R2O Case Study – Microburst Decision Support

Friends and Partners of Aviation Weather (FPAW)

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Major Accidents Attributed to Microburst Wind Shear

Experiments and studies by scientists

1970 – 1990: Fatal wind shear accidents comparable to fatal air carrier collision accidents

Fatal Accidents	# Accidents	# Fatalities
Accidents Associated with Aircraft Collisions	6	258
Microburst Wind Shear Accidents	4	499

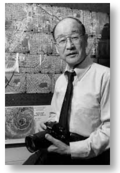
St. Louis
38 fatalities; 6 injured

New York
112 fatalities; 12 injured
June 1975

Denver
15 injured

Philadelphia
86 injured
June 1976

Fujita report on NY 1976



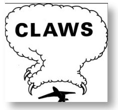
Tucson
0 injured

NIMROD 1978

JAWS 1982

New Orleans
153 fatalities; 9 injured
July 1982

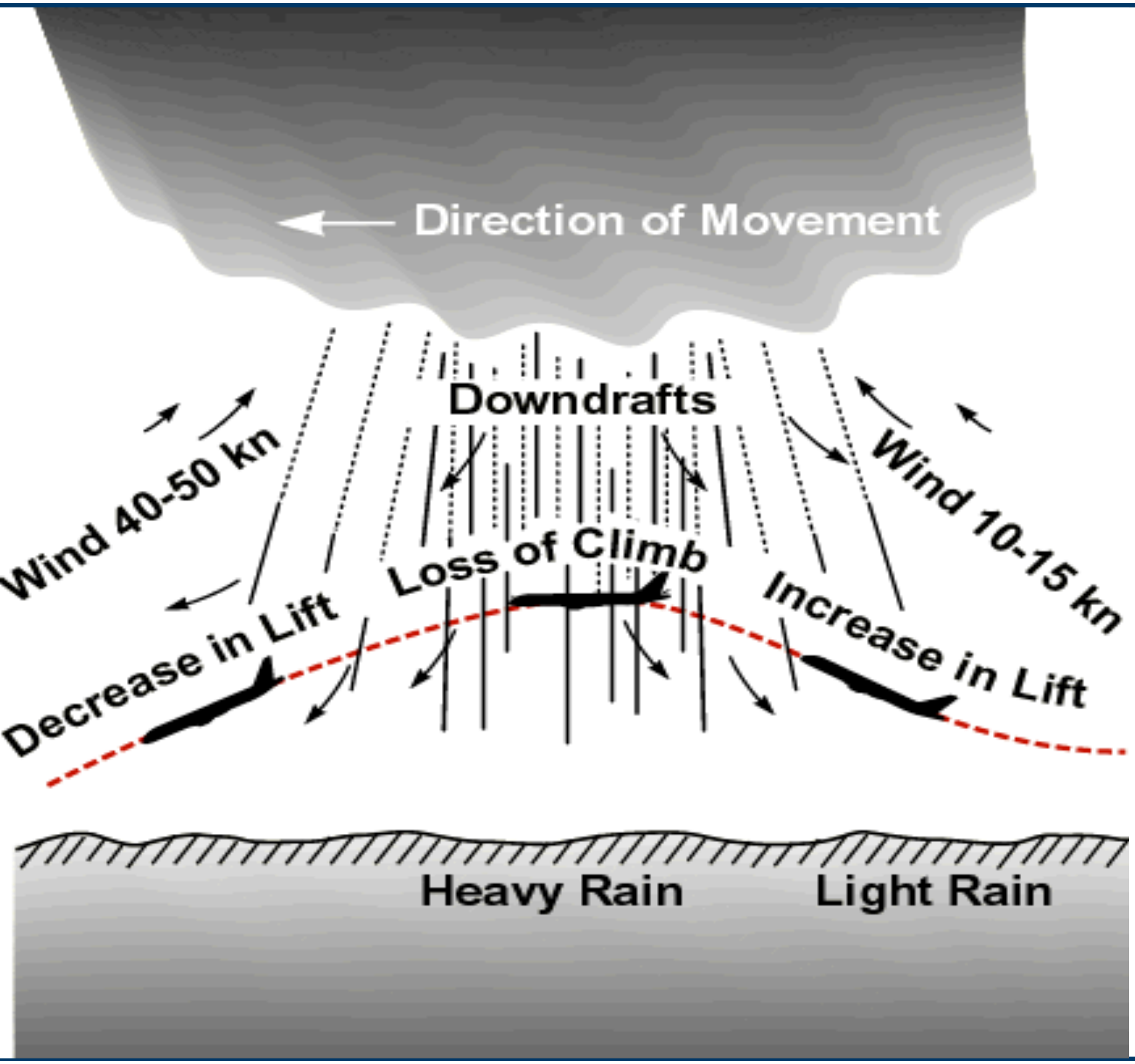
CLAWS 1984



Dallas
130 fatalities; 130 injured
August 1985

Charlotte
37 fatalities; 16 injured
July 1994

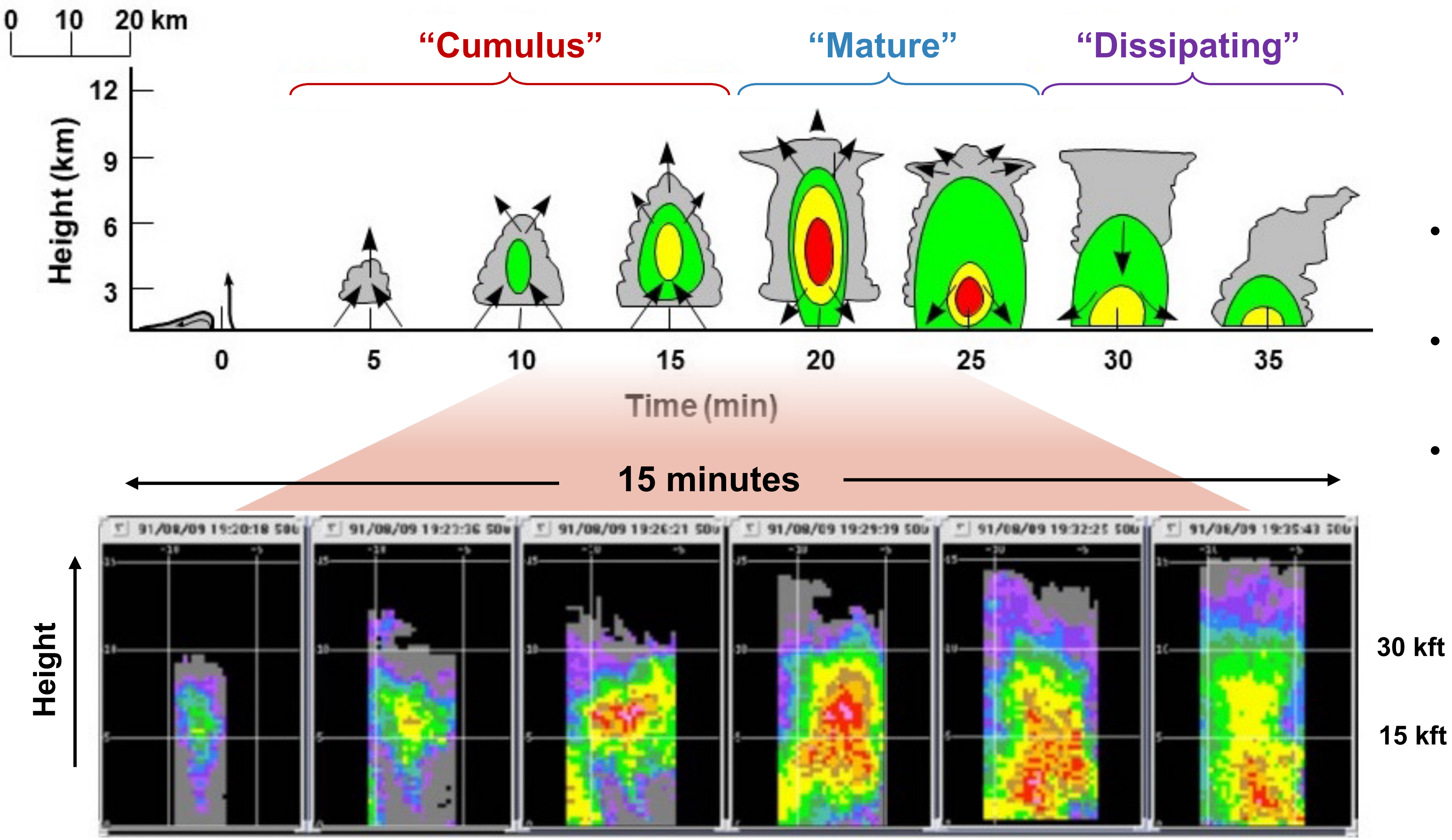
Microburst Hazard to Air Vehicles



Challenges for Pilots

- Recognition is difficult
- Time available for recognition is short (5 to 15 seconds)
- Effective crew coordination is essential
- Pilot training at the time did not emphasize most effective responses
  - Flight path must be controlled with pitch attitude
  - Reduced airspeed may have to be accepted to ensure flight path control
- Operationally significant encounters were infrequent for individual pilots
- Rapid time evolution of phenomena: reports from preceding pilots may understate the hazard

Time Evolution of Microburst-Producing Storms



- **Storms can rapidly change with time**
- **Microburst outflow occurs when rain shaft reaches ground**
- **In dry environments such as Denver, rain may not reach the ground**

How Key Issues in "Microburst Product" R2O Were Addressed

Key Element of Microburst R2O	How Accomplished
Understanding microburst phenomena and its hazard to aircraft	Scientific studies and experiments (e.g., Fujita*, NIMROD, JAWS, NCAR, NASA)
Reliable automated detection of microbursts and warning generation	MIT Lincoln Laboratory R & D using Lincoln prototype TDWR
Procedures for ATC and pilot use of microburst warnings	NCAR CLAWS real time radar meteorologist detections 1984
	FAA TDWR/LLWAS User Group 1986-1989
	FAA Procedures 1988
	Airline policies for pilots 1988
Training of pilots to manage microburst encounters	Windshear Training Aid (Boeing for FAA, 1987)
	Airline flight simulators (1991–present!!!!)
Success in acquisition, deployment and operational use of the TDWR	Collaboration between FAA, Lincoln, Raytheon and various R&D laboratories plus pilot training

*T. Theodore Fujita, 1985: "The Downburst," The Univ. of Chicago SRMP Research Paper # 210

A First Step in R2O – Research Radar Meteorologist Generated Microburst Alerts Provided to Pilots in Real Time

In 1984, the Classify, Locate and Avoid Wind Shear (CLAWS) project demonstrated that microbursts could be detected by radar and that information could be relayed manually in a timely manner to pilots operating at Denver Stapleton Airport

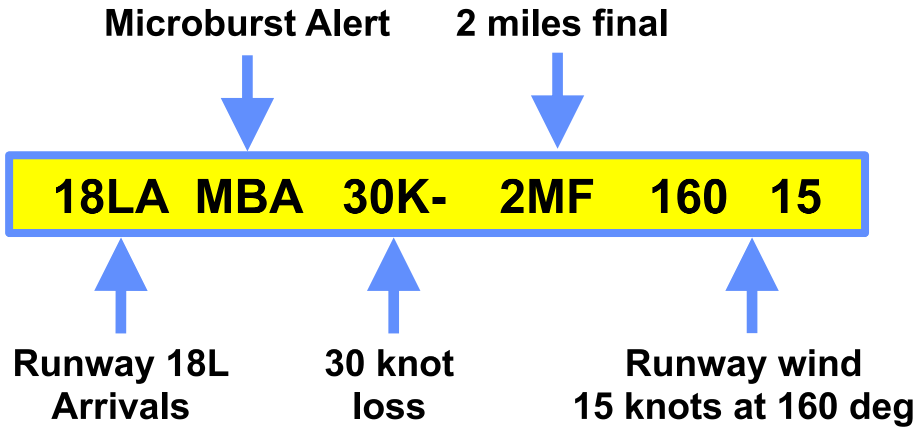
Classify, Locate, Avoid Wind Shear (CLAWS) project Denver Stapleton Airport (1984). Dr. John McCarthy.
(Photo by Charles Semmer)

TDWR Operational Concept and Requirements

Operational Concept for Warning Pilots

Tower controller reads out wind shear warnings from ribbon display along with runway winds

Ribbon Display



Microburst Alert

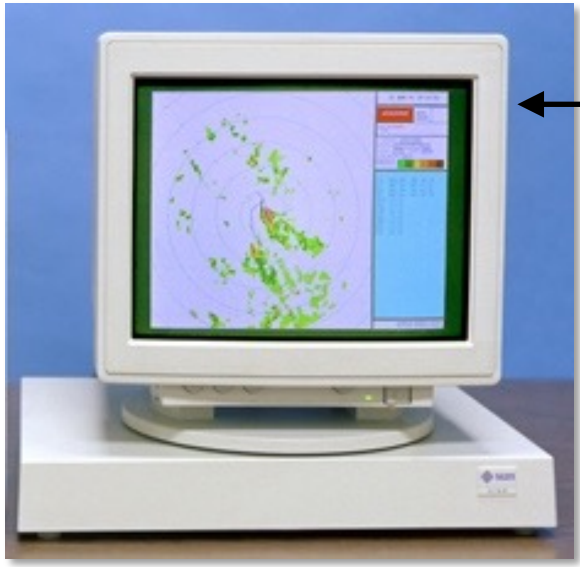
2 miles final

18LA MBA 30K- 2MF 160 15

Runway 18L Arrivals

30 knot loss

Runway wind 15 knots at 160 deg



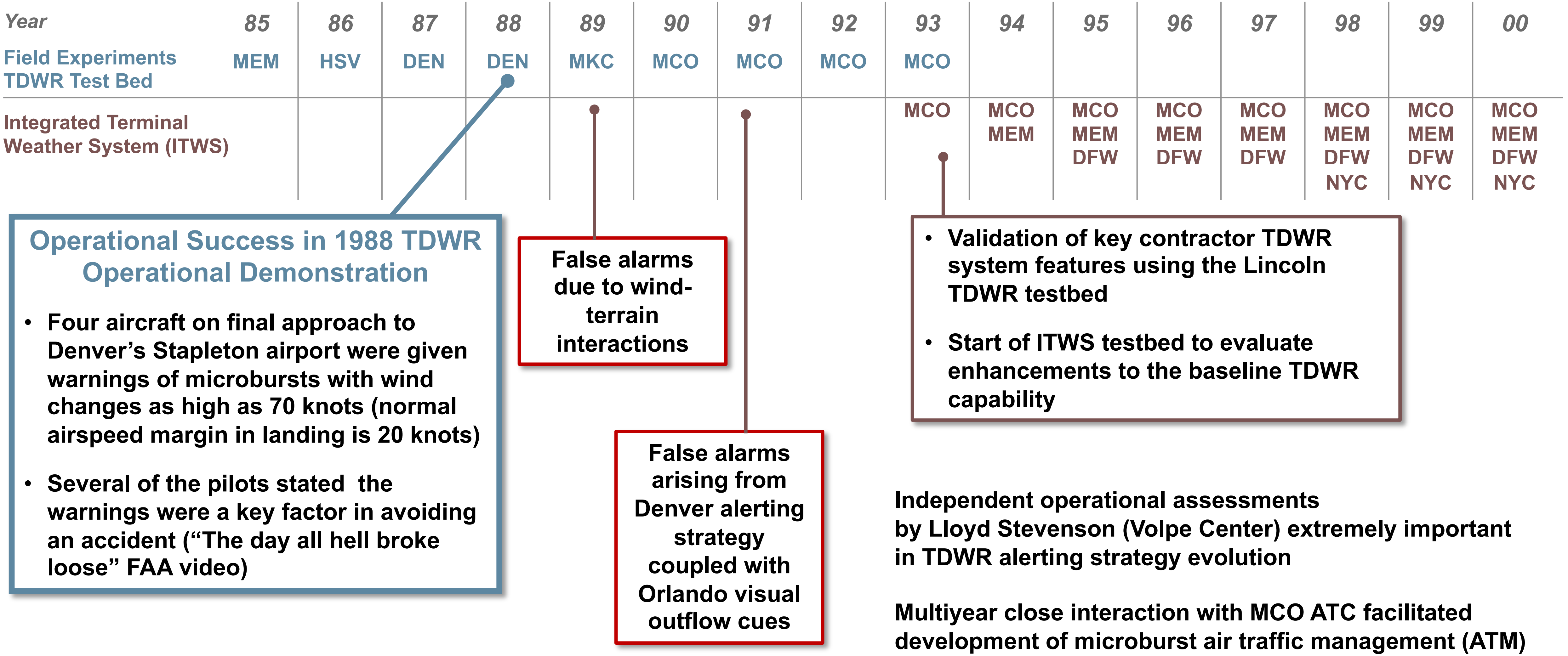
Plan view display for ATC to minimize the usage of runways and approach/ departure paths that are impacted by microbursts

Airline guidance to pilots: Do not land or take off on a runway with a microburst alert in effect

Technical Performance Requirements

- Probability of detection > 95% for microbursts with a false alarm probability < 5%
- Accuracy of wind shear estimate should be within ± 5 knots or 20% (whichever is greater) for at least 70% of detections

Automated Windshear Detection Testbed Time History



Year	*85*	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*00*
Field Experiments TDWR Test Bed	MEM	HSV	DEN	DEN	MKC	MCO	MCO	MCO	MCO							
Integrated Terminal Weather System (ITWS)									MCO	MCO MEM	MCO MEM DFW	MCO MEM DFW	MCO MEM DFW	MCO MEM DFW NYC	MCO MEM DFW NYC	MCO MEM DFW NYC

Operational Success in 1988 TDWR Operational Demonstration

- Four aircraft on final approach to Denver's Stapleton airport were given warnings of microbursts with wind changes as high as 70 knots (normal airspeed margin in landing is 20 knots)
- Several of the pilots stated the warnings were a key factor in avoiding an accident ("The day all hell broke loose" FAA video)

False alarms due to wind-terrain interactions

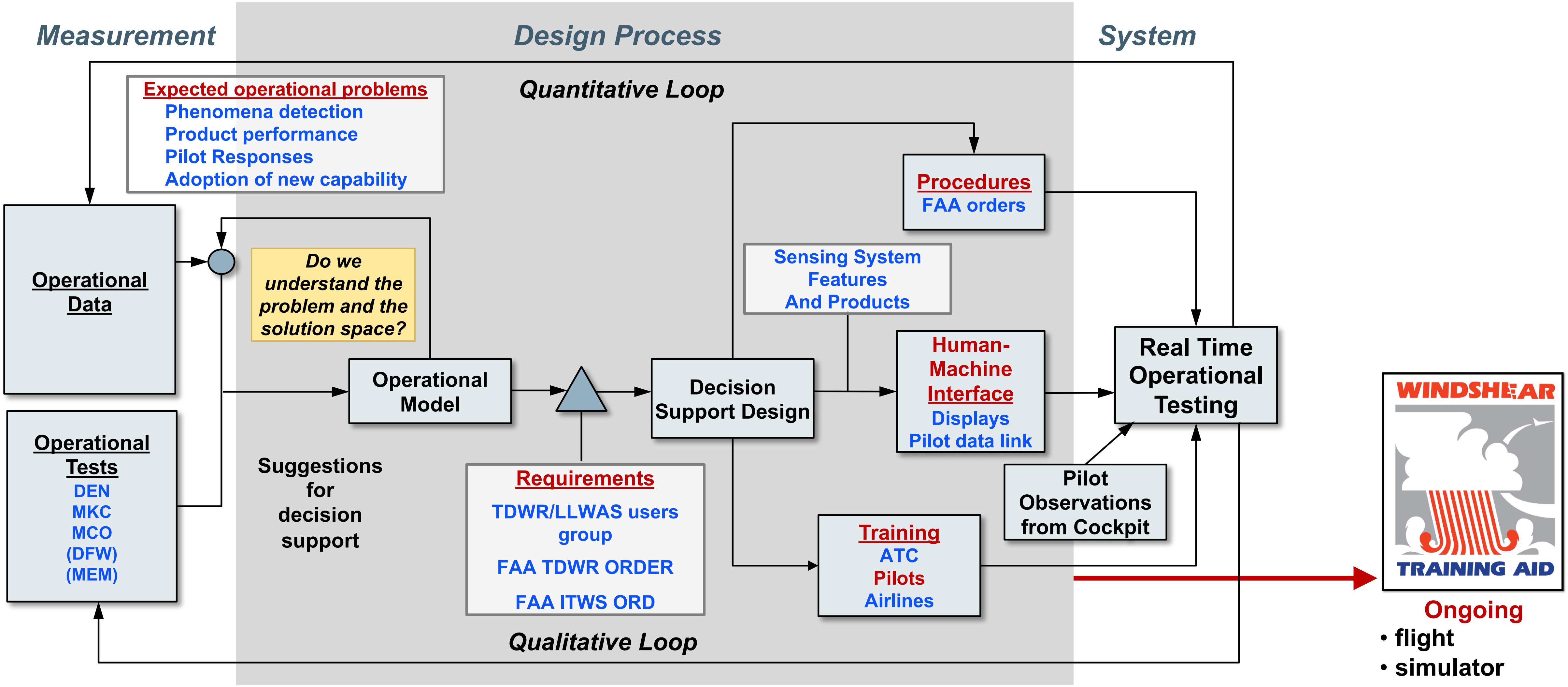
False alarms arising from Denver alerting strategy coupled with Orlando visual outflow cues

- Validation of key contractor TDWR system features using the Lincoln TDWR testbed
- Start of ITWS testbed to evaluate enhancements to the baseline TDWR capability

Independent operational assessments by Lloyd Stevenson (Volpe Center) extremely important in TDWR alerting strategy evolution

Multiyear close interaction with MCO ATC facilitated development of microburst air traffic management (ATM)

Iterative Process for Operational Windshear Avoidance R2O



Measurement

Design Process

System

Quantitative Loop

Expected operational problems
Phenomena detection
Product performance
Pilot Responses
Adoption of new capability

Operational Data

Do we understand the problem and the solution space?

Operational Tests
DEN
MKC
MCO
(DFW)
(MEM)

Operational Model

Suggestions for decision support

Requirements
TDWR/LLWAS users group
FAA TDWR ORDER
FAA ITWS ORD

Decision Support Design

Procedures
FAA orders

Sensing System Features And Products

Human-Machine Interface
Displays
Pilot data link

Training
ATC
Pilots
Airlines

Real Time Operational Testing

Pilot Observations from Cockpit

Qualitative Loop

WINDSHEAR TRAINING AID

Ongoing
- flight
- simulator
- usage

Summary

- The microburst R2O program has been very successful: no fatal US accidents in over 25 years.
- Deployed operational elements included:
  - Ongoing pilot training (including annual flight simulator usage with microburst events)
  - Ground based windshear warning systems (TDWR, LLWAS, ASR-9 WSP)
  - Airborne windshear warning systems
- Key elements of this success included:
  1. Real time operational prototype usage before <u>and</u> while procurement was underway
  2. Multidisciplinary TDWR/LLWAS user group (FAA managers and tower ATC personnel, NASA, ALPA, ATA, Boeing, United, NBAA, AOPA, NTSB, NCAR, Lincoln, Langley, MITRE)
  3. Ongoing independent assessment by Volpe early on and during the development program
  4. Operationally oriented testing in a number of different environments
  5. Continuing production system improvements after deployment
- Data-driven prototype evaluations and benefits analyses that iteratively fed back into the prototype design were a key element at arriving at an operationally effective system

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McCarthy, et. al., 2022: Addressing the Microburst Threat to Aviation Research-to-Operations Success Story, Bulletin of the American Meteorological Society, 103, E2845–E2861, https://doi.org/10.1175/BAMS-D-22-0038.1