Aircraft Encounters With Thunderstorms in the Terminal Area

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Attachment 1

Outline

- Introduction
- NASA-funded DFW TRACON arrivals study
  - Methodology
  - Sensitivity to flight-specific variables
  - Weather variables correlated with penetration / deviation
- Factors on Final Approach
- Summary

Weather Information and Roles

- Pilots
  - Check ATIS & TWIP
  - Use airborne radar
  - Observe visual cues
  - Monitor radio frequency for wind shear alerts and PIREPs
  - May solicit PIREPs
- Airline Dispatchers
  - Weather data from vendors
  - Rarely contact the pilot in the TRACON
  - Sometimes give advice about the necessity of diversion
- Tower Controllers
  - Read centerfield winds
  - Read wind shear alerts
  - Have limited access to six-level precipitation
  - May relay PIREPs
- TRACON Controllers
  - Observe six-level precipitation on monochrome display
  - No access to wind shear information
  - May relay PIREPs

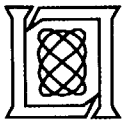
Level 3 Rule of Thumb

"There is no attraction to penetrate any echo of level 3 and above. The hazards are plentiful. Strong and violent convection is indicated by level 3 (and above) cores. The churning and turbulence will exist in the entire storm and not simply in the area of maximum reflectivity. Airline pilots avoid convective level 3 with vigor." (emphasis added)

Dave Gwinn
"Approach Radar for Weather Avoidance"
IFR: The Magazine for the Accomplished Pilot
June 1993

Precipitation Intensity

NWS LEVEL	INTENSITY	RAINFALL (IN/HR)	6-LEVEL DEPICTION	AIRBORNE DEPICTION
6	Extreme	> 7.1	Red	Red
5	Intense	4.5 – 7.1	Red/Orange	Red
4	Very Strong	2.2 – 4.5	Orange	Red
3	Strong	1.2 – 2.2	Yellow	Red
2	Moderate	0.2 – 1.2	Dark Green	Yellow
1	Weak	< 0.2	Light Green	Green



DFW Study: Background

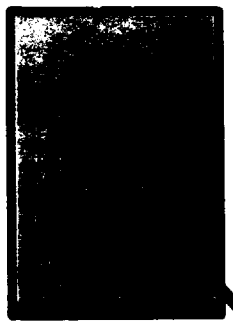
- **Motivation:**
  - **Successful development of ATC decision support tools for use during convective weather requires:**
    - **Predicting the location of the weather**
    - **Predicting where the pilots will request deviations**
- **Study Goals:**
  - **Determine which variables are correlated with behavior**
  - **Examine feasibility of probability-of-deviation classifier**
- **Also applicable to:**
  - **Terminal area safety**
  - **Weather representation for controllers**

Study Approach

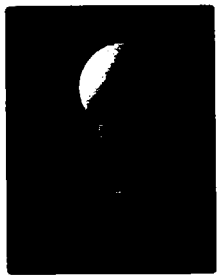
- Collect 60+ hours of weather and flight track data
- Identify penetrations and deviations
- Extract weather and flight variables for every encounter
- Perform statistical analysis

Note: None of the aircraft encounters with weather in this study resulted in accidents or, to the best of our knowledge, injuries.

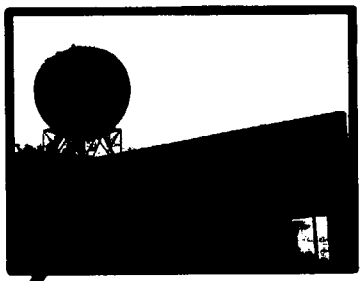
Integrated Terminal Weather System (ITWS)



ASR-9



TDWR



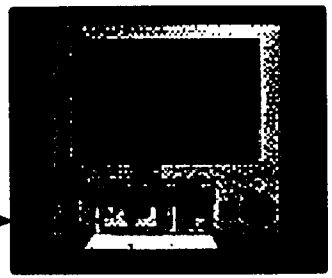
NEXRAD

Pilots

AWOS/ASOS

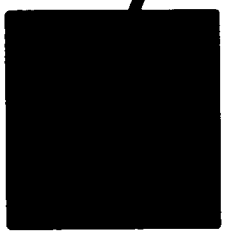
ITWS Real-time Processor

Microburst Prediction
Gust Front Prediction
Storm Location & Motion
Storm Cell Information
Terminal Winds
Tornado



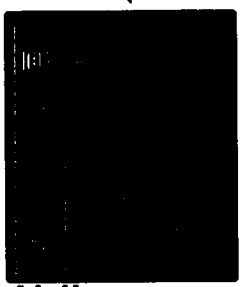
Controllers

LLWAS

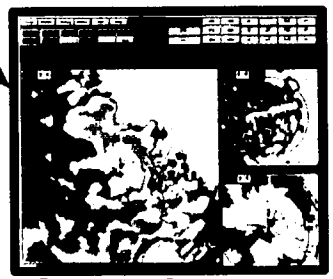


Lightning

Aircraft



Airlines
– Dispatch
– Ramp Tower

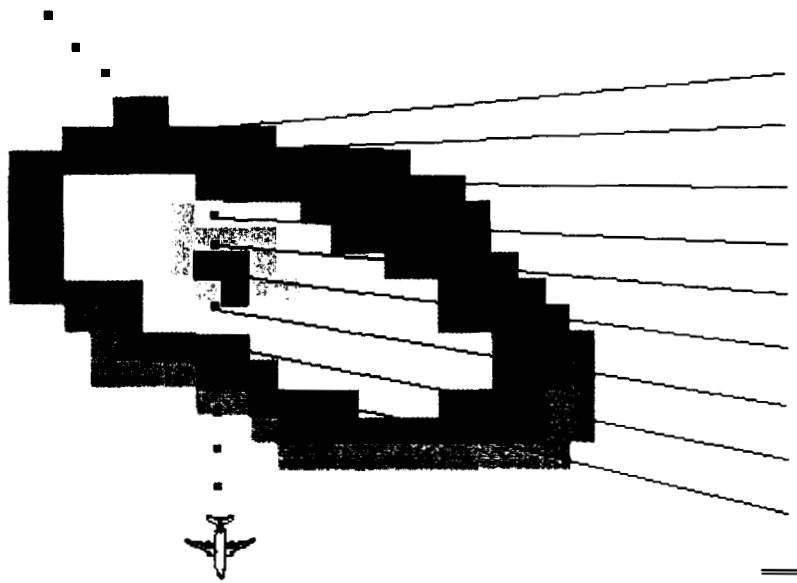


Supervisors
Traffic Managers
– TRACON
– ARTCC TMU
CWSU

Weather and Flight Variables

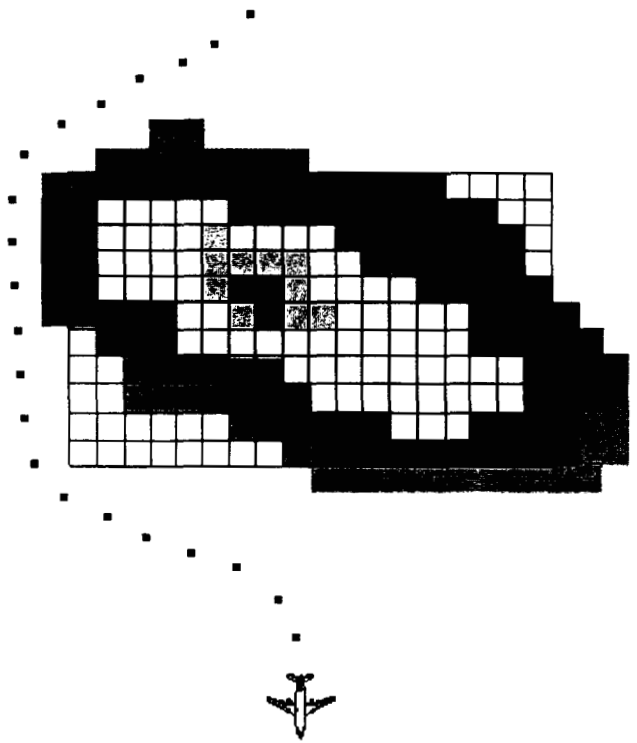
- ASR-9
  - Six-level precipitation
  - Weather coverage
- TDWR & NEXRAD
  - Reflectivity
    - Vert. integrated liquid H_2O
    - Max reflectivity
    - Altitude of max reflectivity
    - Center of mass
    - Echo top, bottom, thickness
  - Hail
  - Microburst
  - Gust front
- National Lightning Detection Network
  - Cloud-to-ground flashrate
- Flight Data
  - Flight id
  - Aircraft type
  - Arrival fix
  - Arrival runway
  - Range from airport
  - Pathlength inside TRACON
  - Leader / Follower
  - Altitude
  - Arrival time
  - Delay

Storm Cell Penetrations



dz	maxval	precip	top	bot	center	mb
33.5	36.8	2	7.3	4.2	5.9	0.0
38.9	42.1	2	9.8	4.0	5.7	0.0
41.0	48.5	2	10.4	3.8	5.2	0.0
44.8	49.9	3	(10.7)	2.7	4.7	0.0
49.8	(56.9)	4	10.6	1.8	(4.8)	0.0
(53.1)	54.3	(5)	10.1	(1.0)	3.8	0.0
49.2	52.7	4	9.9	1.2	3.7	(40.0)
48.5	49.2	2	9.5	2.4	4.3	0.0
42.8	46.1	2	9.2	3.6	5.4	0.0
53.1	56.9	5	10.7	1.0	4.8	40.0

Storm Cell Deviations



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:	:	:	:	:	:	:
53.1	56.9	5	10.7	1.0	4.8	40.0

Dataset

DATE	TIME (UT)	HOURS	# DEV	# PEN
4/24/97	1530 - 1900	3.5	53	104
5/9/97	0130 - 0800	6.5	12	72
5/19/97	2030 - 0830	12	219	437
5/30/97	1845 - 0200	7.3	91	94
6/10/97	0030 - 0730	7	17	46
6/16/97	2130 - 0830	11	25	143
6/22/97	1845 - 2245	4	65	58
6/23/97	1600 - 2200	6	100	103
7/5/97	1300 - 1830	5.5	60	253
TOTAL		62.8	642	1310

Sensitivity to Flight Factors

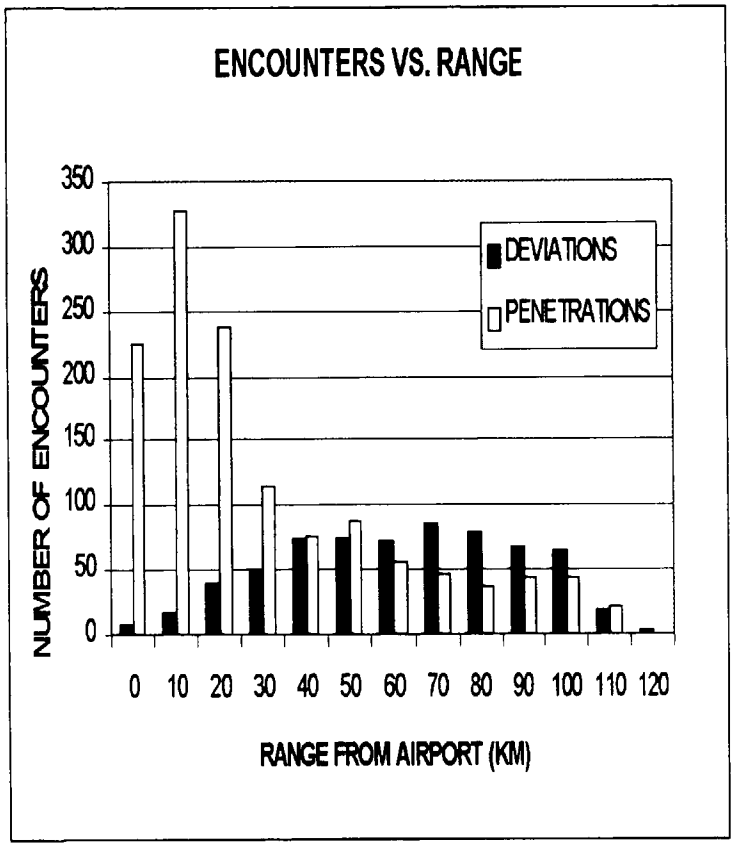
Test	Categories		Significance
Longer-Than-Normal Flight Time	Normal Time	Delayed 15+ minutes*	0.01
Following a Leader	Leader	Follower*	0.01
Day vs. Night	Day	Night*	0.01
Airline by Airline	AAL, EGF, SWA, DAL, ASE		No Differences

* More Likely to Penetrate Level 3+ Weather

Predictability of Behavior

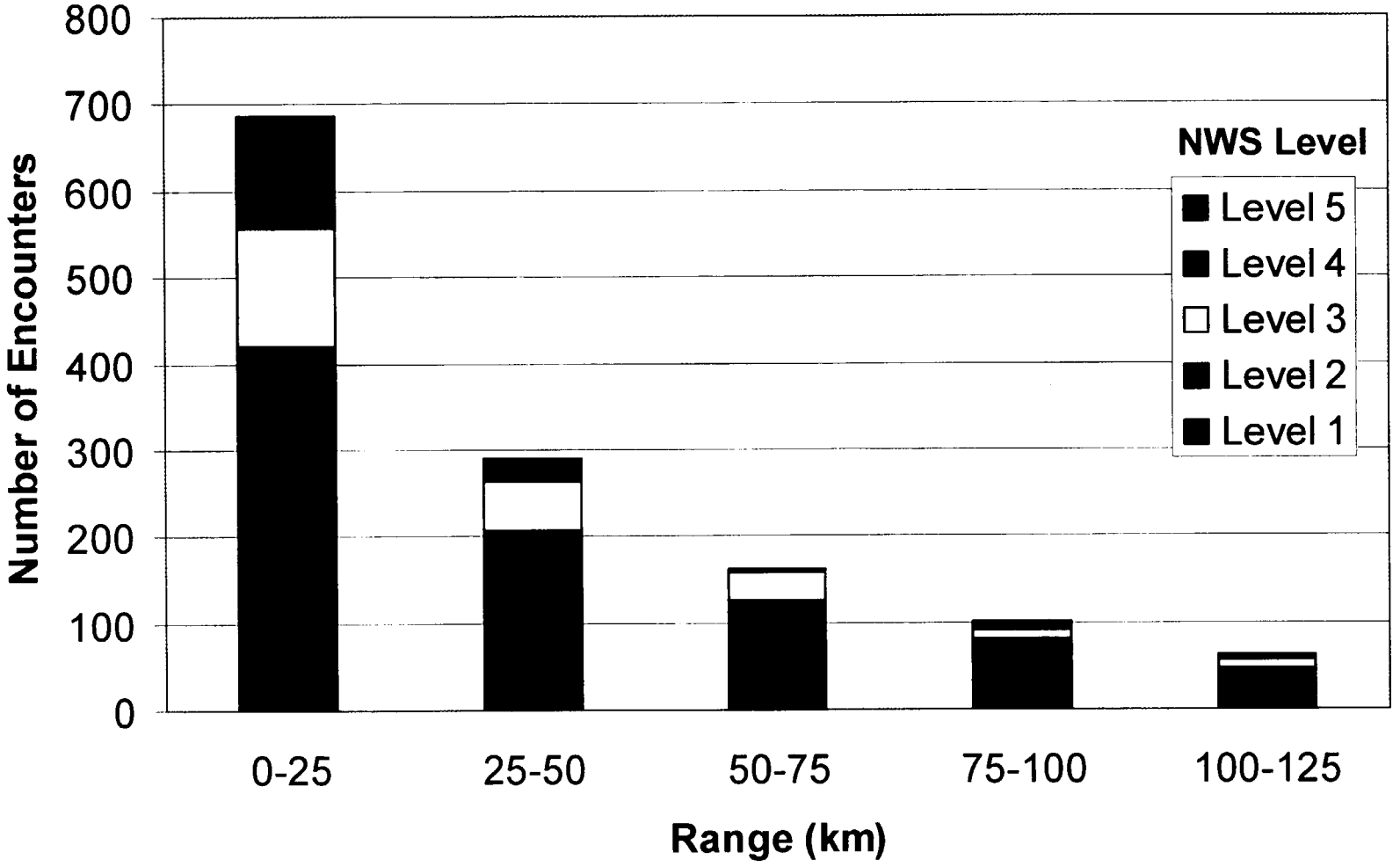
- Far from the airport (> 25 km) three types of variables were correlated with penetration / deviation behavior:
  - Storm intensity
  - Weather coverage
  - Range from the airport
- Our statistical classifiers predicted pilot behavior correctly between 70 and 85 percent of the time.
- Near the airport, however, the pilots almost never deviated.

Range From Airport



- Nearly all encounters near airport were penetrations
- Aircraft penetrated NWS levels 3, 4, and 5 near the airport.
- Behavior near the airport was not correlated with storm intensity variables

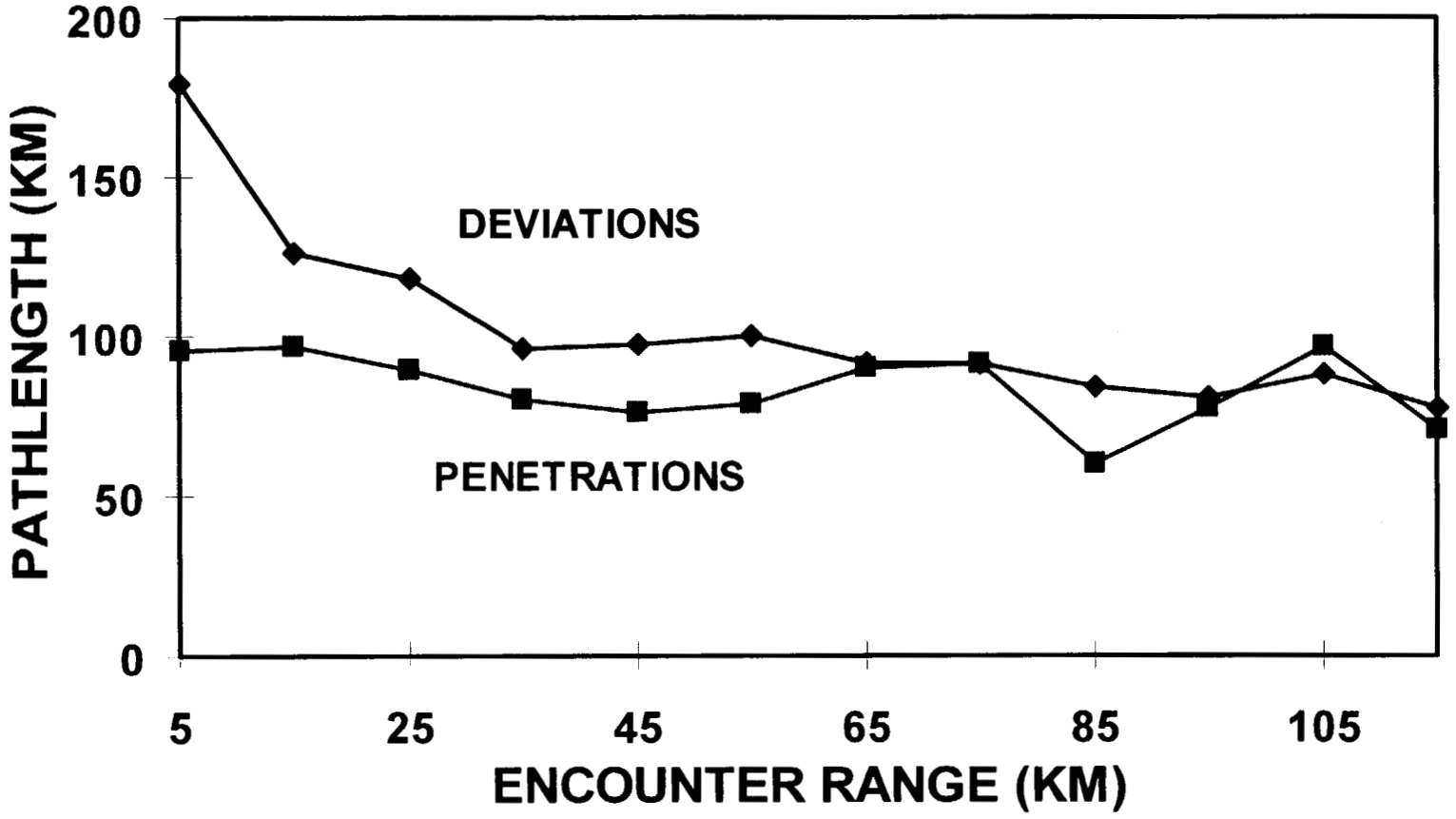
Penetrations By Intensity and Range



Potential Factors Near the Airport

- Less lateral leeway
- High cockpit workload
- Pilots may rely on storm appearance as well as verbal reports from pilots and controllers rather than radar information

Deviation Penalty Near The Airport



Summary

- Far from the airport, penetration & deviation behavior seems to be predictable given knowledge of storm intensity and weather coverage.
- Near the airport, pilots in this study consistently penetrated intense precipitation -- sometimes leading to missed approaches and aborted approaches.
- Pilots were more likely to penetrate intense precipitation when:
  - following another aircraft
  - delayed in the current leg of flight
  - flying after dark
- There were no statistically discernable differences in the behavior of pilots from different airlines in this study.
- Full report available at:

http://WWW.LL.MIT.EDU/AviationWeather/reports.html