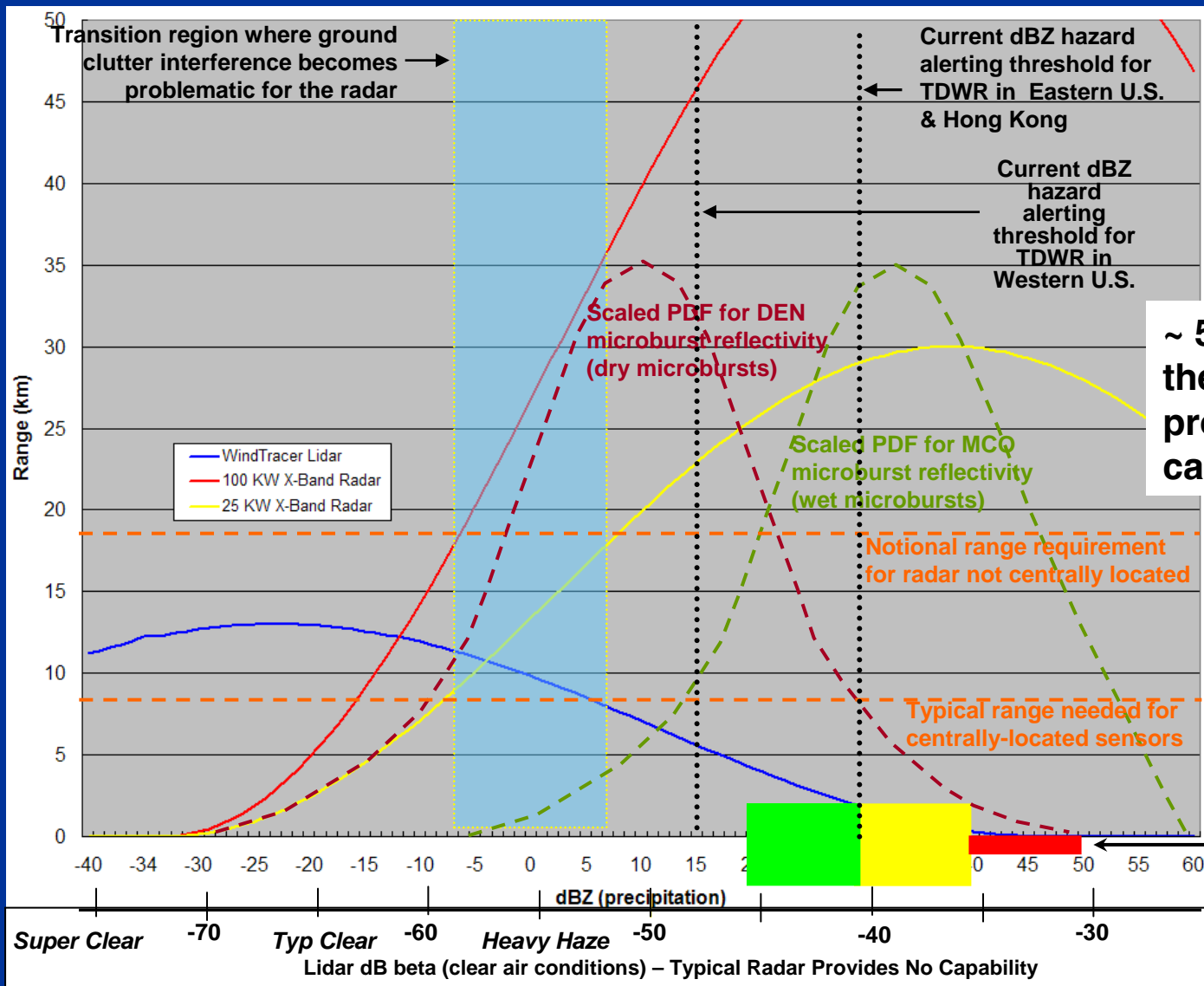


- **Goals**

- Create an all weather wind hazard detection system that combines clearer air capabilities of Lidar with the adverse weather capability of Radar
- Provide coverage for airport terminal area (10-15 km distance minimum)
- Minimize total system cost to allow cost-effective deployment



Lidar and Radar Performance Rain and Clear Air



~ 50 KW X-band radar & the WindTracer Lidar provide ALL WEATHER capability

Additional Benefits - Radar



- **Spatial surveillance of medium range (radius 50km)**
- **Detection/tracking/nowcasting of significant weather regions**
- **Using polarimetric radar systems: echo classification**

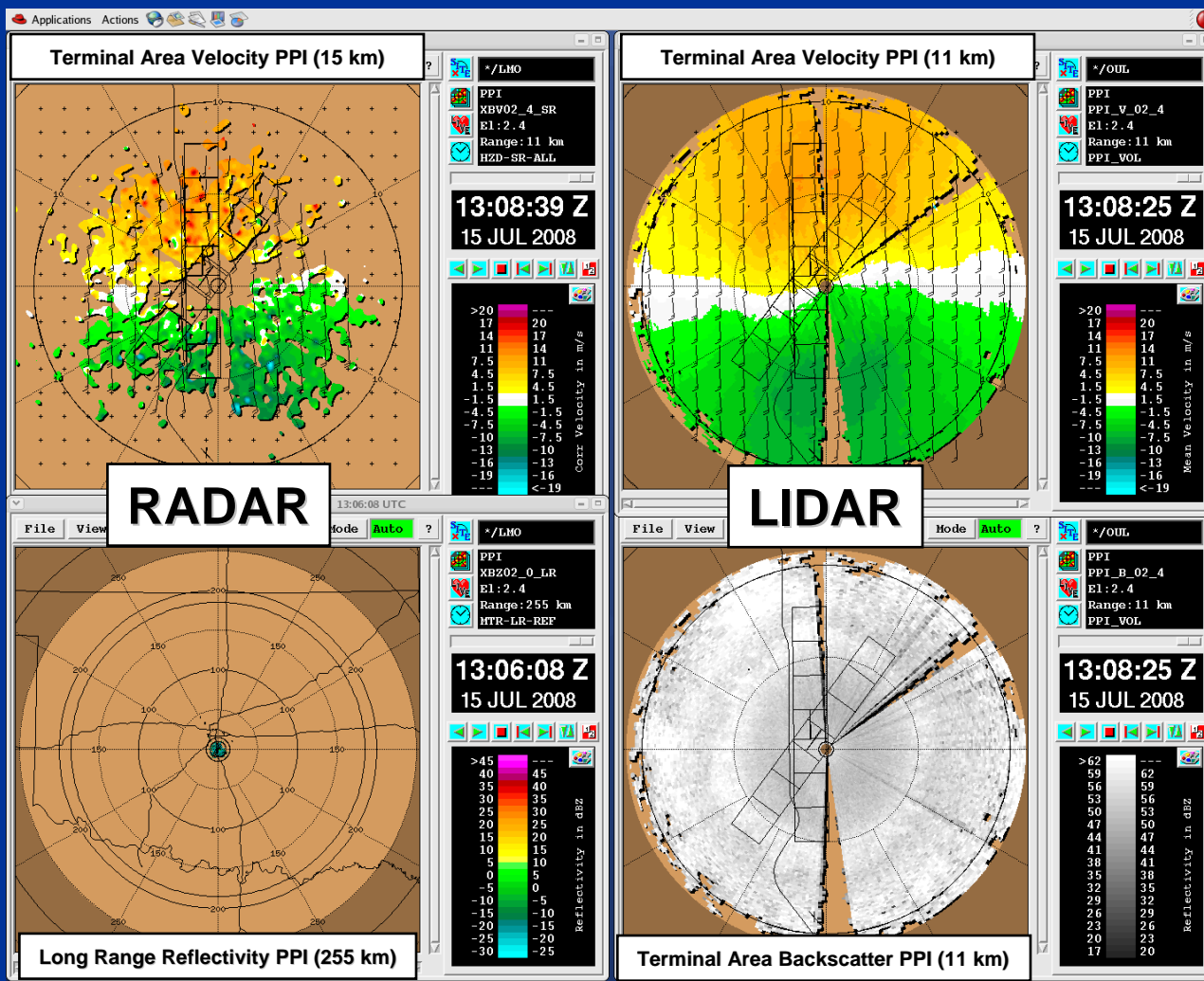
Initial Implementation



Summer, 2008

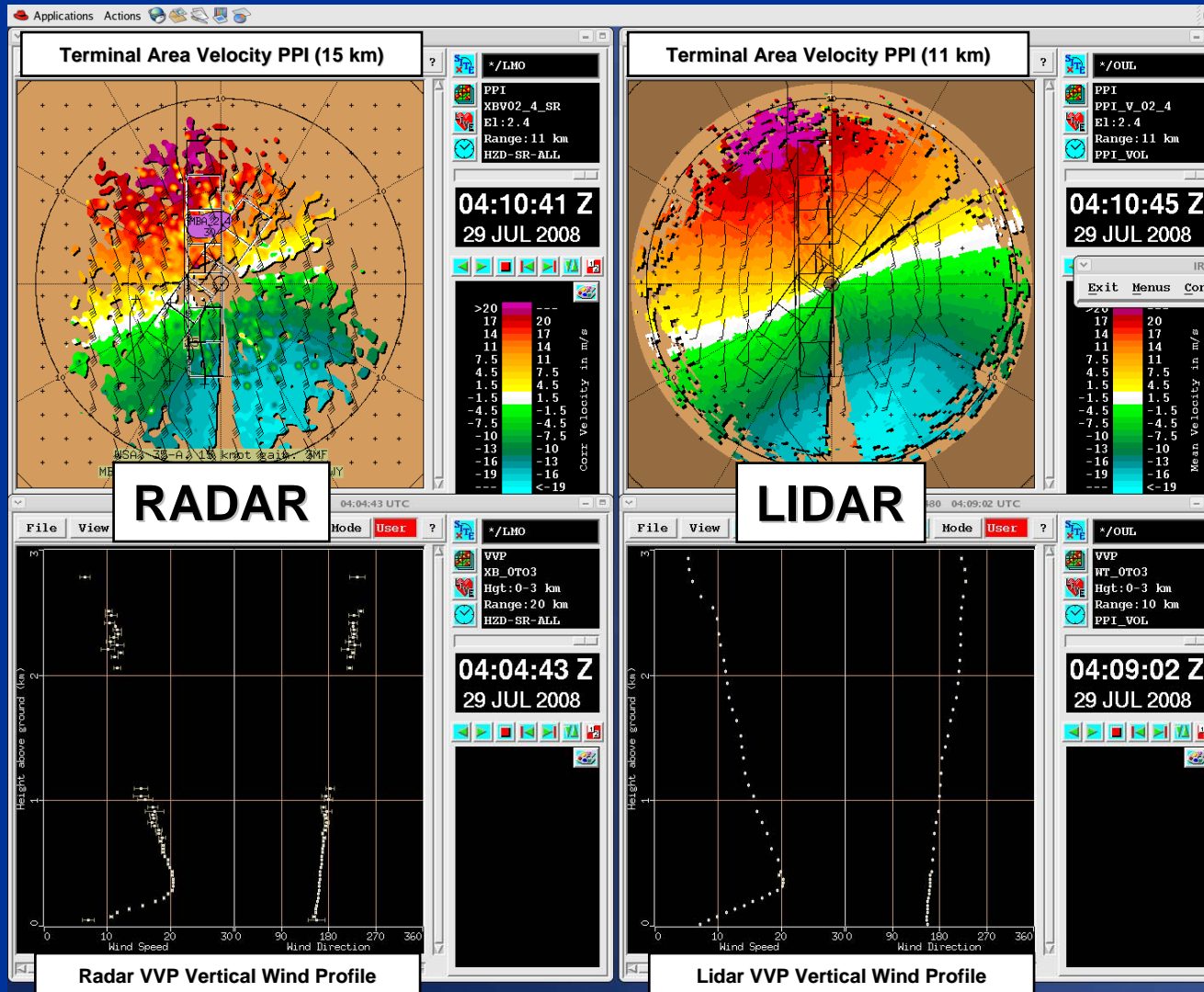
WindTracer loaned by FAA

Lidar Picks up where Radar Drops Off



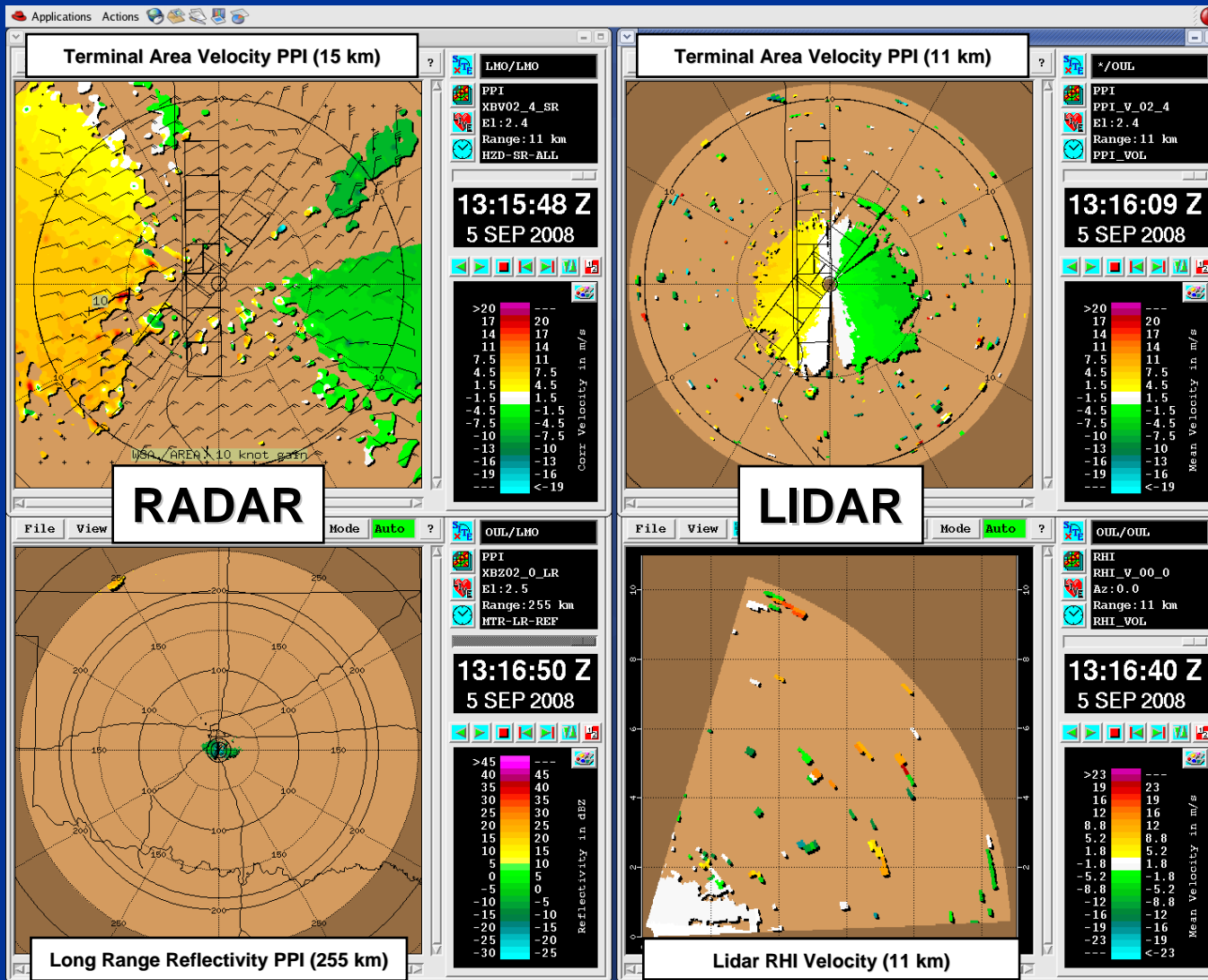
- Good aerosol backscatter, Lidar outperforming Radar
- METAR KOUN
151311Z AUTO
16009KT 10SM CLR
25/22 A3008 RMK
AO2

Windy Day Agreement – PPI and Vertical Wind Profile Agreement



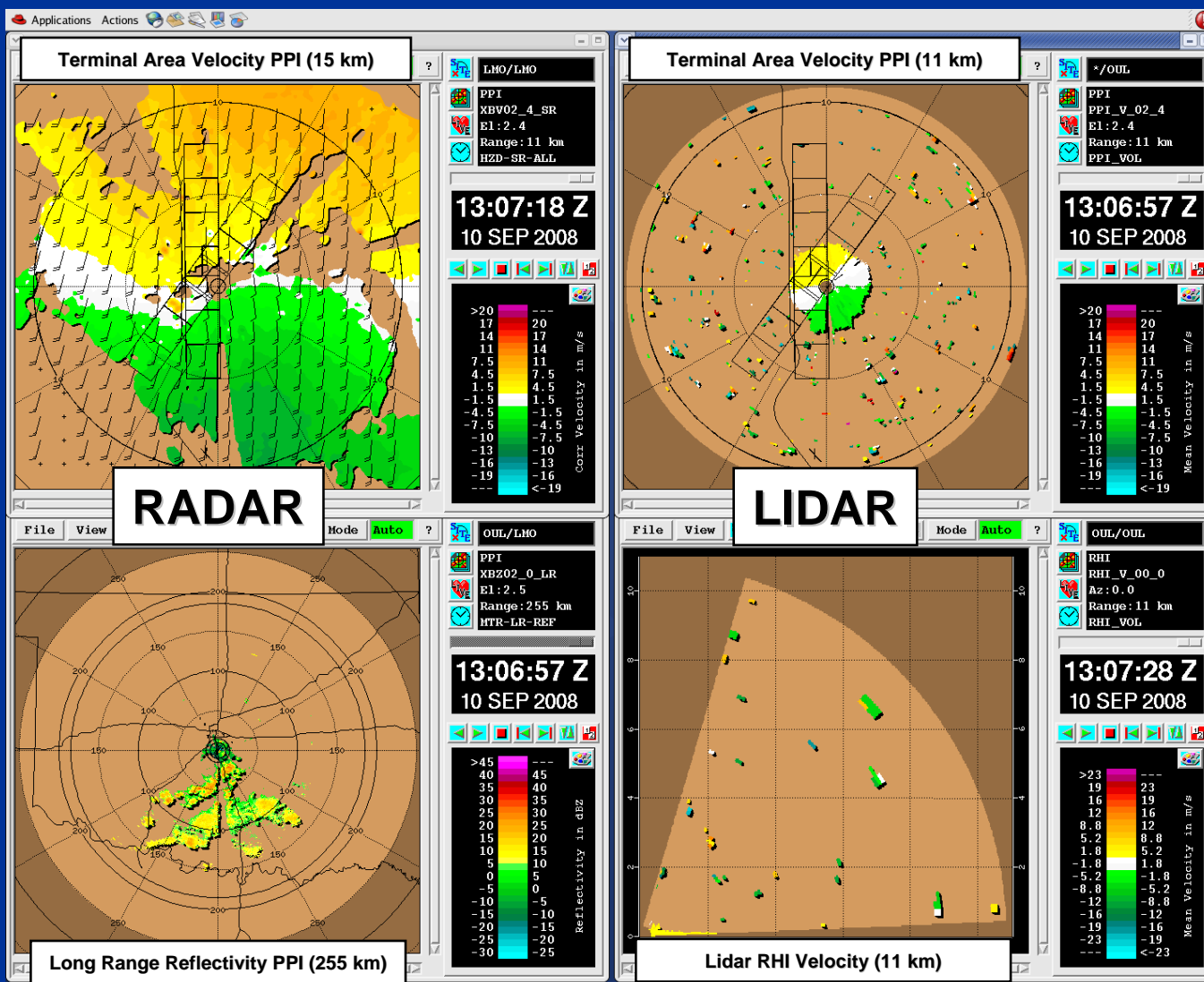
- Windy day
- Comparison of Radar and Lidar wind profiles
- METAR KOUN
290414Z AUTO
15014G18KT 10SM
CLR 33/17 A2979
RMK AO2

Misty day performance— Radar Picks Up Where Lidar Drops Off



- Visibility reduced by mist
- Lidar performance limited by weather
- Radar picks up where Lidar drops off
- METAR KOUN
051310Z AUTO
00000KT 7SM BR
CLR 18/18 A3001
RMK AO2

Rainy day performance— Radar Picks Up Where Lidar Drops Off

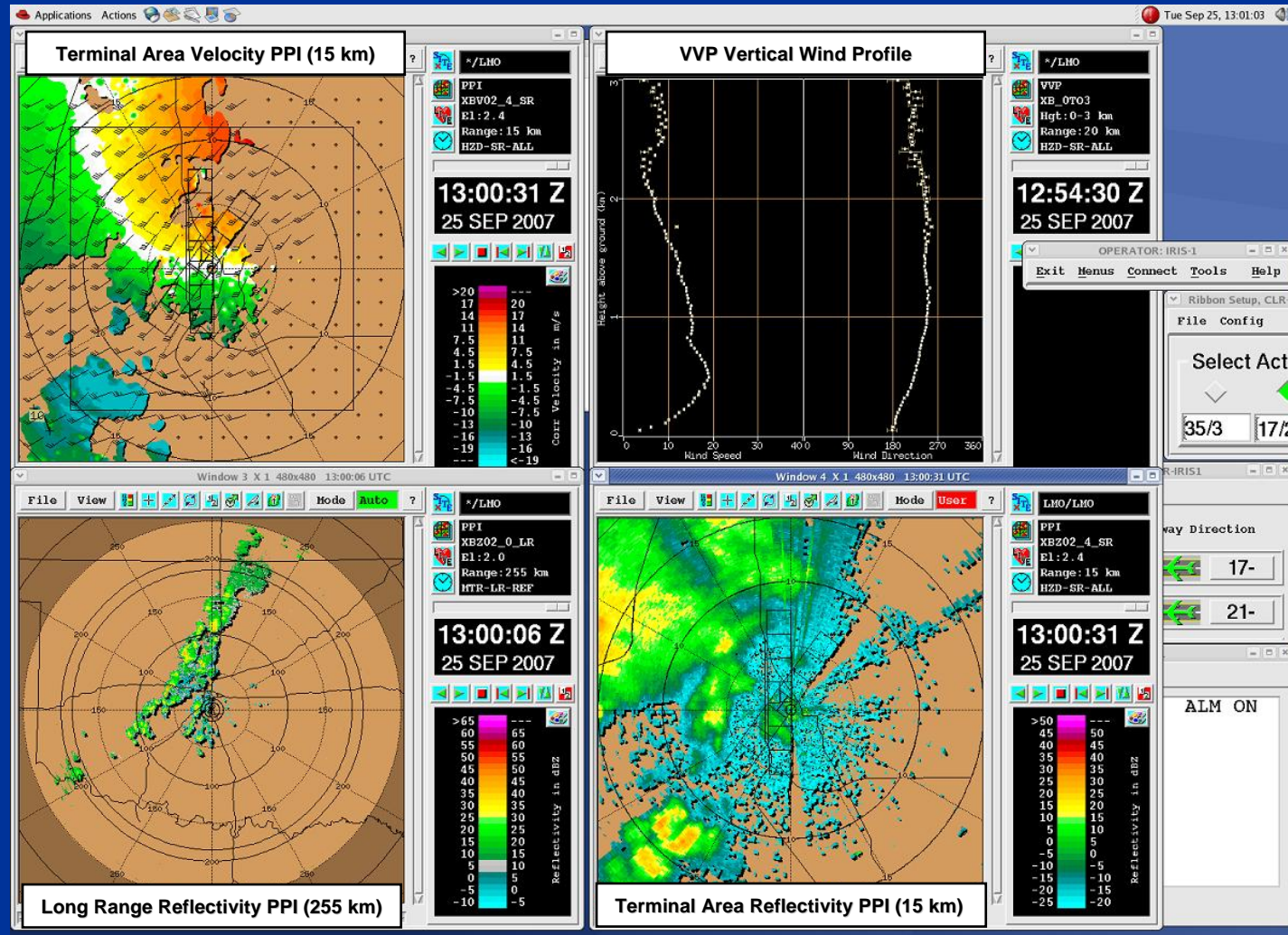


- Lidar performance reduced by rain and low overcast
- Radar fills in most of the gaps
- METAR KOUN
101311Z AUTO
15004KT 1 3/4SM
RA OVC004 21/21
A3001 RMK AO2

Radar Performance – Storm Detection



- Range performance out to 250 km
- X-band signal does attenuate more than longer-wavelength alternatives in heavy storms
 - But focus is terminal area





DWD ITWS/LLWAS Project



- **Deutscher Wetterdienst (DWD) Low Level Windshear Alert System**
- **Key element of ITWS**
- **Prime contractor SELEX, supported by LM**
- **Frankfurt and Munich Airports**



**METEOR 50DX Dual
Polarization Weather Radar**



+

**WindTracer® WTX
1.6 µm Doppler Lidar**



=

**All Weather
Terminal
Area Wind
Shear
Alerting**

Seamless Data Fusion through SELEX Rainbow[®] 5 Software

Acquisition

Processing

Display

METEOR 50DX Polarimetric Weather Radar

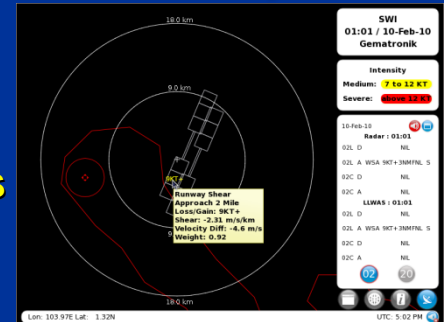


Courtesy SELEX GmbH

WindTracer[®] WTX 1,6um Doppler Lidar



Runway oriented speed
loss / gain
Base wind profiling
Processing of horizontal wind fields
Glide slope monitoring
Runway oriented alerts on adverse
weather condition
Airport airspace monitoring and
feature detection
Storm structure analysis
Di- and convergence detection
Echo classification (rain, hail, etc.)
Protected area alerts
Data import (LLWAS-3, lightning
detection, etc.)
Data export (Asterix CAT008)



Courtesy SELEX GmbH

Rainbow 5 Touchscreen based Meteorological Situation Display (RainScout)



Courtesy SELEX GmbH

SELEX Rainbow® 5 Software



Operational in **50+** countries

Platform independent:

Windows XP / 7, Linux

Usage of latest software technologies

More than 60 meteorological products in operation

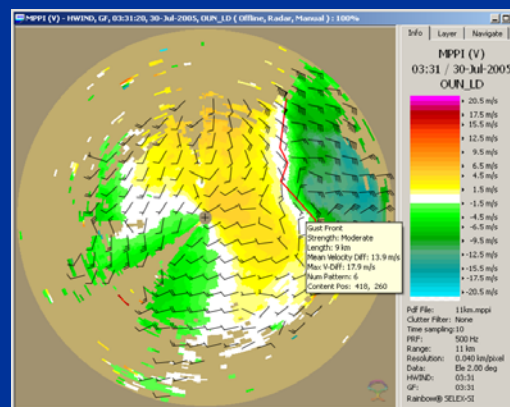
NEXRAD / TDWR style product implementations

Now-casting capabilities

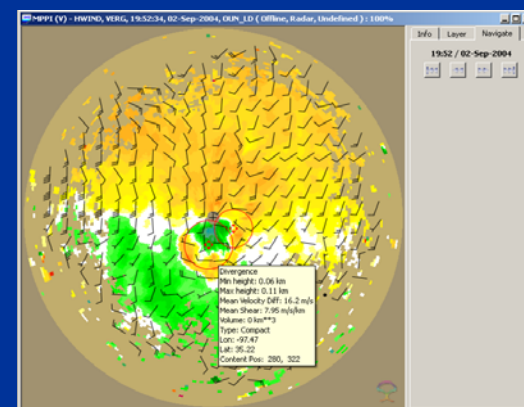
Integration of other sensors

GIS support

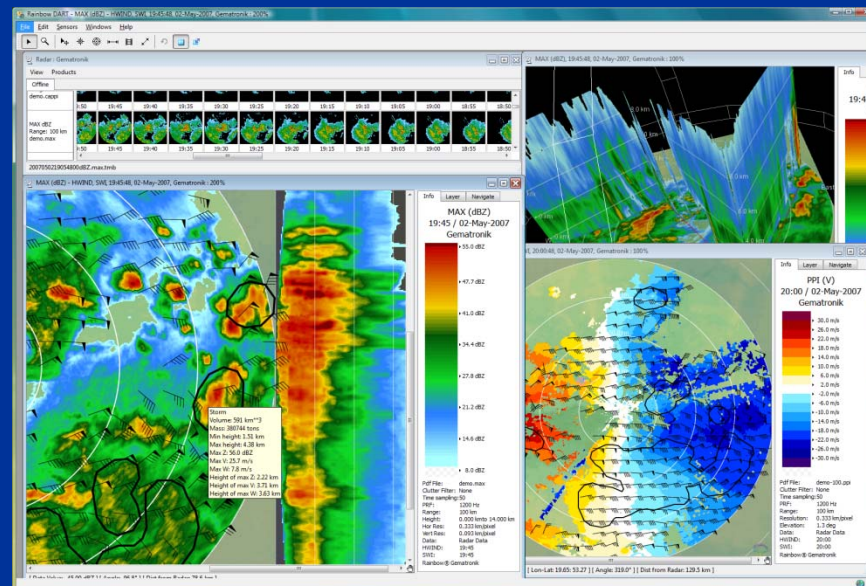
Data export



Lidar detected gust front.
Processed and displayed on RB5

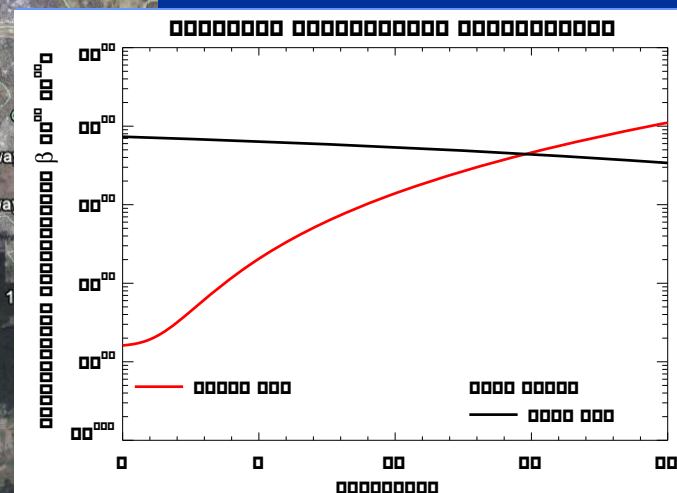
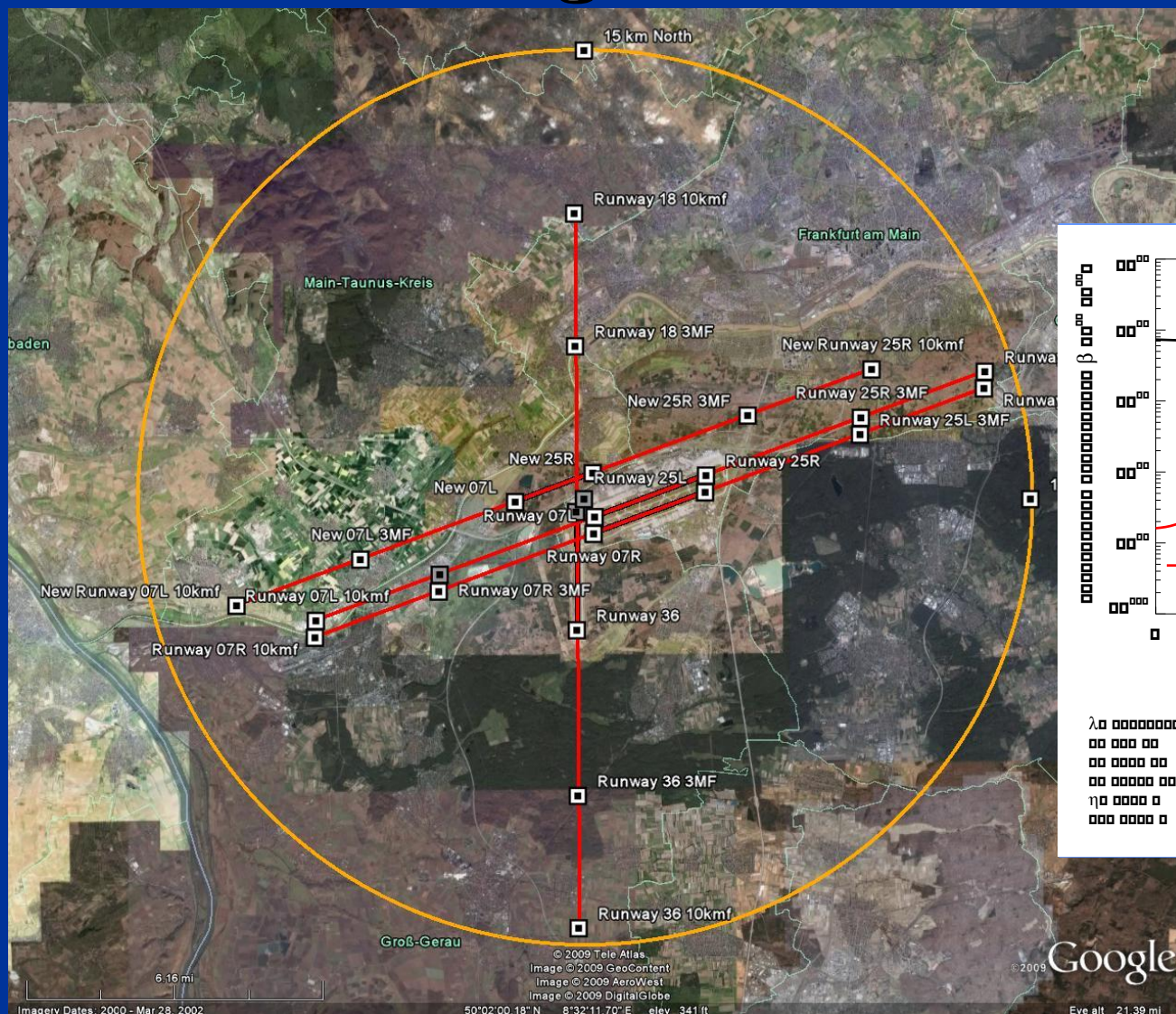


Lidar detected microburst.
Processed and displayed on RB5



RB5 Display & Analysis application

Frankfurt Airport – Illustrative Lidar Coverage



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Key Performance Indicators



Parameter	WindTracer®	METEOR 50DX
Application	Wind shear detection in “dry” conditions	Windshear detection in “wet” conditions
Maximum Range	10 – 15 km	Typically 50-100 km
Minimum Range	300 m	500 m
Frequency	Infrared (eye-safe):1.6 um wavelength	9 GHz X-Band Radar
Detectable Velocity	+/- 38 m/s	+/- 80 m/s
Range Resolution	60 m	50 m
Scan Modes	PPI, RHI, VAD	PPI & RHI & 3D
Maximum Scanning Speed	20 deg/sec	36 deg/sec
Peak Power	>5 kW	75 kW, Magnetron
Pulse Repetition	750 Hz typical	300 – 2500 Hz
Mean Power	2 Watt	Total: < 2.5 KW
Beamwidth	Collimated, <0.001 deg/pulse	< 1.4 deg
Antenna gain	N / A	> 38.5 dB



DWD ITWS/LLWAS Project



- **Project initiated in late 2009**
- **System installations begin late 2010**
- **Verification phase through much of 2011**
- **Final acceptance by end of 2011**

Summary



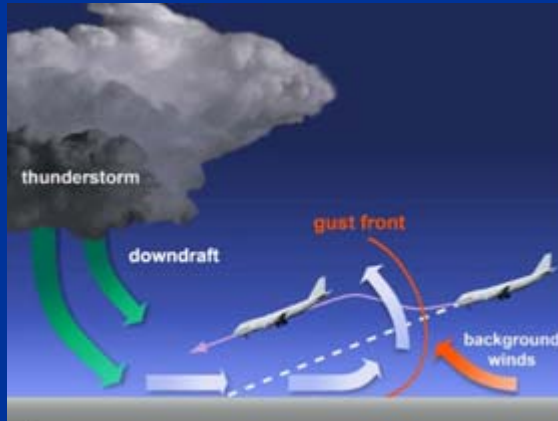
- **Lidar installations have augmented large C-band radars to address deficiencies**
- **Pairing X-band Doppler Radar with Lidar is more cost-effective for terminal-area wind sensing**
 - Recent measurements support complementary nature of the two sensors
- **DWD's ITWS/LLWAS project provides first opportunity to deploy integrated sensors**
 - SELEX and LMCT working together to install radar/lidar solution for Frankfurt and Munich



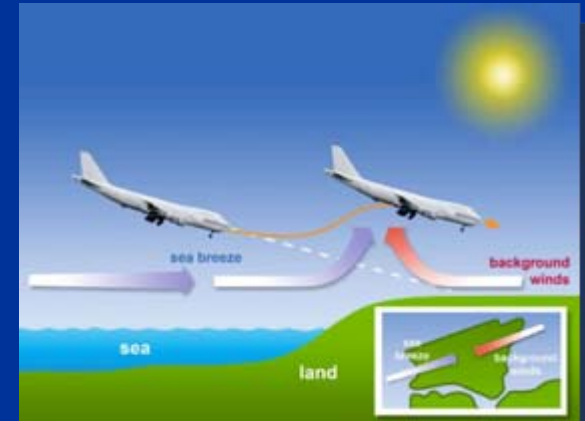
Types of Wind Hazards



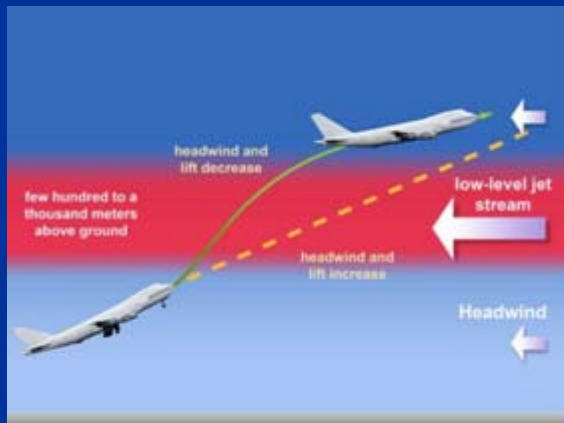
Microburst Wind Shear



Gust Front Shear



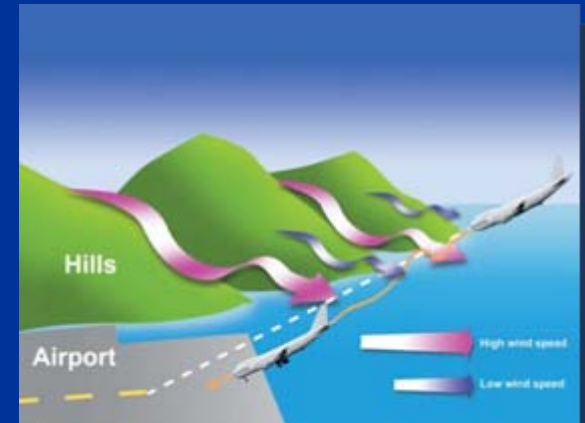
Sea Breeze Shear



**Low-Level Jets
and Other Vertical Shear**



Turbulence



**Terrain-Induced Shear
and Turbulence**

WindTracer® Key Installations



**Wake Turbulence Research &
Wind Shear Measurement**

Wind Shear Measurement



New York JFK International Airport
St. Louis Lambert International Airport
San Francisco International Airport
Atlanta Hartsfield International Airport
Las Vegas McCarran International Airport



London Heathrow Airport

Coming soon to:
Palermo Airport
Frankfurt Airport
Munich Airport



Hong Kong International Airport (2)
Tokyo Haneda Airport
Tokyo Narita Airport

Coming soon to Japan:
Haneda Airport 2
Kansai Airport

System Design



- Industry experts consulted to help specify the system
- Numerous radar vendors were surveyed for initial/baseline system

Guiding Principles:

- Focus on terminal-area coverage
- Let Lidar take care of low dBZ conditions
- Keep Radar dish diameter small (~2m)
- Utilize 'common' radar wavelength

- Flexibility of software integration enables alternate radars to be considered

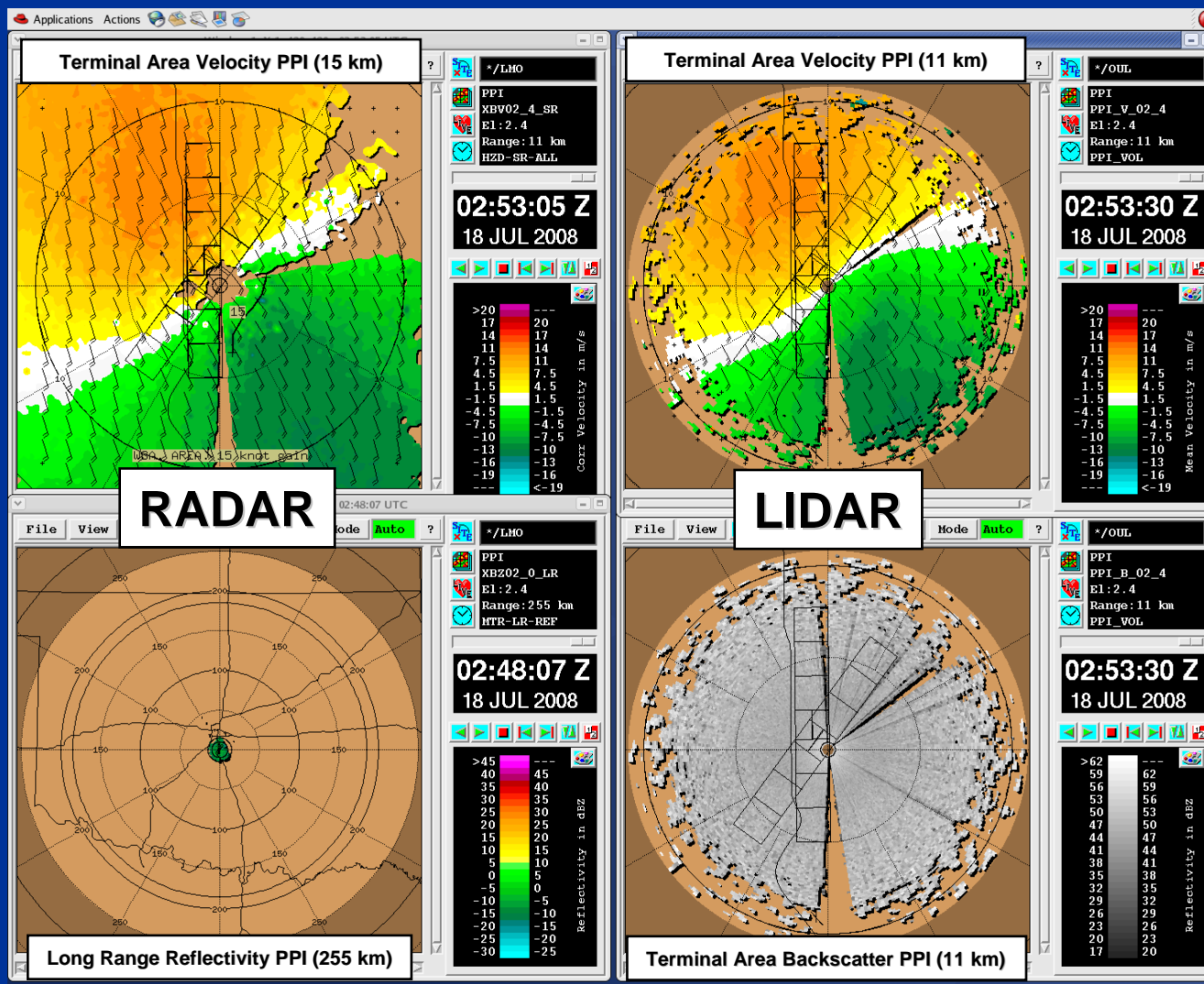
Test Radar Specifications



- **Radtec 200-I Radar**
 - 8.4257 GHz Magnetron, 200 kW Transmitter
 - 0.4, 0.6, and 0.8 microsecond pulse widths
 - 2 m Kavouras Reflector
 - Offset feed to improve clutter performance
 - First side lobe down 31.0 dB from peak
 - 40.4 dBi Gain
 - 1.63 degree beam width
- Co-located with WindTracer temporarily loaned by FAA

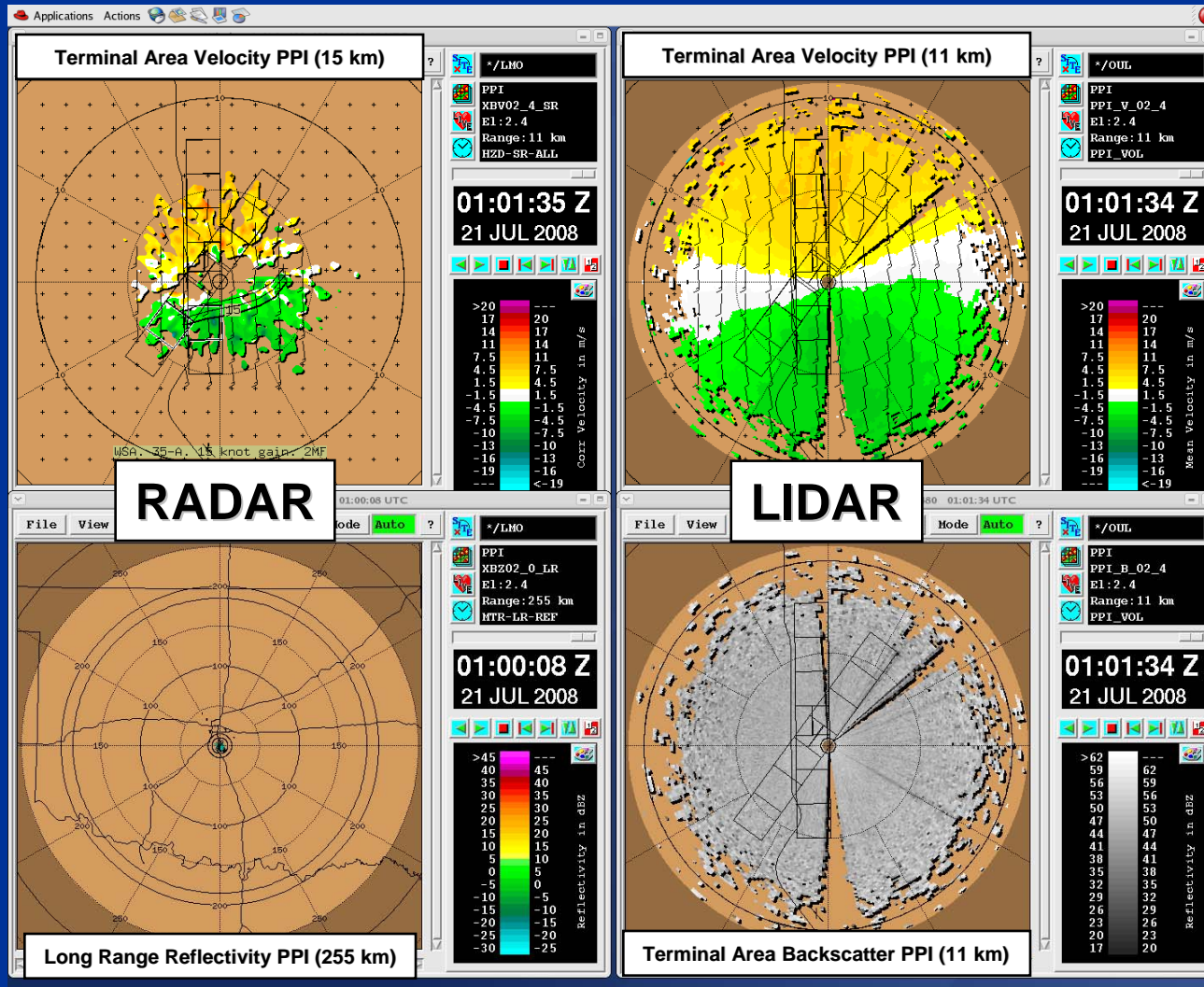


Lidar and Radar have Performance Overlap...



- Good comparison between the two systems
- Lower backscatter than the previous slide, but better radar performance
- METAR KOUN
180251Z AUTO
13008KT 10SM CLR
30/21 A2998 RMK
AO2

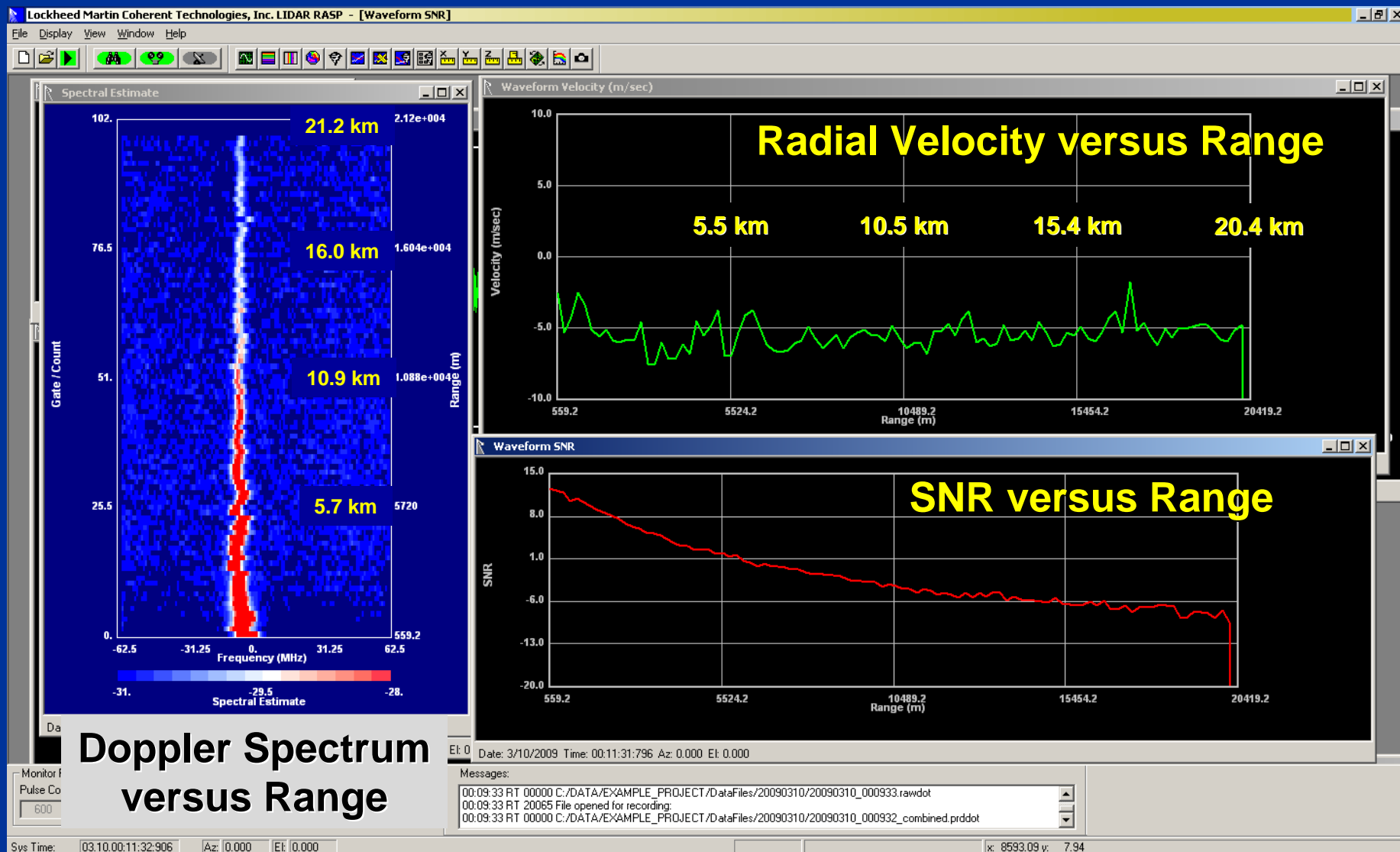
Aerosol Backscatter does not predict radar performance...



- Very similar aerosol backscatter to last slide
- Radar performance completely different
- METAR KOUN
210111Z AUTO
16005KT 10SM CLR
33/17 A3000 RMK
AO2

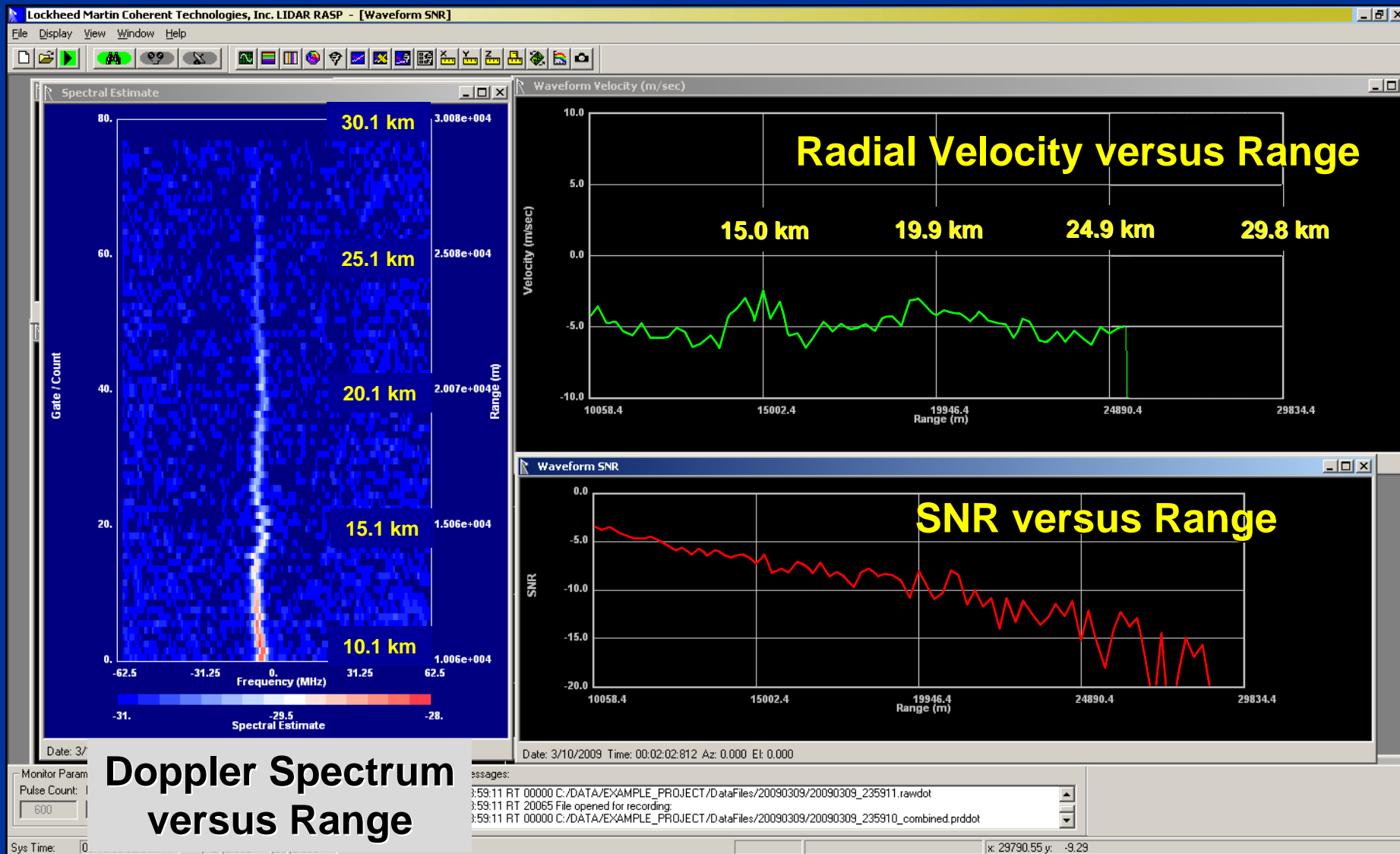
Demonstrated >20 km Performance

1 Hz Update Rate, Colorado USA

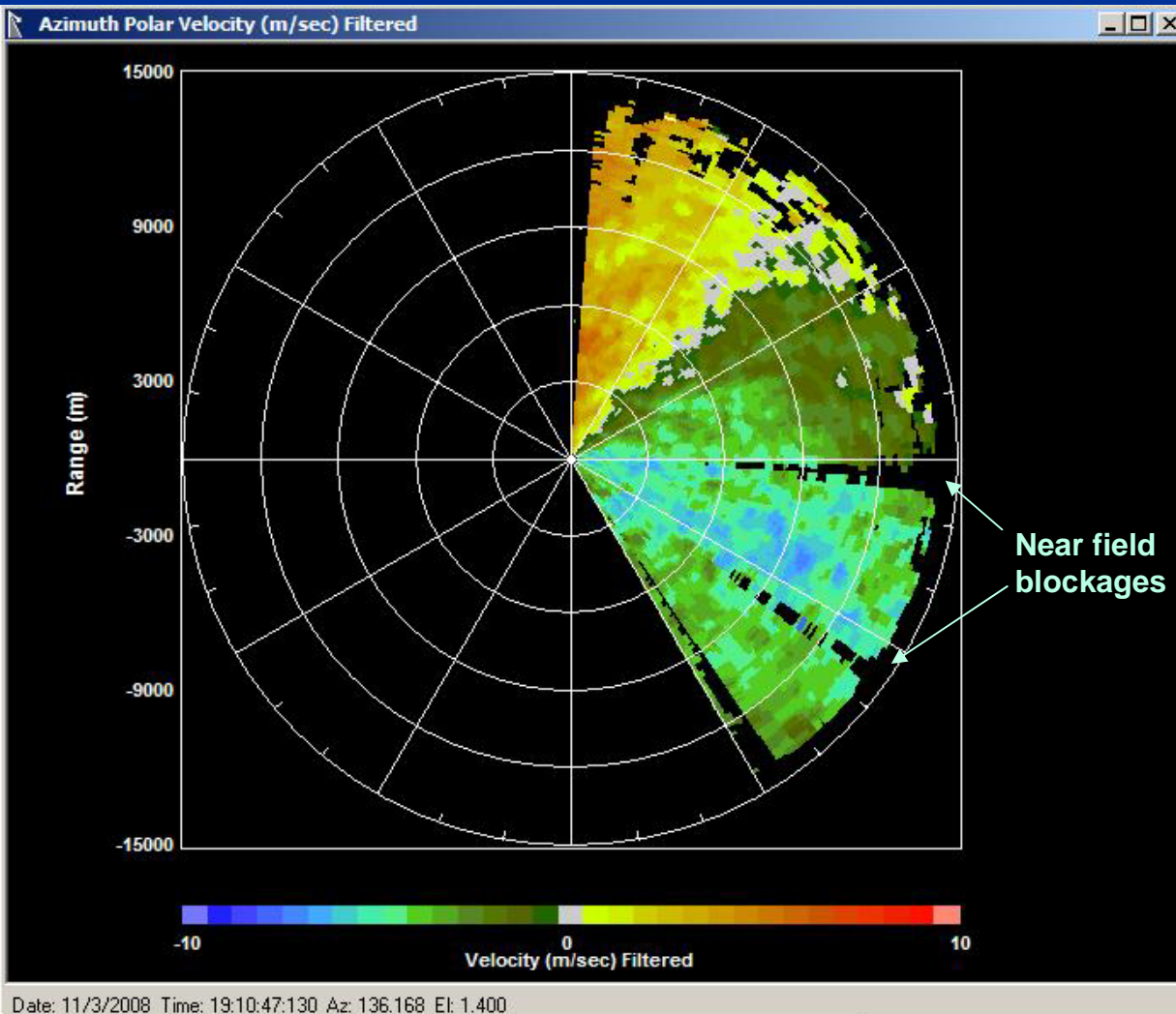


Demonstrated 25 km Performance

1 Hz Update Rate, Colorado USA



Demonstrated ~15 km performance coverage (250+km²) in Colorado



Simple config changes allow trade of update rate and spatial resolution for greater range

Better performance will be achieved for lower altitude, higher aerosol loading environments