Testbeds - Types, Characteristics, and Necessary Conditions for Success

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Motivation for Talk

• Many NRC reports, workshops, *BAMS* articles, etc. have recommended that testbeds (of some kind) be established to facilitate new research to operations activities that improve the delivery of weather and water information to various regions or customers.

• Here we briefly summarize several existing testbeds, the need for new ones, some necessary characteristics of successful testbeds, and attributes associated with creating new urban testbeds
Definition of Testbed

- A definition of a testbed was provided by Dabberdt et al (2005 BAMS) and repeated in 2 NRC reports: “Observing Weather and Climate FROM THE GROUND UP: A Nationwide Network of Networks” (NoN) and “When Weather Matters: Science and Services to Meet Critical Societal Needs” (WWM).

- A testbed is a working relationship in a quasi-operational framework among measurement specialists, forecasters, researchers, the private sector, and government agencies aimed at solving operational and practical regional problems with a strong connection to end users. Outcomes from a testbed are more effective observing systems, better use of data in forecasts, improved services, products and economic/public safety benefits. Testbeds accelerate the translation of R&D findings into better operations, services and decision-making. A successful testbed requires physical assets as well as substantial commitments and partnerships.
Types of Testbeds

• **Observational-Numerical** (or Observational-Forecasting)

• **Research-to-Operations** (observational assets missing)  E.g. - NCEP testbeds (AWT, CTB, HMT, HWT, JHT .........)

• **Analysis and Modeling Testbeds** (E.g. - DTC, JCSDA)

• **Research Testbeds** (E.g. - DoE ARM sites in SGP, Alaska and western Pacific; most obs. systems in same vertical column)

• Others?
Desired Attributes of Effective Testbeds*

- Involve multiple partners that contribute funds, resources and/or fund-raising efforts
- Partners work with stakeholders and end-users *ab initio* in testbed planning
- Mission, expected outcomes and measures of success (evaluation) are well-defined
- Flexibility to adapt to new opportunities and challenges
- End-to-end: Obs → research → ............ to decision-makers
- Effort (in resources, time, personnel, coordination, etc.) not under-estimated

* From NoN and WMM NRC reports
Desired Attributes of Effective Testbeds (cont.)

• Provide real data tests of (i) benefits of new measurement systems (to compare with OSSE’s; determine “optimal mix”) (ii) observing strategies (e.g., targeted obs), etc. before national deployment

• Data, products, etc. easy to access and understand

• Establish effective governance system among partners that is transparent, acquires needed resources, protects IP and data rights (if relevant), maintains archive, communicates with end users, etc.
Sequence for Use of Testbed to Evaluate Observing Systems

- Develop concept for new observing system
- **Build a prototype**
- Calibrate, field test, etc. in lab or non-op. setting
- **Incorporate system in testbed; integrate with other observing systems**
- Incorporate data into a data assimilation and modeling system (determine errors, forward model, etc.)
- **Do Observing System Tests – with all existing systems included** – to assess benefit of new system to analysis, forecasts, end-user applications, etc.
- If benefit is positive, deploy system in an operational network
Testbed Benefits Loop (BAMS 2005)

Input:
1. Develop and introduce new ideas, data, etc.
2. Revise and iterate

Test and refinement loop

Output:
1. Operationalize new methods
   - NWS, NOS
   - OAR
   - State and Local agencies

Experimentation and demonstration
Impact assessments
Urban Testbeds

• Especially recommended in recent WWM report and many times previously

• **Standing Committee in OFCM on “Urban Meteorology - Joint Urban Test Bed”**

• Needed to understand/forecast unique problems of urban areas
  – Urban heat island
  – Urban flooding
  – Street level weather and urban (street) canyon wind flow
  – Evolution of urban boundary layer
  – Air quality; transport and dispersion; attainment issues
  – Very-high resolution analysis/modeling; forecast support for emergencies
Specific Aspects of Urban Testbeds

• Attributes of a Particular Region (to evaluate when considering different sites for creation of a testbed)
  – Demographic info. and weather sensitivities
  – Economic infrastructure
  – Existing observing systems
  – Radar coverage info.
  – Financial support: Academic; Local; State; Federal; Private
  – Infrastructure needs and providers

• Potential Research and Applications Opportunities

• Lessons Learned from other Testbeds
## Attributes of Urban Testbeds

### General Statistics

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PURPOSE</th>
<th>DFW INFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan population</td>
<td>Desire large affected population</td>
<td>6.5 million (2009 est.)</td>
</tr>
<tr>
<td>Gross metro product (GMP)</td>
<td>Magnitude of economic activity &amp; potential markets</td>
<td>$380 billion (2008 est.)</td>
</tr>
<tr>
<td>Weather vulnerability</td>
<td>Indicates weather threats/sensitivities &amp; forecast/warning needs</td>
<td>Severe weather (hail, tornadoes, wind); strong fronts/mesoscale systems; some winter weather (ZR); heat, air pollution, etc.</td>
</tr>
<tr>
<td>Water vulnerability</td>
<td>Do flooding, surge, etc. threats exist; water management needs</td>
<td>Some flooding – Trinity River, local creeks &amp; roads; short-term droughts</td>
</tr>
</tbody>
</table>
# Attributes of Urban Testbeds

## Economic Infrastructure

<table>
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<tr>
<th>CATEGORY</th>
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<tbody>
<tr>
<td>Airports</td>
<td>Indicate potential aviation impacts</td>
<td>DFW (~ 640,000 T&amp;L - 2009); also Love, Alliance and several other regional airports</td>
</tr>
<tr>
<td>Highway transportation</td>
<td>Indicate potential road weather vulnerability</td>
<td>I-35, I-45, I-30, and I-20 (also I-635, I-820, many local parkways and freeways)</td>
</tr>
<tr>
<td>Outdoor sporting venues</td>
<td>Need for wx info. and warnings for large outdoor crowds</td>
<td>Rangers Ballpark; Cotton Bowl/SMU/TCU/other stadiums; Six Flags; TX Speedway; Cowboys Stadium (retractable roof)</td>
</tr>
<tr>
<td>Media</td>
<td>Indicates potential media markets; # of TV households</td>
<td>2.5 million households (5th largest); many TV stations</td>
</tr>
</tbody>
</table>
# Attributes of Urban Testbeds

## Current Observing Systems (surface-based)

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<tr>
<td>Surface</td>
<td>Indicates available networks &amp; potential gaps</td>
<td>NWS ASOS/Coop; FAA AWOS; Priv. networks (Weathernet); more…. (use MADIS)</td>
</tr>
<tr>
<td>Upper Air</td>
<td>Indicates existing vertical profiling capability</td>
<td>FWD raob (twice daily); 1 GPS MET; ACARS/TAMDAR; profilers?</td>
</tr>
<tr>
<td>Radar</td>
<td>Indicate local radar coverage and potential gaps</td>
<td>KFWS Nexrad 14 mi. S of FTW 2 TDWR (DAL and FTW)</td>
</tr>
<tr>
<td>Other</td>
<td>Indicates observational assets from other agencies, PS, etc.</td>
<td>TNRCC Air Monitoring Network (131); CoCoRaHS; DAL Alert raingages (58)</td>
</tr>
</tbody>
</table>
# Attributes of Urban Testbeds

## Radar Coverage Info. (for local WSR-88D)

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</thead>
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<tr>
<td>Percent Doppler radar coverage at or below 5000 ft within 100 km of city (FAA – Cho 2010)</td>
<td>Indicates low-level gaps</td>
<td>83%</td>
</tr>
<tr>
<td>Percent multi-Doppler radar coverage at or below 5000 ft within 100 km of city (FAA – Cho 2010)</td>
<td>Indicates dual-Doppler analysis area</td>
<td>67%</td>
</tr>
<tr>
<td>Percent dual-pol coverage at or below 5000 ft within 100 km of city (FAA – Cho 2010)</td>
<td>Indicate dual-pol coverage, where QPE should be more accurate</td>
<td>66%</td>
</tr>
</tbody>
</table>

*Could do above for 1000 ft, e.g., or for different areas*  Indicates very low-level gaps
### Attributes of Urban Testbeds

#### Local Support

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<tr>
<td>Coordinating agency available?</td>
<td>Facilitates connections to stakeholders; assists with infrastructure, funding, etc.</td>
<td>North Central Texas Council of Governments</td>
</tr>
<tr>
<td>NWS</td>
<td>Support of local NWS offices</td>
<td>Yes - FWD FO, SRH, RFC</td>
</tr>
<tr>
<td>Emergency managers</td>
<td>Coordination with EMs; access to Emergency Operations Centers</td>
<td>Yes</td>
</tr>
<tr>
<td>Private sector</td>
<td>Partnerships with private sector; sharing of assets, etc.</td>
<td>TBD</td>
</tr>
</tbody>
</table>
## Attributes of Urban Testbeds

### Financial Support

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<tr>
<td>Research funding agencies</td>
<td>Support for research problems that can be addressed with new network</td>
<td>CASA ERC (NSF) (for first 2 years); New proposals</td>
</tr>
<tr>
<td>Local governments</td>
<td>Demonstrate buy-in from local end-users</td>
<td>Yes, via NTCCOG</td>
</tr>
<tr>
<td>NWS/NOAA</td>
<td>Support indicates value of effort to NWS mission</td>
<td>FWD FO; SRH; RFC (in kind) NWS OST would like to support if possible</td>
</tr>
<tr>
<td>Private sector</td>
<td>Indicates value of testbed – that it will improve PS products and services; assist market penetration</td>
<td>TBD</td>
</tr>
</tbody>
</table>
## Attributes of Urban Testbeds

### Other (Misc.)

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</thead>
<tbody>
<tr>
<td>Infrastructure support</td>
<td>Source of land, towers, power, communication, access, etc.</td>
<td>Yes, via NTCCOG</td>
</tr>
<tr>
<td>Additional hi-res NWP capability planned</td>
<td>Provision of analyses and forecasts on urban scales (~ 100 m)</td>
<td>Yes, via OU CAPS</td>
</tr>
<tr>
<td>National priority?</td>
<td>Connected to emerging national priorities in weather and climate?</td>
<td>Yes, via NRC “NoN” and “When Weather Matters” reports; other calls for urban studies</td>
</tr>
</tbody>
</table>
NOTE: The list below is just a small sampling of many possible R&D and R2O opportunities in an urban testbed.

1. Assess value of network of X-band radars in urban areas to:
   a) Detect severe weather near the surface (where NEXRAD can’t)
   b) Improve QPE and flash flood warnings in local basins
   c) Provide real time wind analyses at <1 km scales to model dispersion of pollutants and other hazardous (biological/chemical/radiological) substances
Research and Applications Opportunities

2. Facilitate data fusion using all available observing systems to demonstrate ability to:
   a) Combine data from different operational and research radars (NEXRAD, TDWR, CASA, ARRC, PS, TV station, mobile, etc.)
   b) Combine above radar info. with surface networks, aircraft (ACARS, TAMDAR) data, ground-based profiling systems, GPS, etc.
   c) Combine above results with satellite data (soundings, cloud-track winds, cloud tops, COSMIC, etc.)
   d) Improve selected analysis products using dual-polarimetric data where they are available
   e) Use 3D-Var, EnKF and hybrid Var-EnKF techniques to produce analyses using all or subsets of these data
Research and Applications Opportunities

3. Use of Testbed data and analyses to:
   a) Perform 4D-data assimilation that produces a near-real-time movie of weather variables in and about the urban area
   b) Initialize storm-scale models to predict hazardous (and quiescent) weather for all seasons at very high resolution (<1 km)
   c) Couple storm-scale model above with urban street-canyon models (dx ~ 10 m) to predict atmospheric (chemical, particulate, etc.) variables within the urban canopy
   d) Couple QPF output from the models to hydrologic models for flood forecasting and water management
   e) Perform Observing Systems Tests to determine relative contribution of each observing system to reduction of forecast error
How to Build and Maintain a Successful Testbed

(Lessons Learned from other efforts)*

Overarching Concepts

• It’s all about the users (get as broad a community as possible)
• Needs a well-articulated, long-term plan based on science questions and societal needs
• Deploying instrumentation without complementary research and science isn’t sustainable
• Data and metadata need to be complete and accessible
• Synergy among measurements is critical and leads to scientific progress
• Constant tension between consistency and adapting to change (needs, instruments, data).
• Expect the unexpected and be flexible

* Most material here is based on Tom Ackerman’s talk at Thermodynamic Profiling Technologies Workshop - April 2011
Programmatic considerations

• Have a grand vision
• Articulate the purpose and benefits
• Who is the intended audience?
• What are the requirements?
• Don’t be quick to compromise
• Instruments and data are a national resource – play well with others
• Periodically review what you are doing and why
How to Build and Maintain a Successful Testbed

**Instrumentation aspects**

- No one instrument solves every problem
- Consider the suite of scientific problems
- What measurements are needed?
- What minimum set of instruments meets these needs?
- What is the cost?
- Can we partner with others?
- Buy commercial when possible
  - Don’t necessarily buy the latest and greatest
  - Consistent performance more important than pushing the limits of capability
- Instruments become obsolete
  - No support; unavailable parts
  - Plan for upgrades and expansion

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- Consistent performance more important than pushing the limits of capability
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How to Build and Maintain a Successful Testbed (cont.)

**Instrumentation Operation**

- Calibrate, calibrate; Monitor, monitor
- Build in-house expertise or develop really strong links to vendors that are committed to operations and science

**Data and metadata**

- Continuity – keep the instruments running
- Consistency – keep the same operating procedures
- Maintain quality controls and document procedures
- Redundant measurements extremely useful for diagnostics and continuity
- Metadata – must be accessible and complete
- Reprocessing – will be required multiple times
- Archive is critical
  - Must work for users; can one get data out
  - Logical structure, easy to understand
  - Support value-added processing
Urban Testbeds - Let’s Get Started

• Can such an effort can be started immediately?
• Will it be a “build it and they will come” enterprise?
• Can we get necessary funding/resource commitments when needed?

• Brenda Phillips will discuss current DFW Testbed effort
NEXRAD Radar Coverage in DFW Area
(Contours are height of lowest beam above ground)