AEROTECH RESEARCH (U.S.A.), INC.

AeroTech's Turbulence Awareness & Avoidance Technologies

Dr. Paul A. Robinson

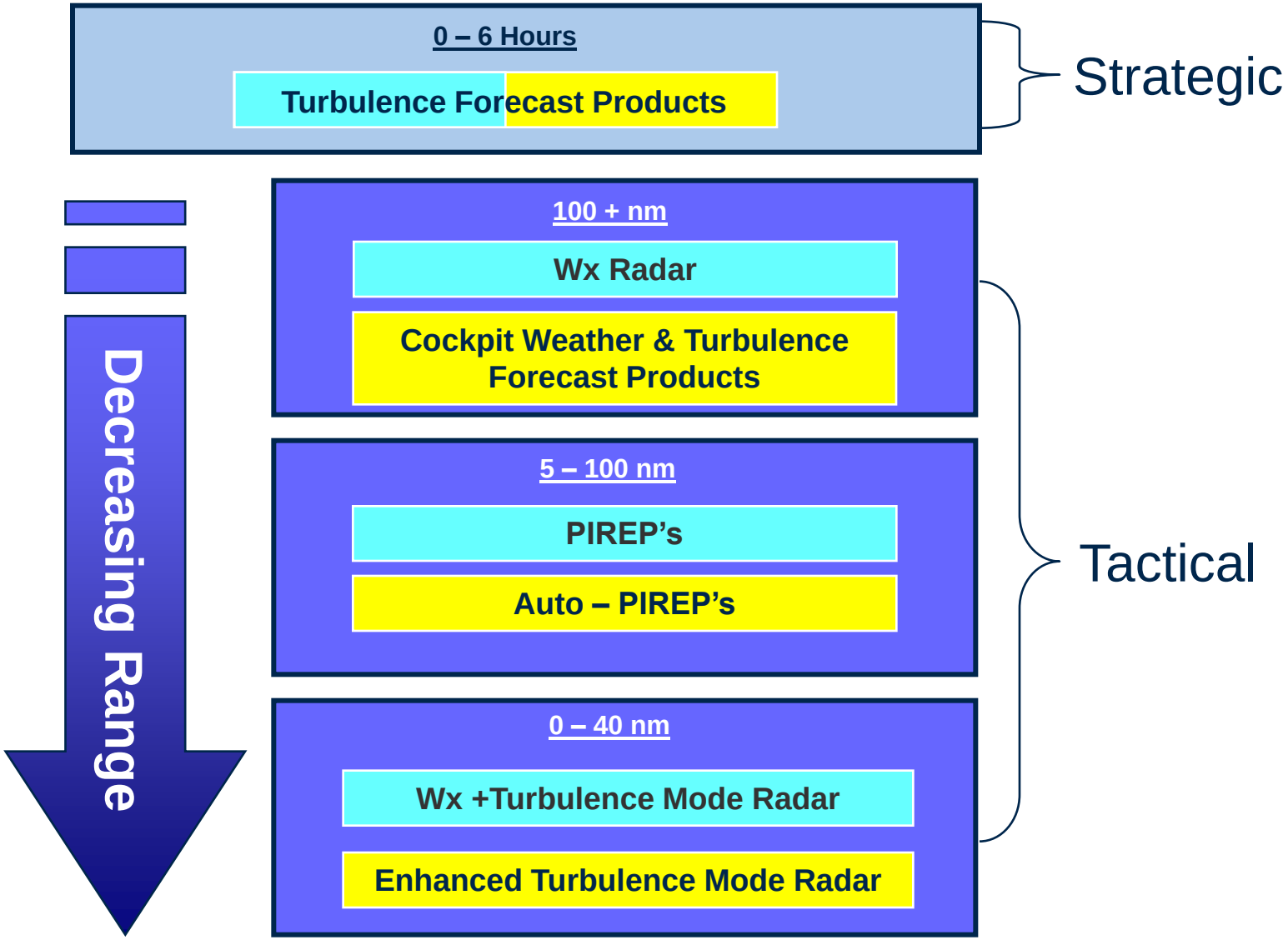
Presentation To Association of Asia Pacific Airlines

March 28, 2007

Presentation Outline

1. Overall turbulence product concept.
2. Turbulence Auto-Pirep System (TAPS) & its uses.
3. Enhanced Turbulence Mode Radar (E-Turb).
4. Cockpit displays.
5. Other applications.

Hierarchy of Turbulence Products



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Turbulence Auto-PIREP System (TAPS)
In-Service Evaluation

A NASA Funded Program

The Turbulence Encounter Reporting Problem

Current turbulence encounters are <u>GROSSLY</u> under reported.

Those PIREPS that <u>are</u> made are:

- **Late**
- **Subjective**
- **Not distributed to all users**

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TAPS Development Goals

To develop a system to support decision-makers with objective and timely information on turbulence hazards.

Initially Identified Users

- Pilots
- Dispatchers
- Maintenance

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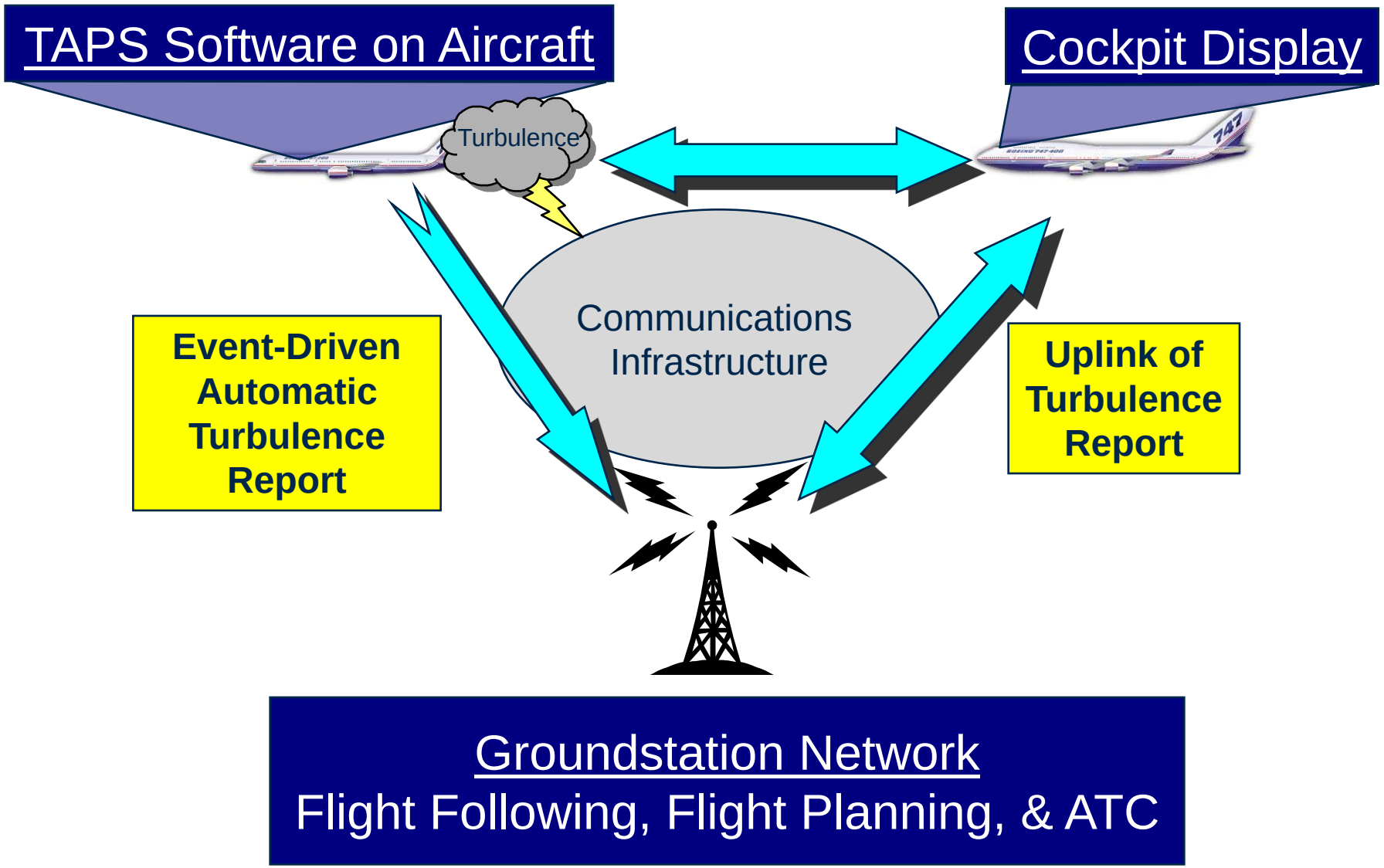
TAPS Architecture



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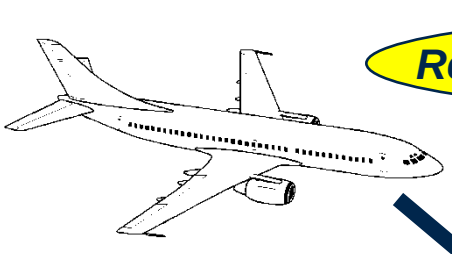
Current TAPS Groundstation Implementation

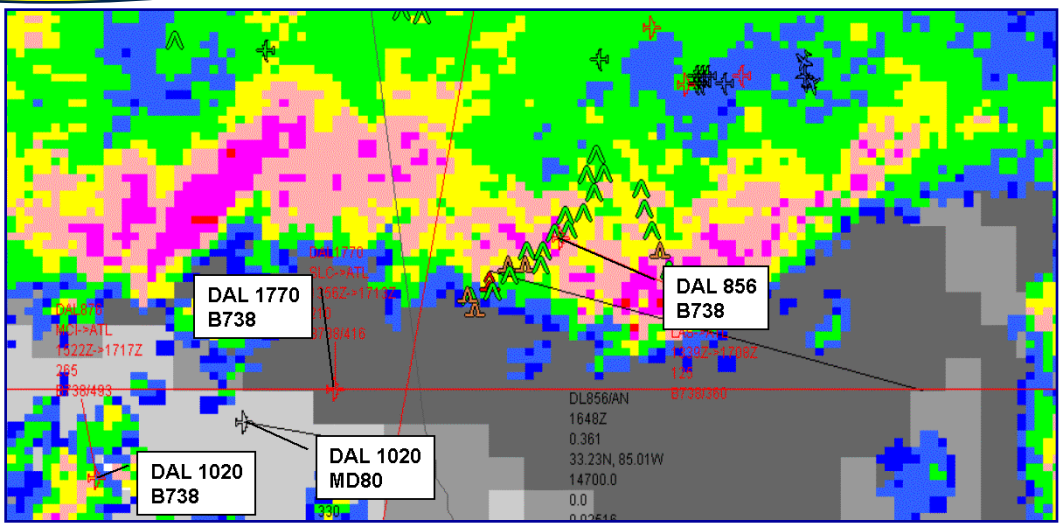


Reporting algorithms implemented on aircraft

Turbulence reports sent to ground

Reports received and relayed to groundstation via ARINC network

Delta Air Lines' B737-800, B767-300,-400 (123 aircraft) + other fleets



ARINC's WebASD℠ real-time display

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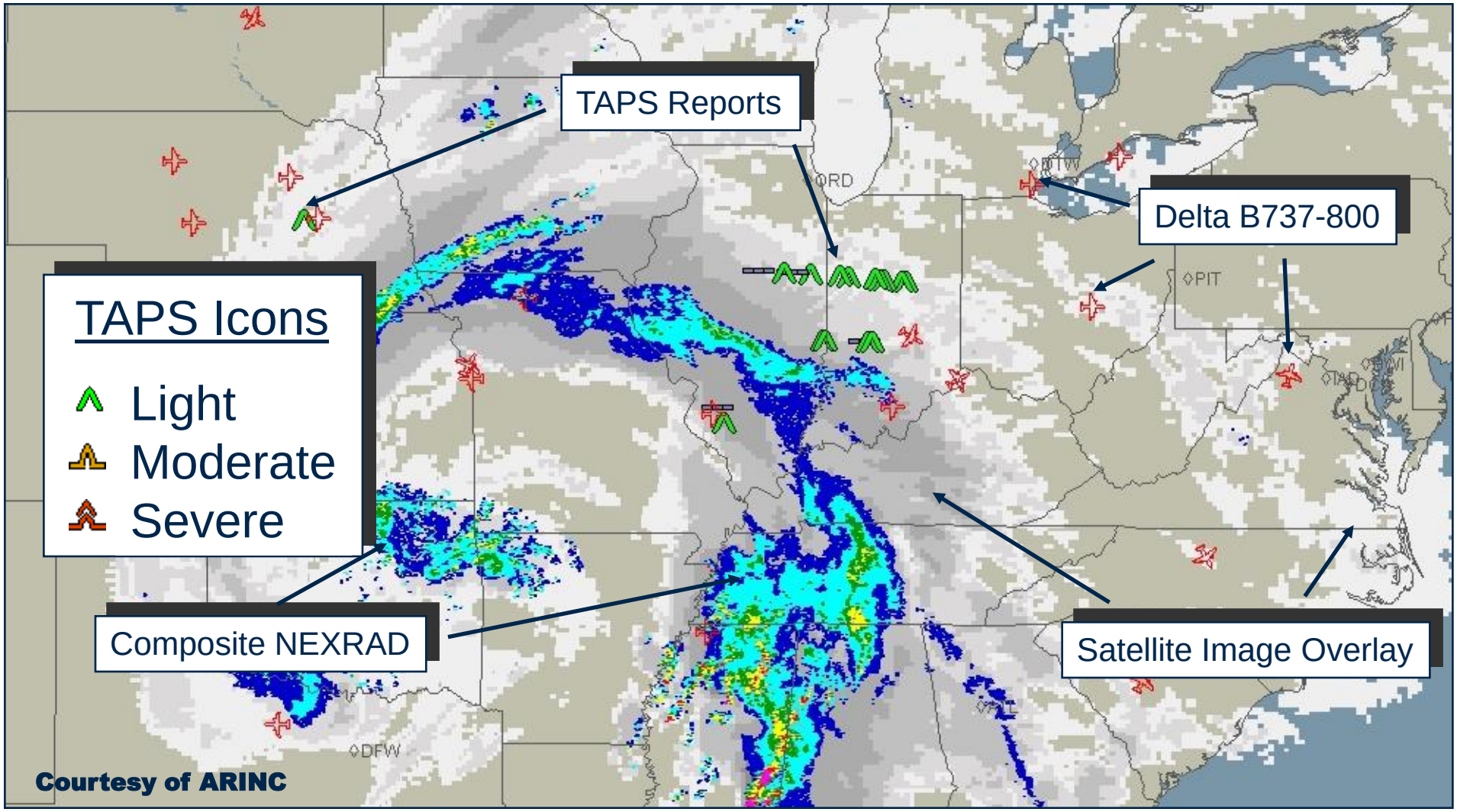
Dispatchers' TAPS WebASD℠ Display



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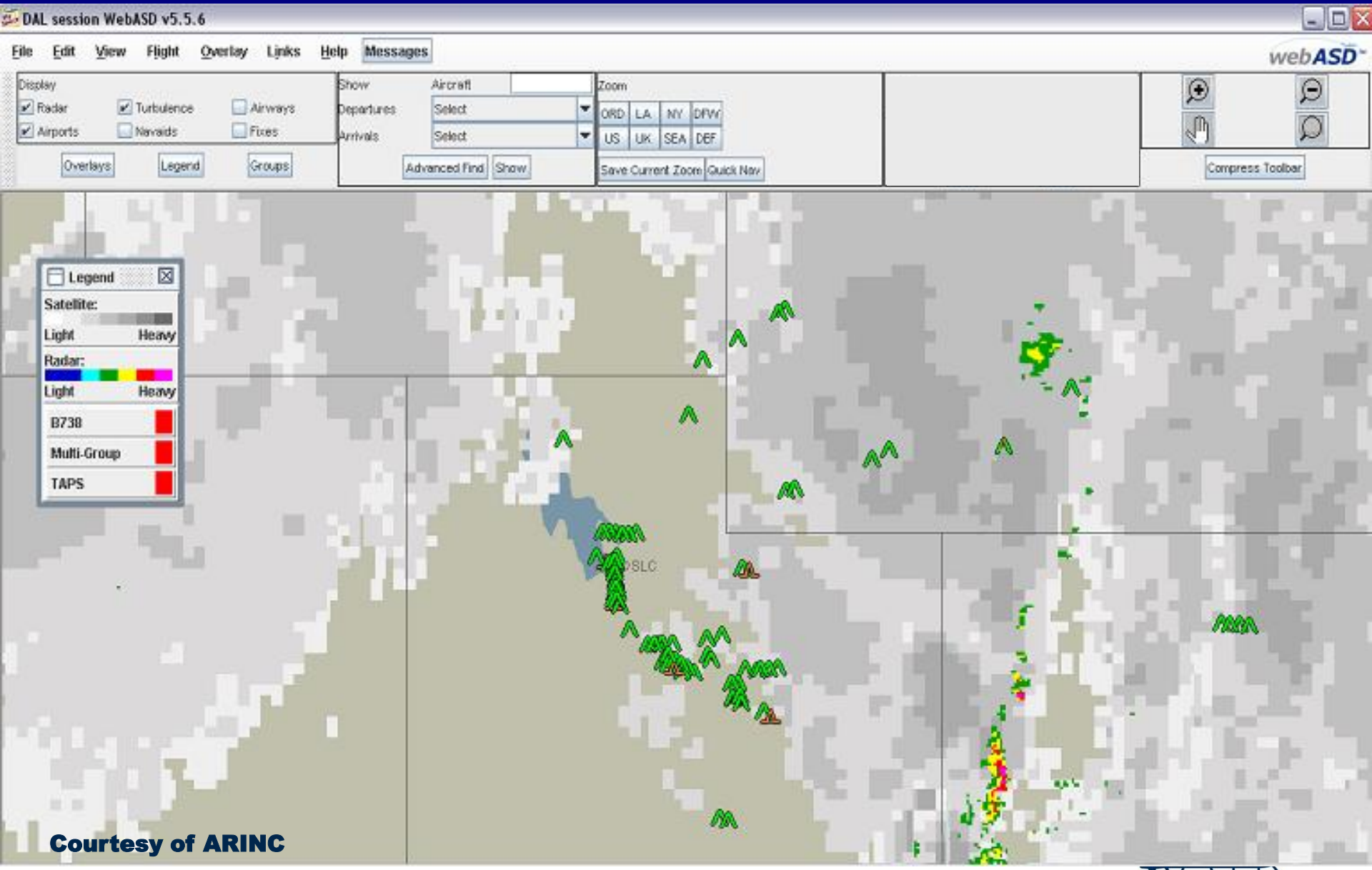
Dispatchers' TAPS WebASD℠ Display



Courtesy of ARINC

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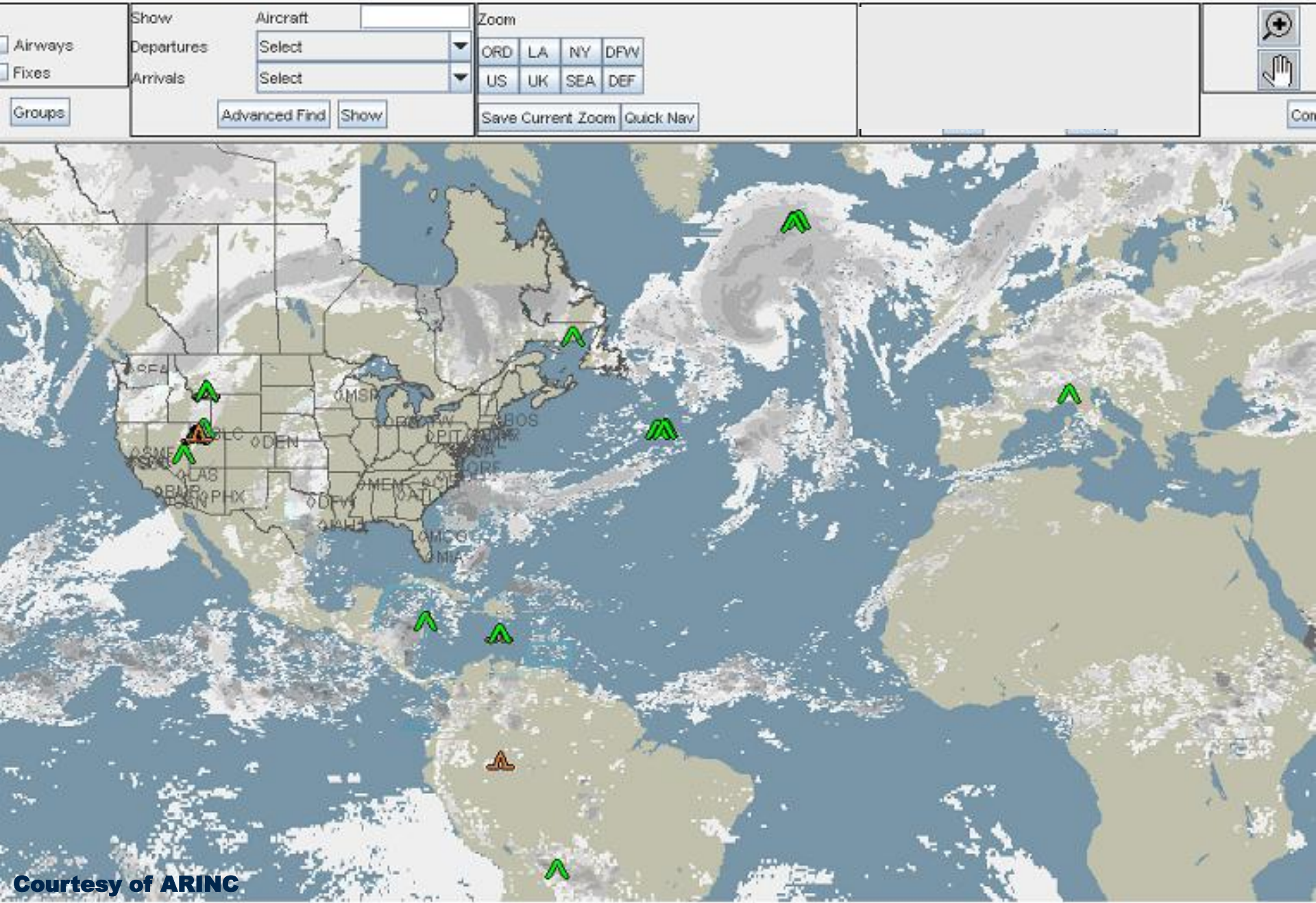
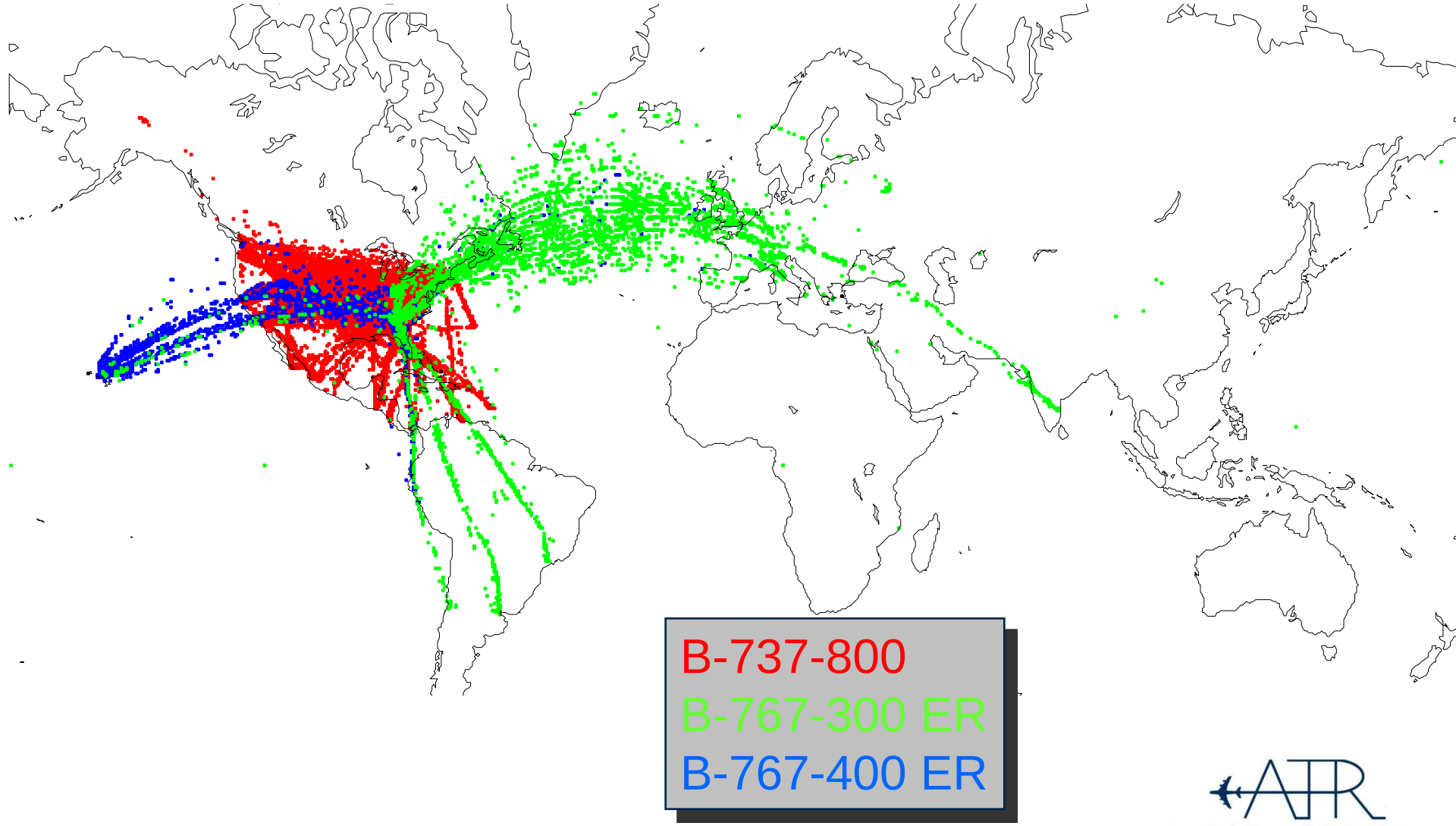
Dispatchers' TAPS WebASD℠ Display



Geographic Distribution of TAPS reports



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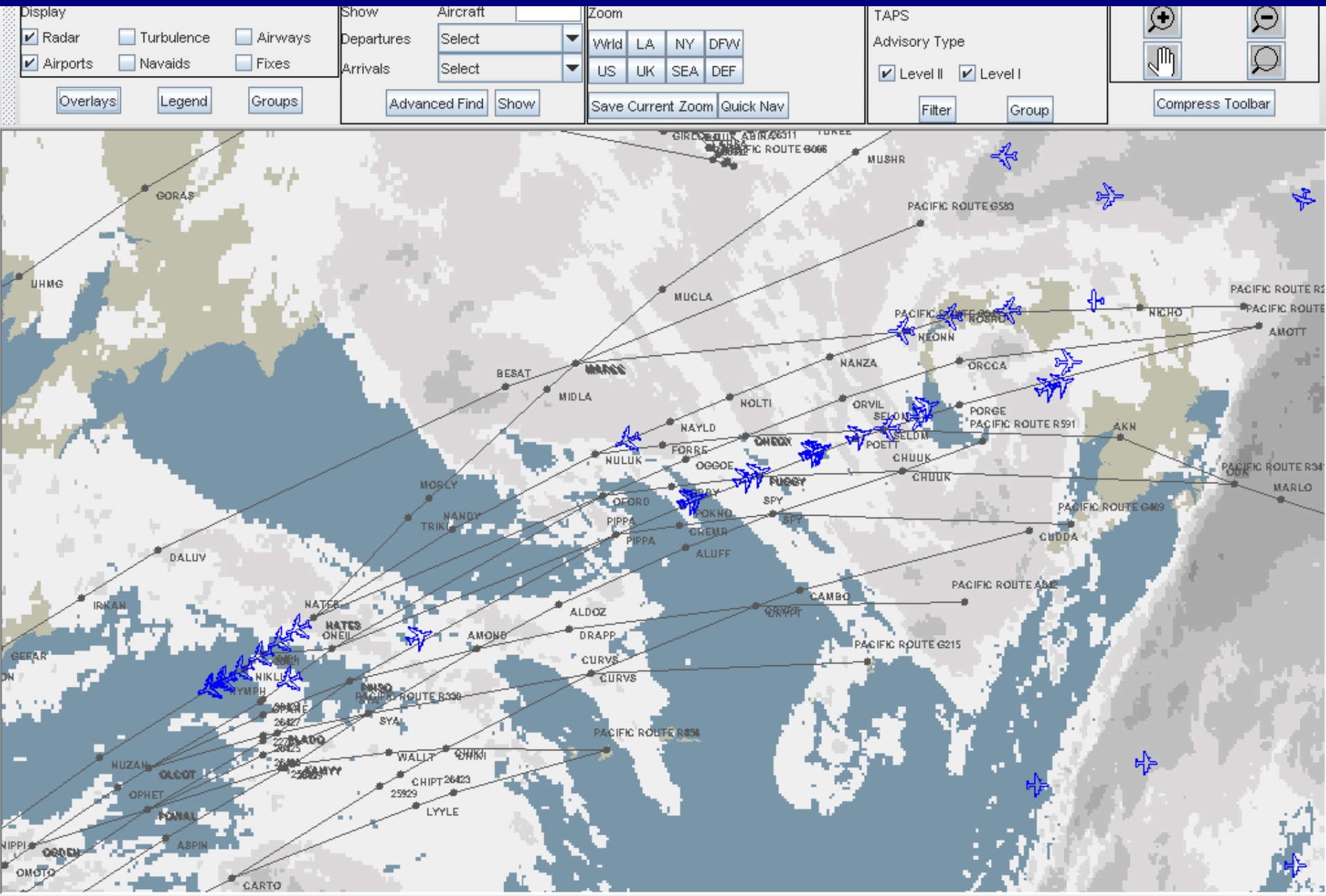
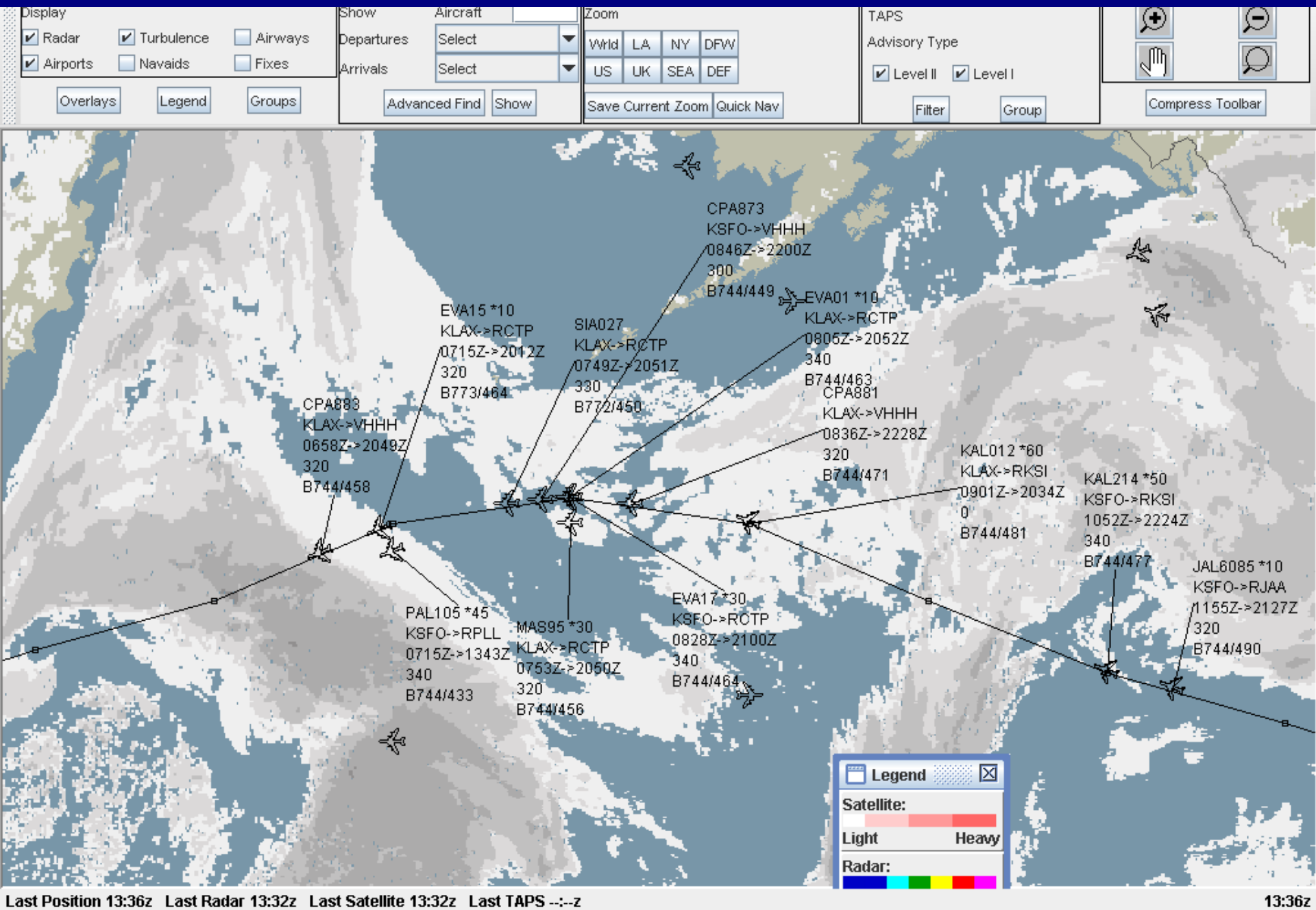
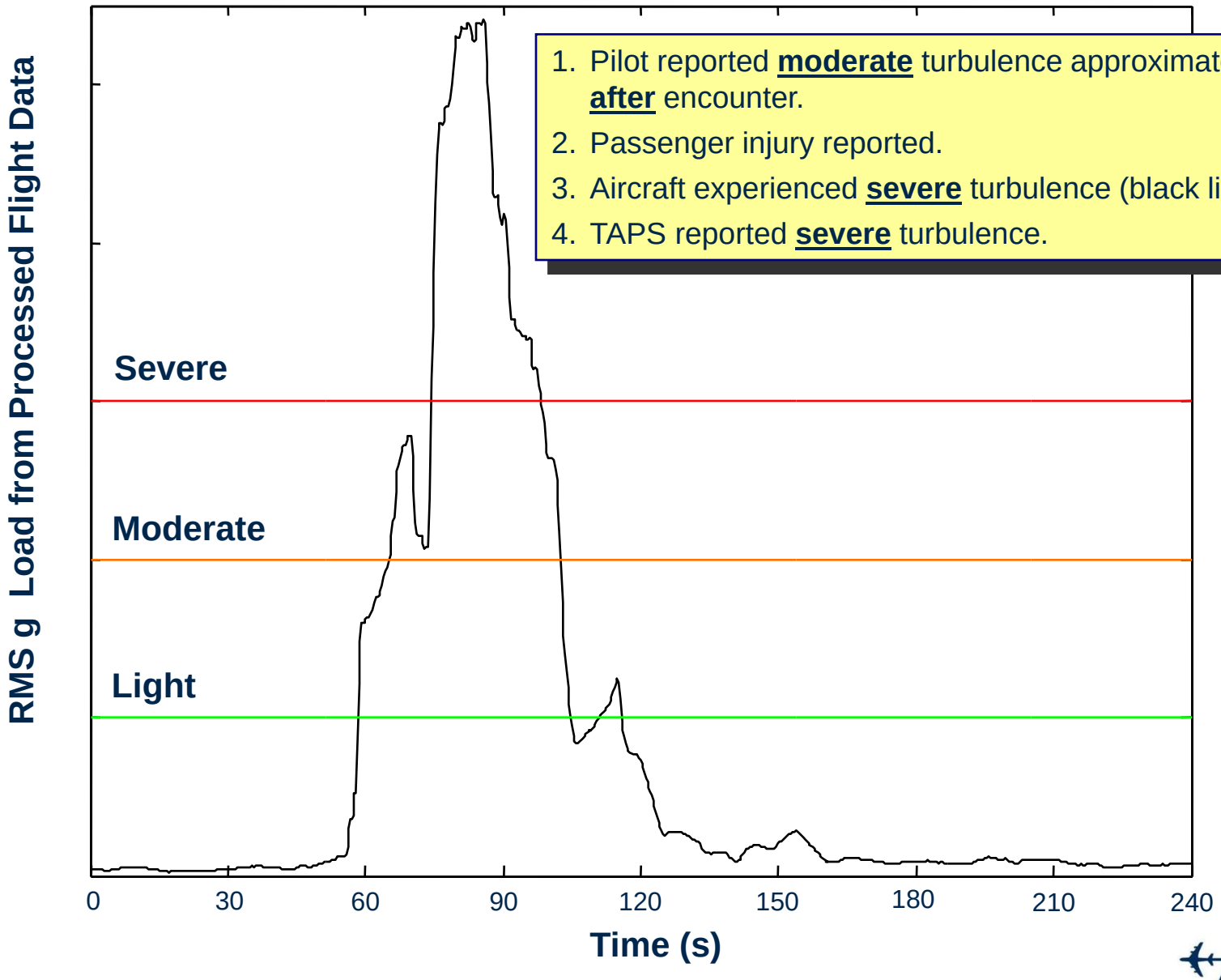
Dispatchers' TAPS WebASD℠ Display



Dispatchers' TAPS WebASD℠ Display



PIREPs vs. TAPS: Underestimation



1. Pilot reported **moderate** turbulence approximately **1 hour after** encounter.
2. Passenger injury reported.
3. Aircraft experienced **severe** turbulence (black line below).
4. TAPS reported **severe** turbulence.

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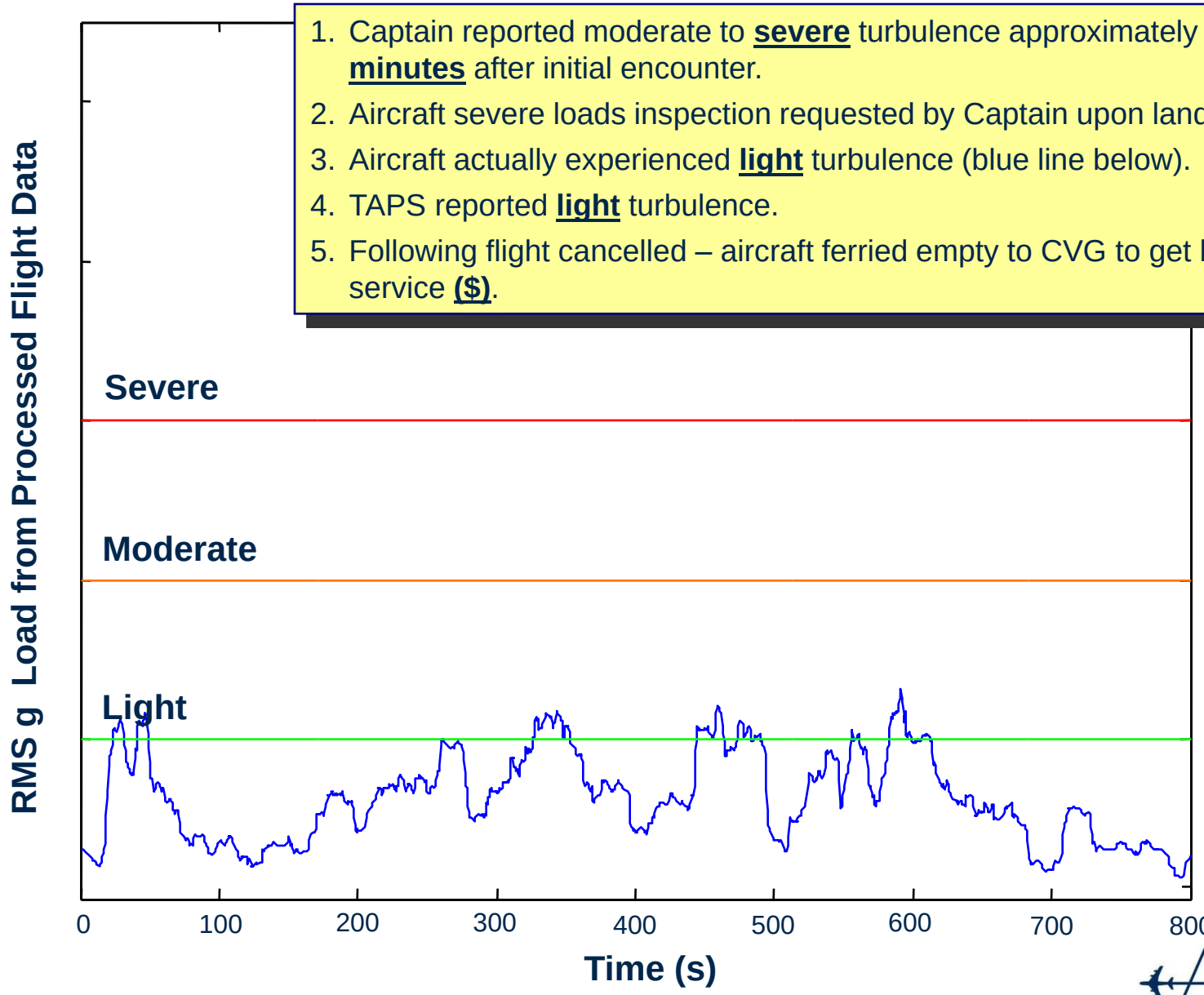
PIREPs vs. TAPS: Overestimation

1. Captain reported moderate to **severe** turbulence approximately **5-10 minutes** after initial encounter.
2. Aircraft severe loads inspection requested by Captain upon landing **($)**.
3. Aircraft actually experienced **light** turbulence (blue line below).
4. TAPS reported **light** turbulence.
5. Following flight cancelled – aircraft ferried empty to CVG to get back into service **($)**.



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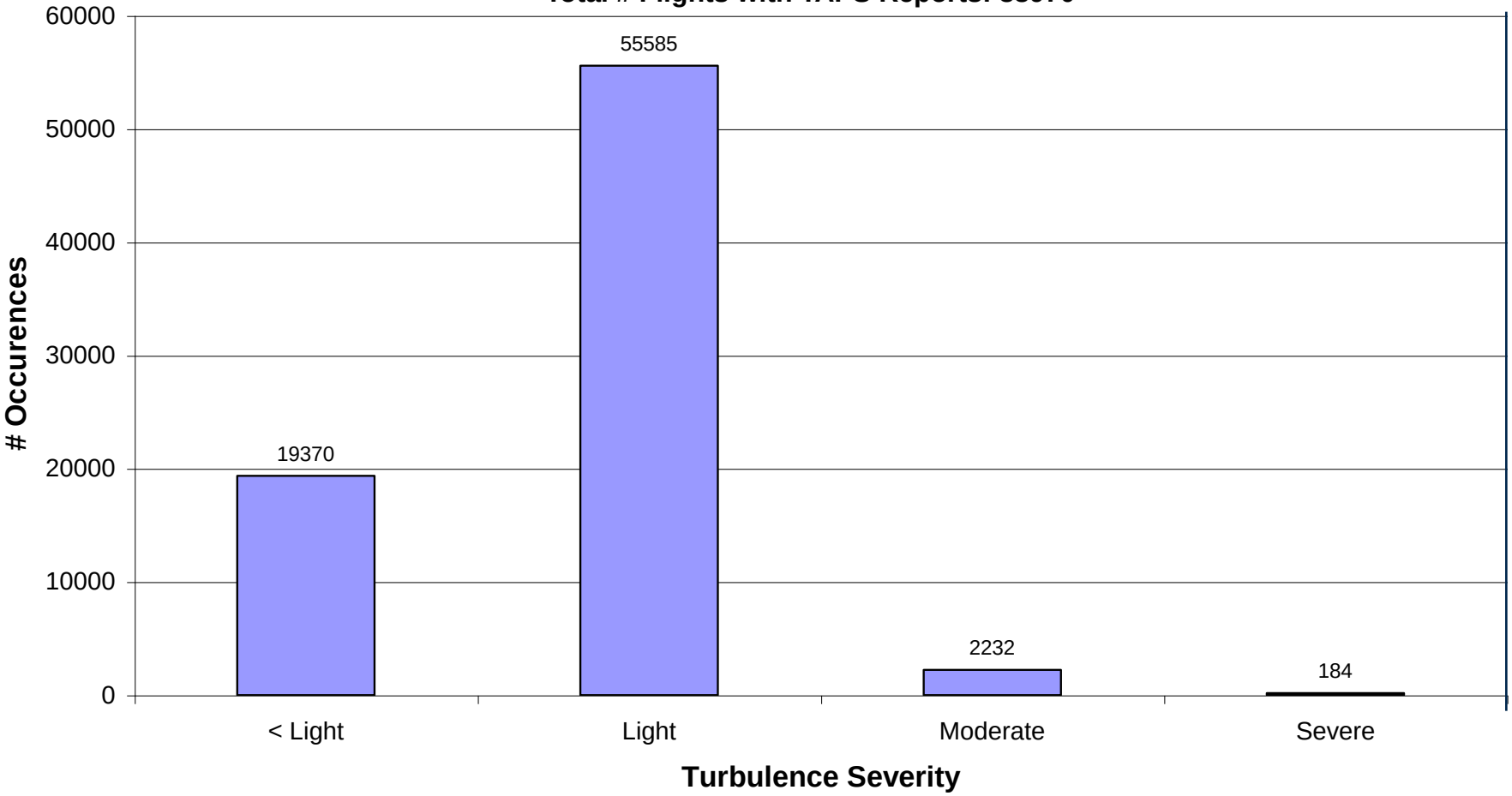
TAPS Report Analysis - Summary

Period Covered: June 10, 2004 – August 16, 2006
Total # Reports: 77371
Total # Flights with TAPS Reports: 33970



Turbulence Under-Reporting & Distribution Issues Resolved

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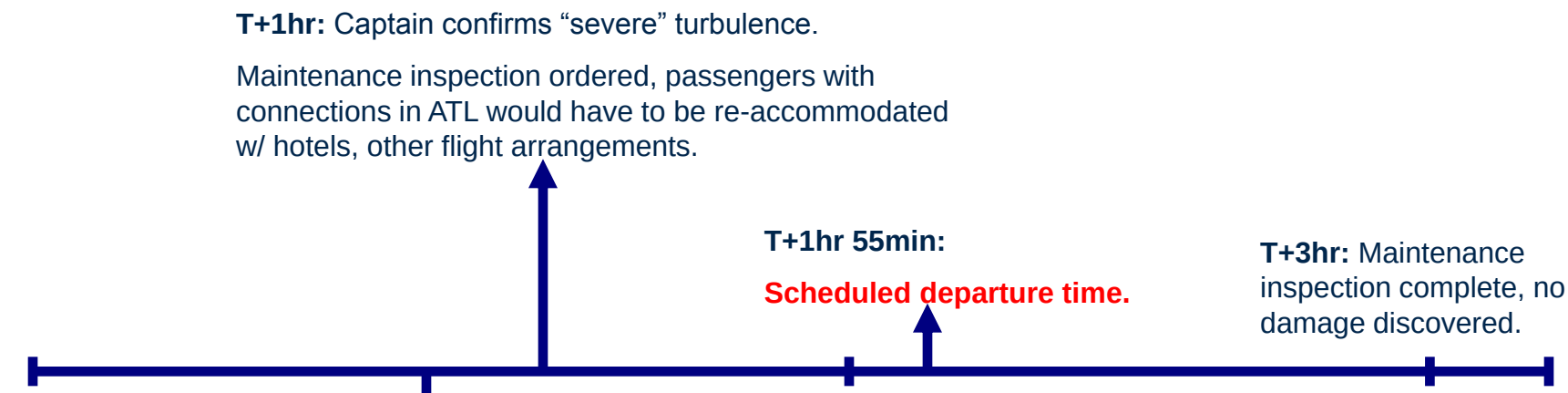
Turbulence Impact on Operations: Today

Actual event: Delta B-737-800 over north Florida encounters "severe" turbulence.



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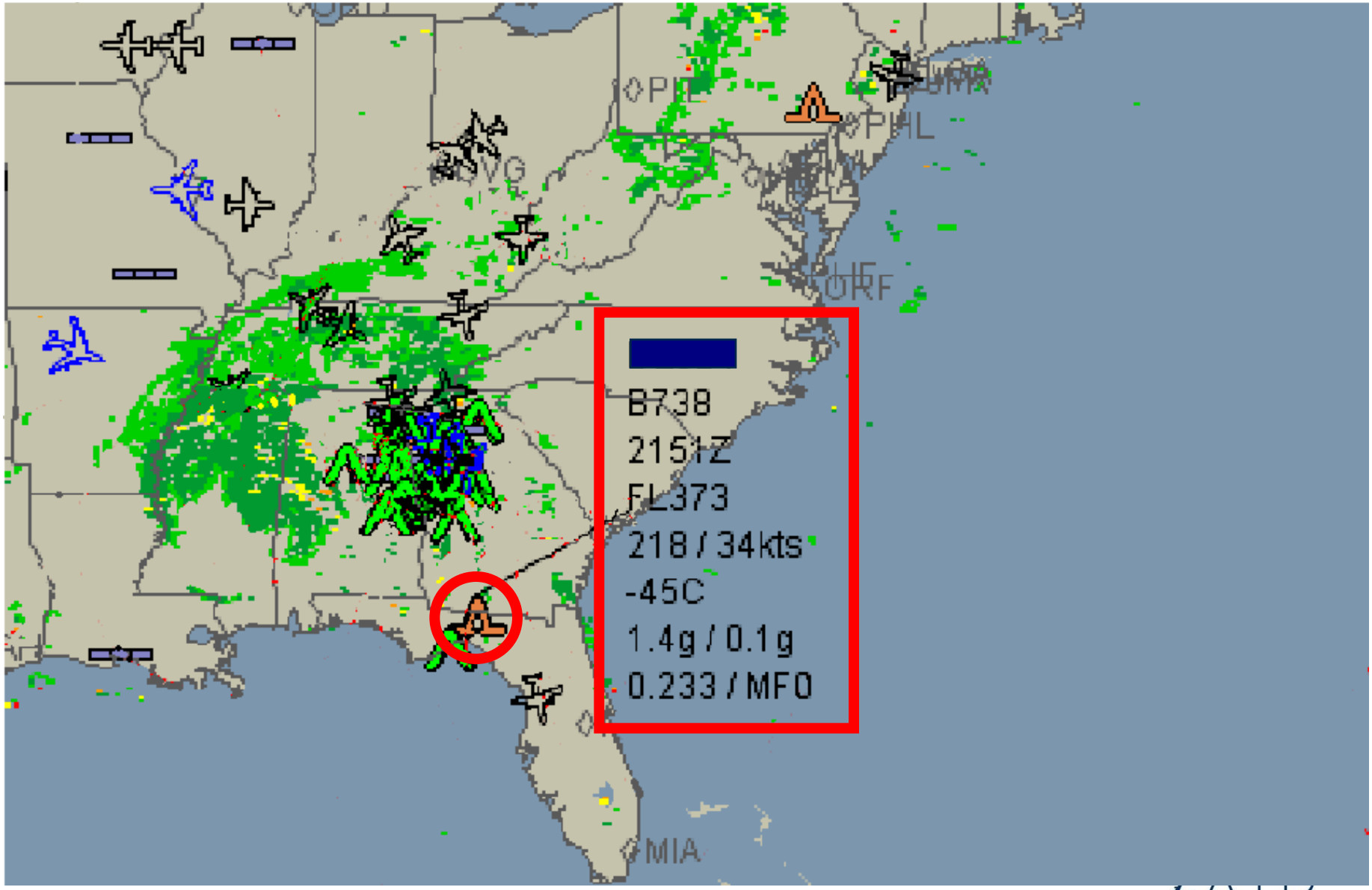
Dispatcher's View of the Event



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Turbulence Impact on Operations: Today +

T+1hr: Captain confirms “severe” turbulence.

Maintenance inspection ordered, passengers with connections in ATL would have to be re-accommodated w/ hotels, other flight arrangements.

Timeline Relying Only on Conventional Pilot Report

T=0:

Event occurs.

T+55min:

Captain notifies dispatcher of event. States event occurred at T=+30.

T+1hr 55min:

Scheduled departure time.

T=1hr 45min:

Contract maintenance arrives ($$).

T+3hr: Maintenance inspection complete, no damage discovered.

T+3hr 22min: Following a departure delay of 1:27, return flight to ATL underway.

Timeline Relying on Real-Time Awareness from TAPS

T+5min: Dispatcher queries crew about any injuries or cabin damage – none apparent. Warns nearby aircraft of turbulence,.

T=0:

Event occurs, 2 reports displayed on WebASD, no need for inspection indicated.

T+1hr 55min:

Return flight to ATL dispatched **on schedule**, **$$** saved.

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Testimonials for TAPS

"At last, a metric that can give a truly objective, easily assimilated assessment of turbulence. Though more work remains for any operational deployment, so far only TAPS has delivered any meaningful results in this area…."

-Matt Fronzak, System Manager,
Delta Air Lines Chief Flight Control Technical Services

"…. TAPS gives us the real-time ability to accurately and objectively determine the need for airframe inspections …… we are very much looking forward to implementing TAPS in order to satisfy this need, reducing delays and cancellations due to unnecessary airframe inspections."

-Kent Horton,
Delta Air Lines Chief General Manager, Avionics Engineering

"TAPS ….. has been validated and is already beginning to have some measure of relevance in my operation."

-Brian Myszkowski,
Delta Air Lines Chief Meteorologist

"Together with TAPS, the enhanced turbulence radar effort marks one of the most exciting developments in the struggle to deliver better quality turbulence hazard information to flight crews and potentially other aviation user groups."

-Tom Staigle
Delta Air Lines Chief Technical Pilot

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TAPS In-Service Evaluation Summary

- Real-time turbulence event reporting system demonstrated in airline operations.
- TAPS reporting system working as designed - very favorable feedback from all users.
- Multiple applications of TAPS report data identified – safety & operational, for example:
  - Airframe inspections
  - Aircraft systems operation
  - Flight safety
  - Meteorological forecast verification
  - Air traffic management
- Over 220,000 flight hours expected by end of evaluation.
- TAPS technology recommended by FAA AC 120-88 (2005).

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TAPS Report Content

	Parameter	Research reports	Proprietary reports	Public reports
1	Time of report	✓	✓	✓
2	Lat/long	✓	✓	✓
3	Altitude	✓	✓	✓
4	Flight number	✓	✓	X
5	Aircraft type	✓	✓	?
6	Gross weight	✓	✓	X
7	Hazard metric value	✓	✓	✓
8	Scaling constant	✓	✓	✓
9	Maintenance flag	✓	✓	X
10	True airspeed	✓	?	X
11	Indicated airspeed	✓	?	X
12	Flap setting	✓	✓	X
13	Turbulence severity (L/M/S)	✓	✓	X
14	Vertical ± accelerations	✓	✓	X
15	Lateral ± accelerations	✓	✓	X
16	Wind speed & direction	✓	?	X
17	Outside air temperature	✓	?	X

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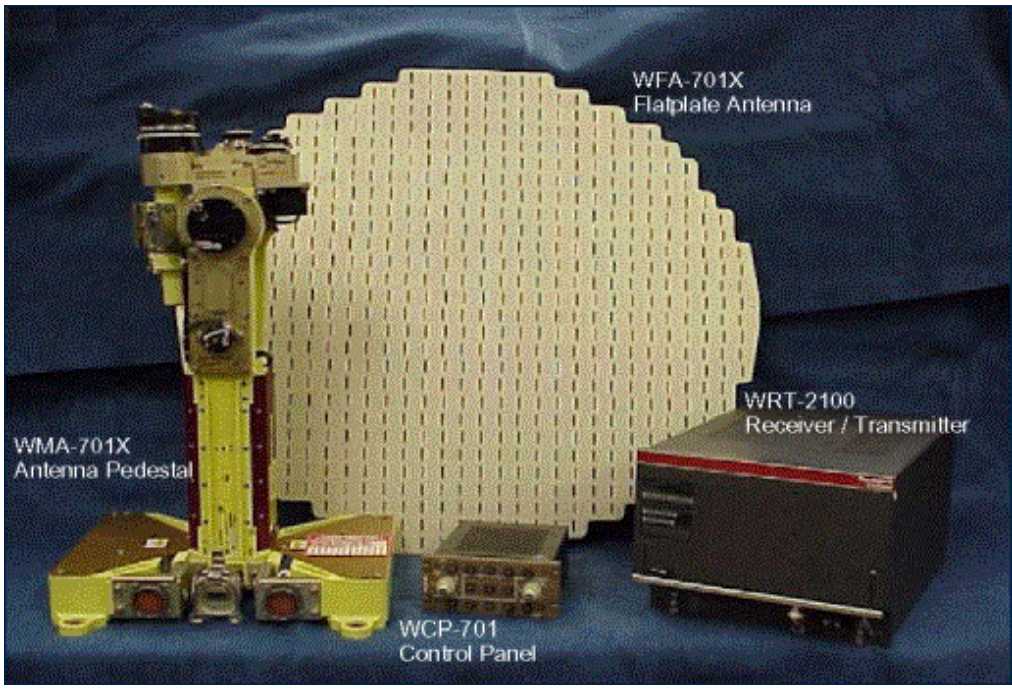
Enhanced Turbulence Mode Airborne Radar
"E-TURB" In Service Evaluation

A NASA Funded Program

E-Turb Radar System Components



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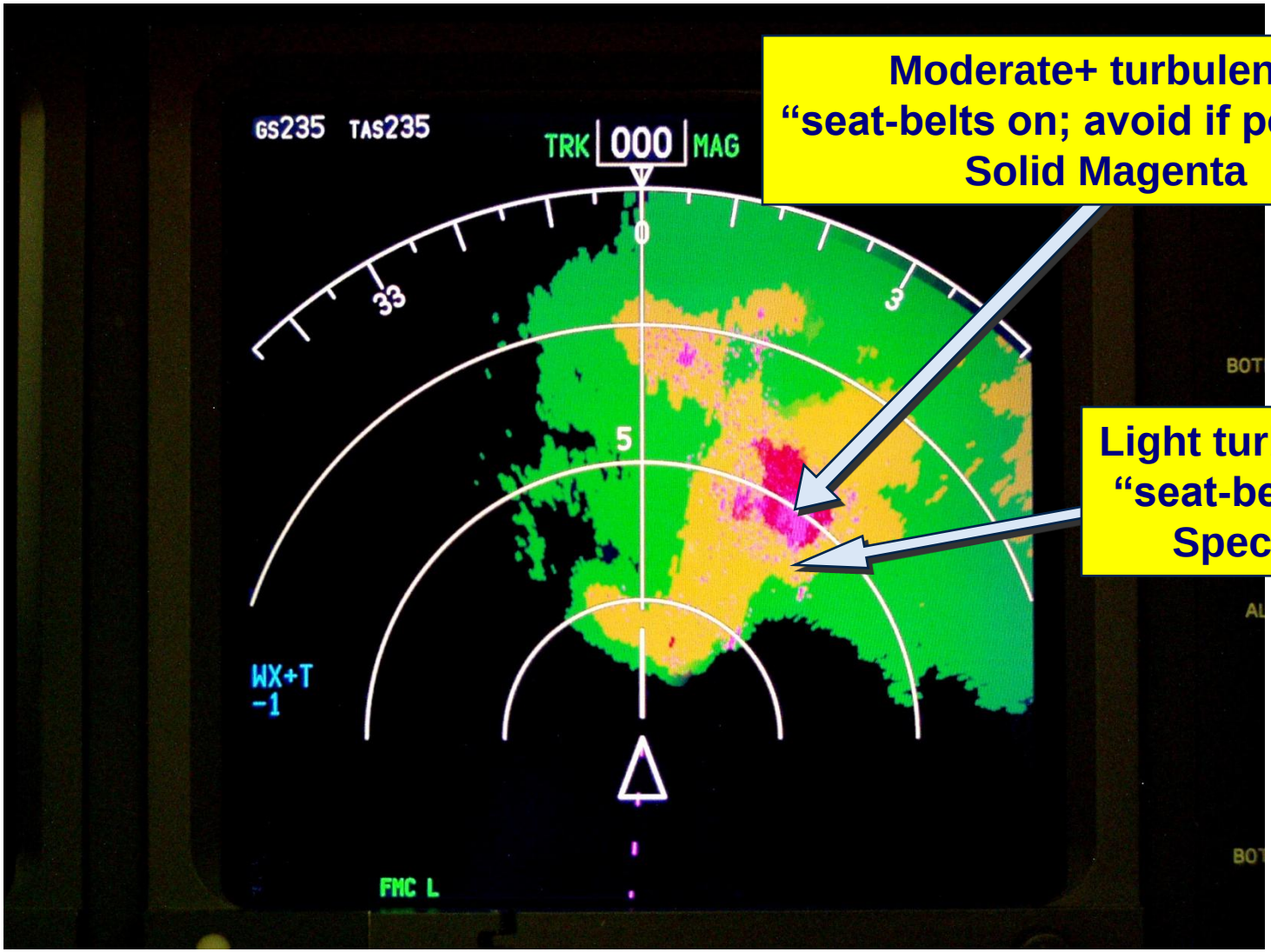
“E-Turb” Radar Display Presentation



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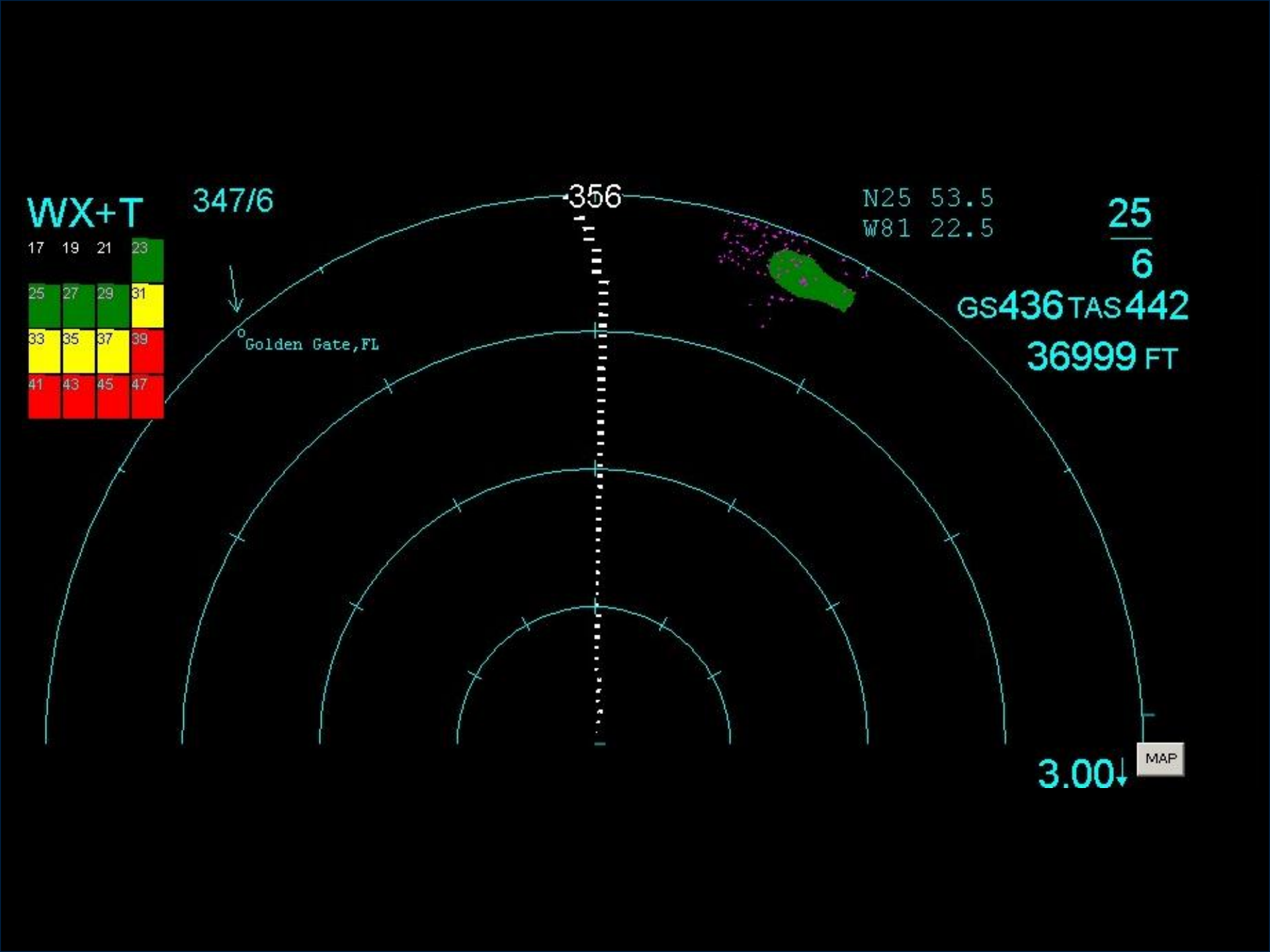
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25 27 29 31
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347/6
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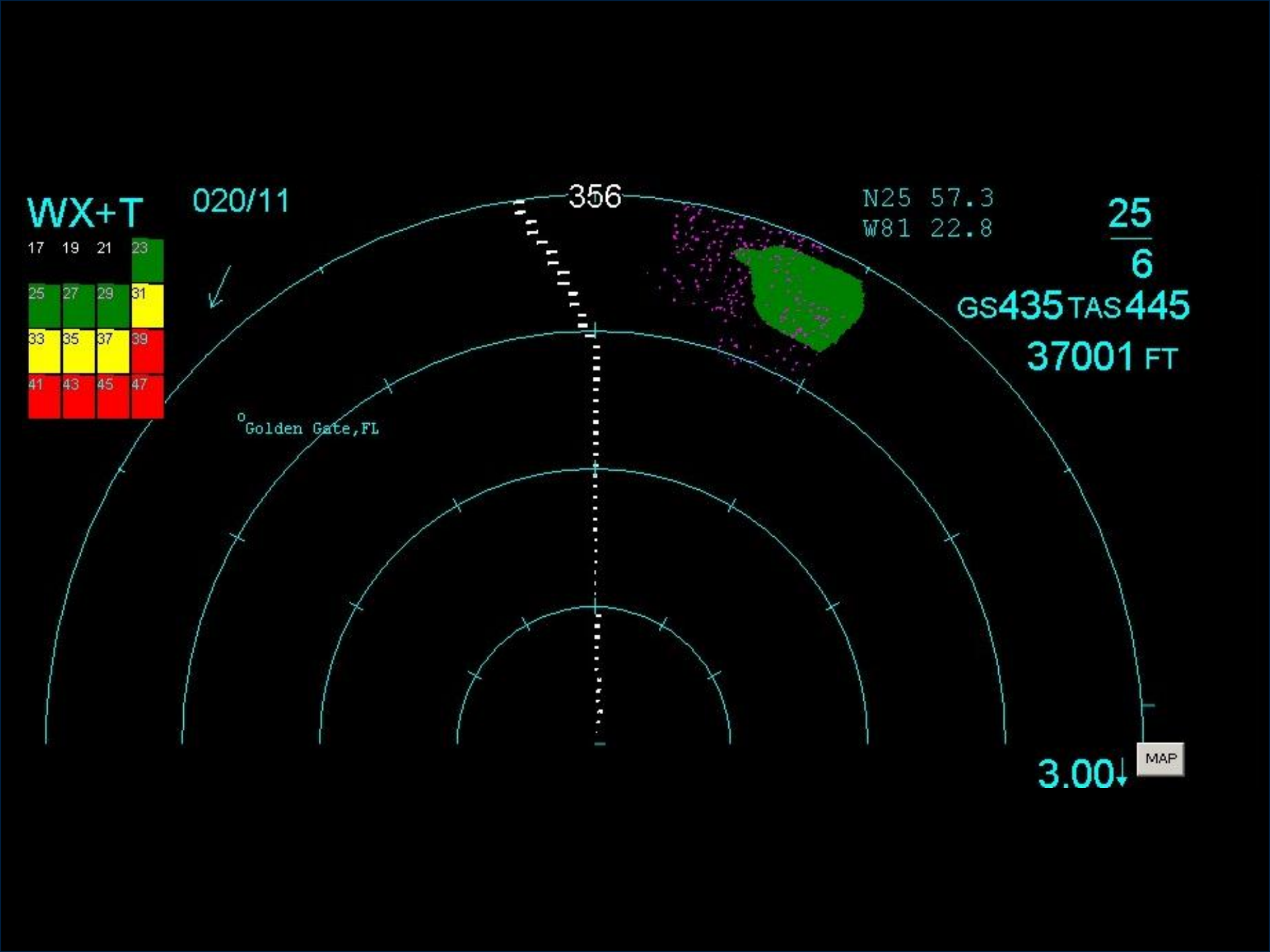
Golden Gate,FL
N25 53.5
W81 22.5
25
6
GS436 TAS442
36999 FT
3.00
MAP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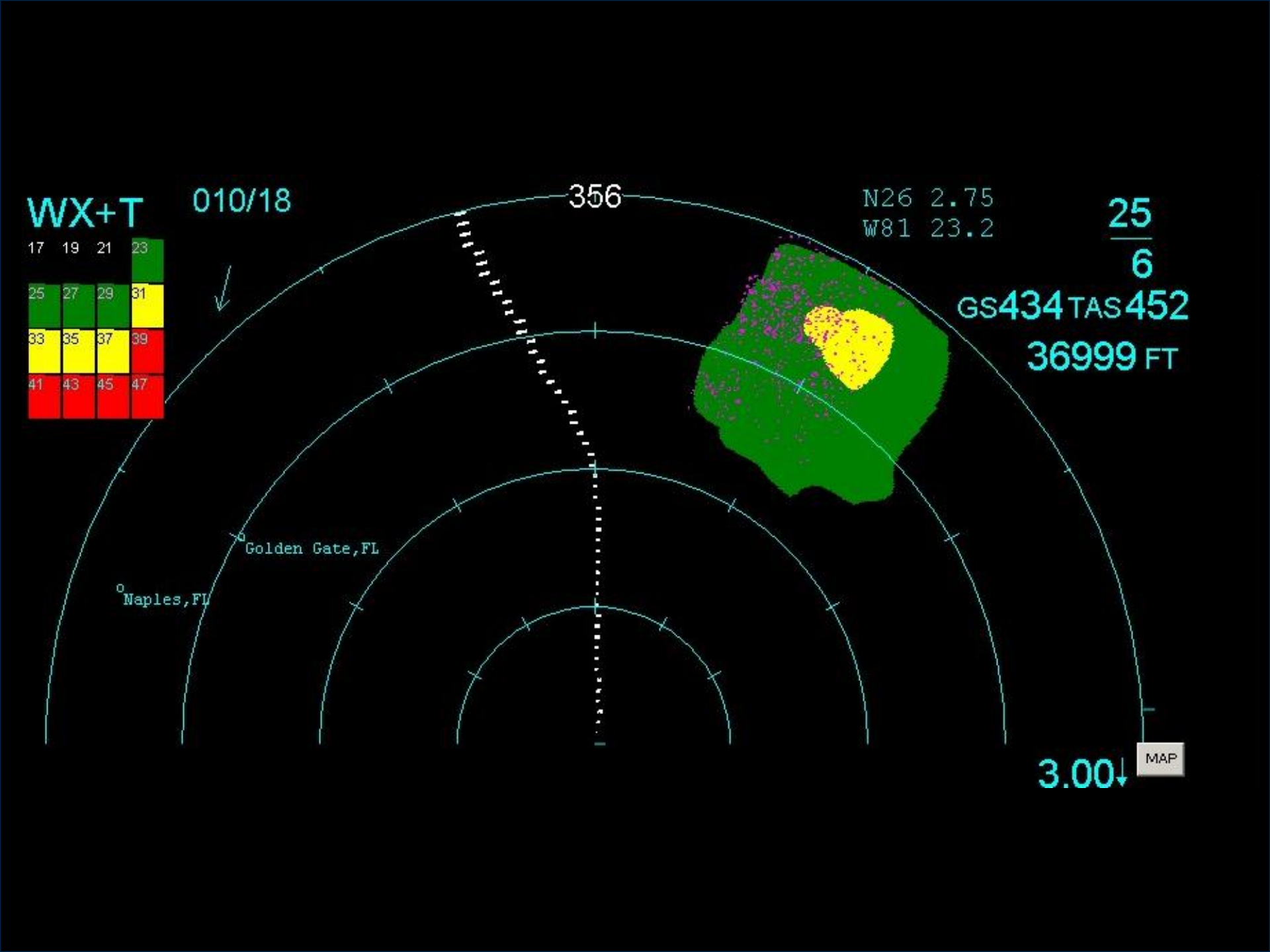
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Naples,FL
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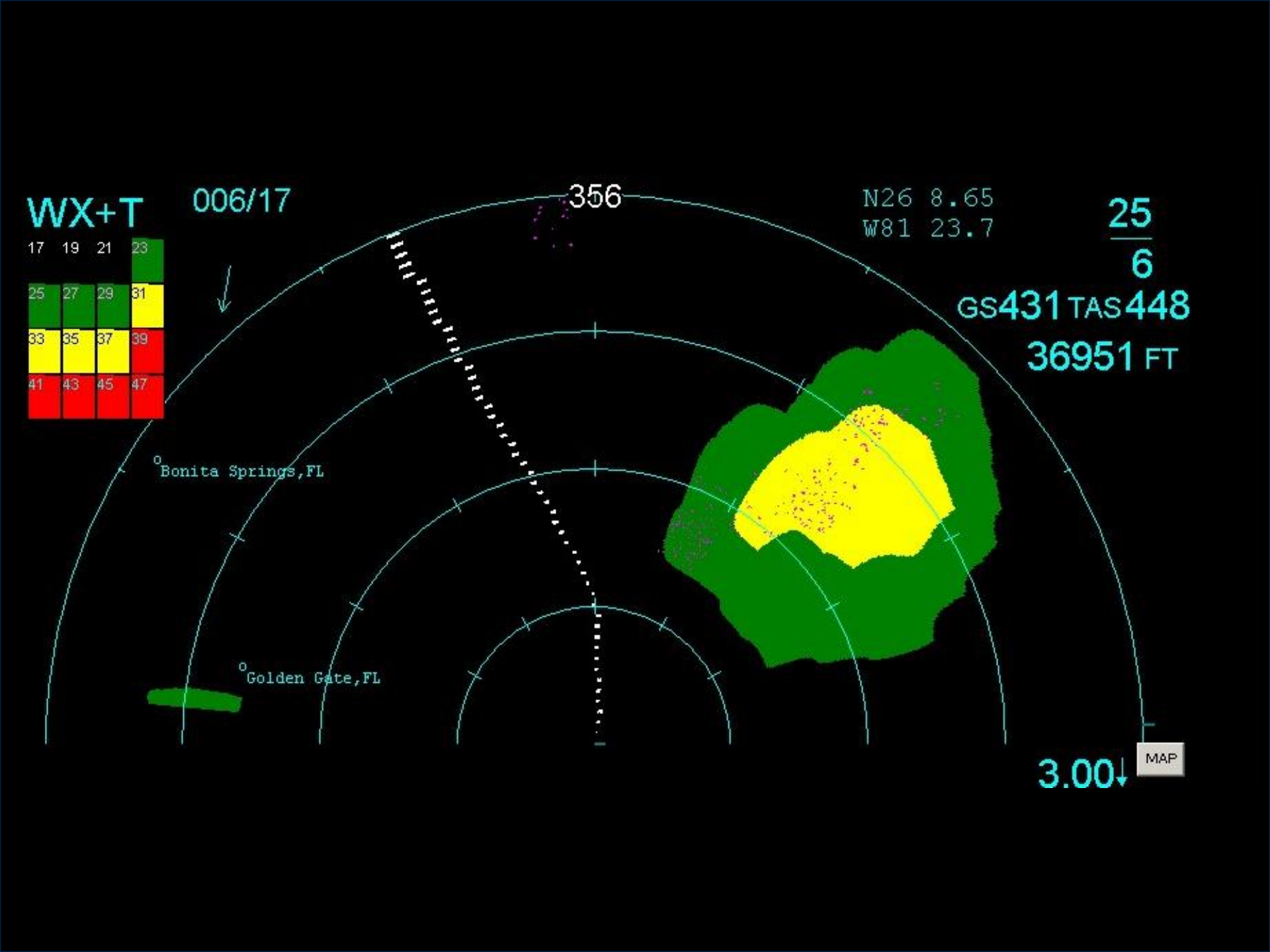
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Golden Gate,FL
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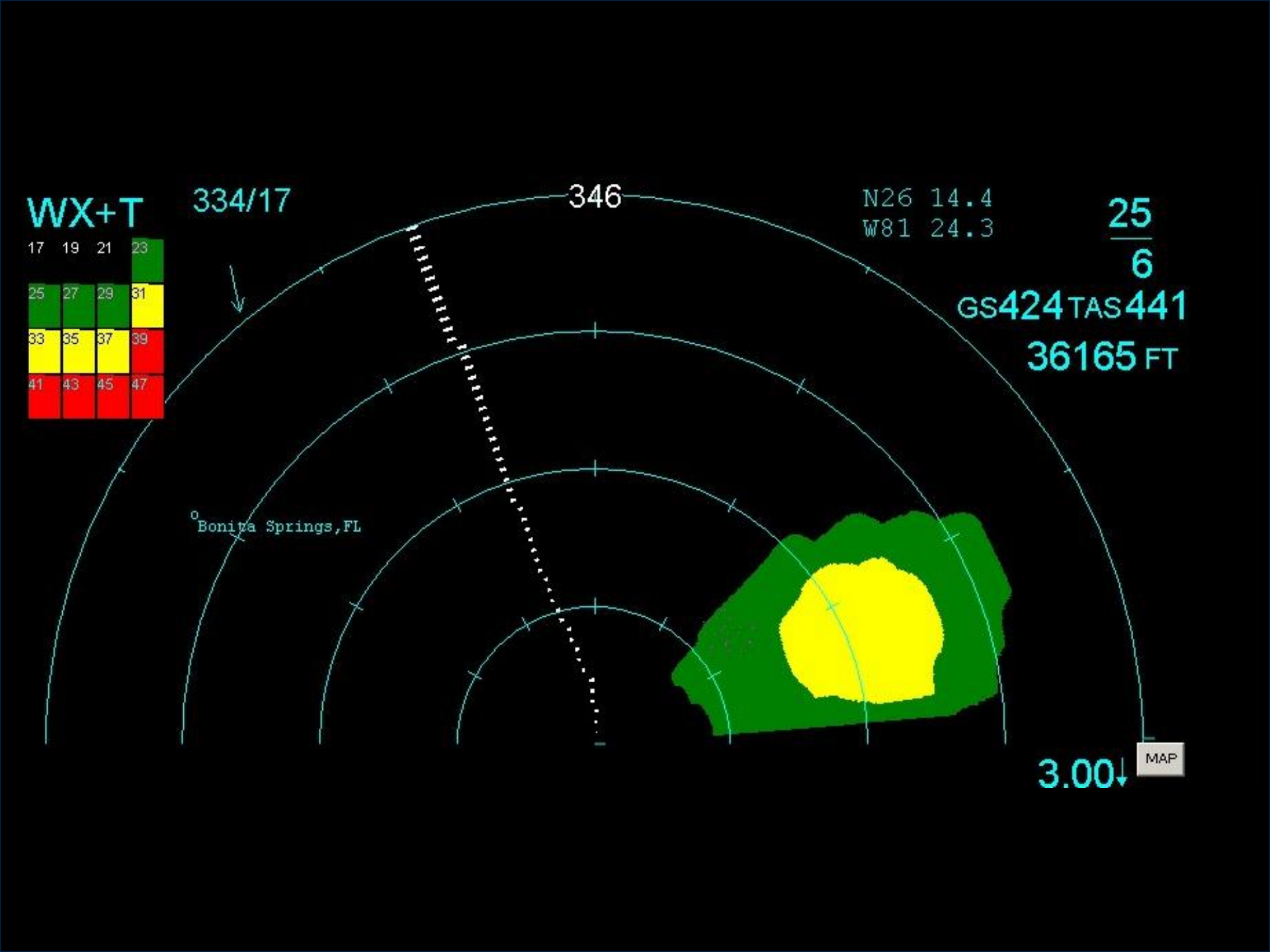
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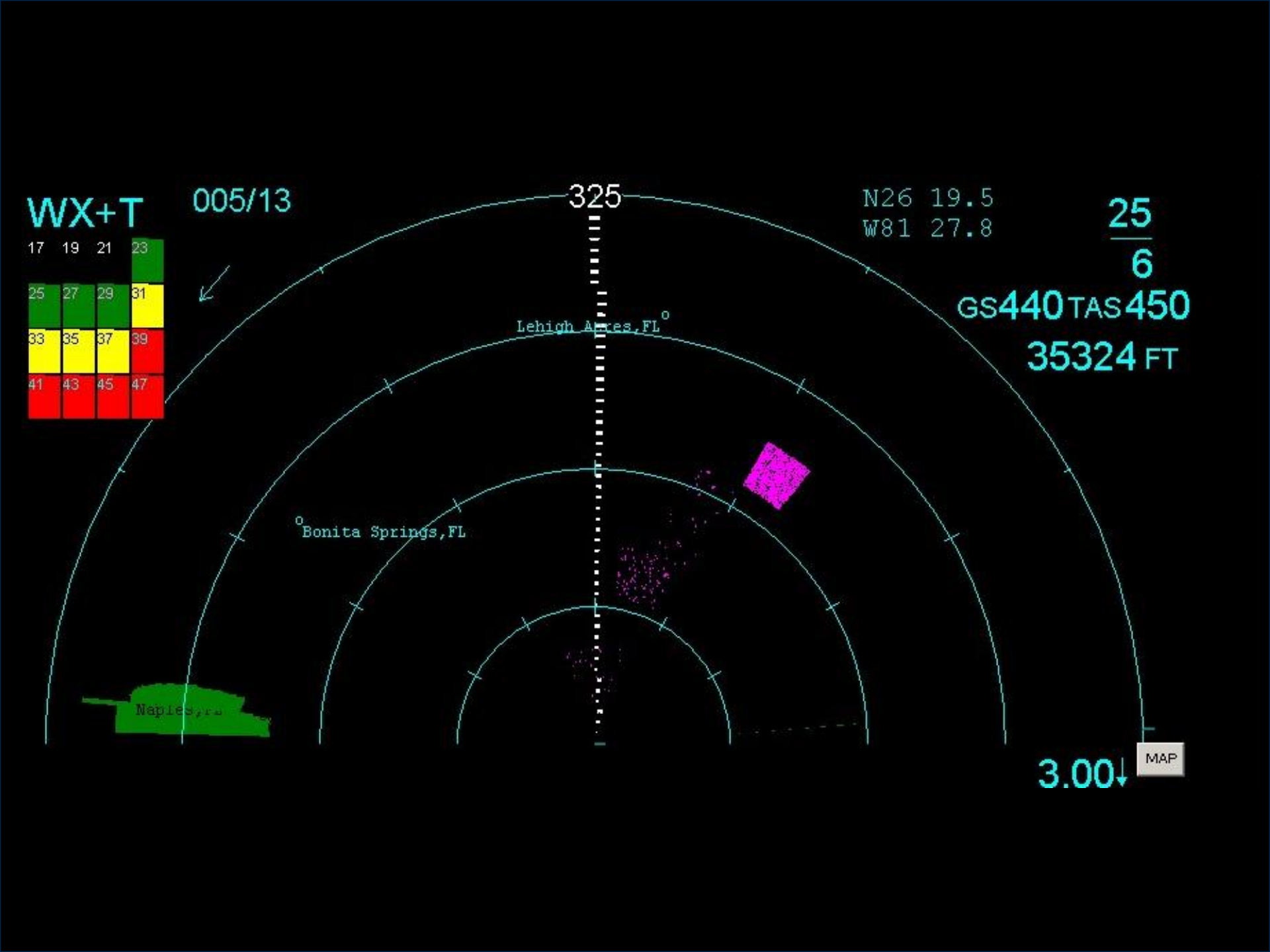
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Bonita Springs,FL
Naples,FL
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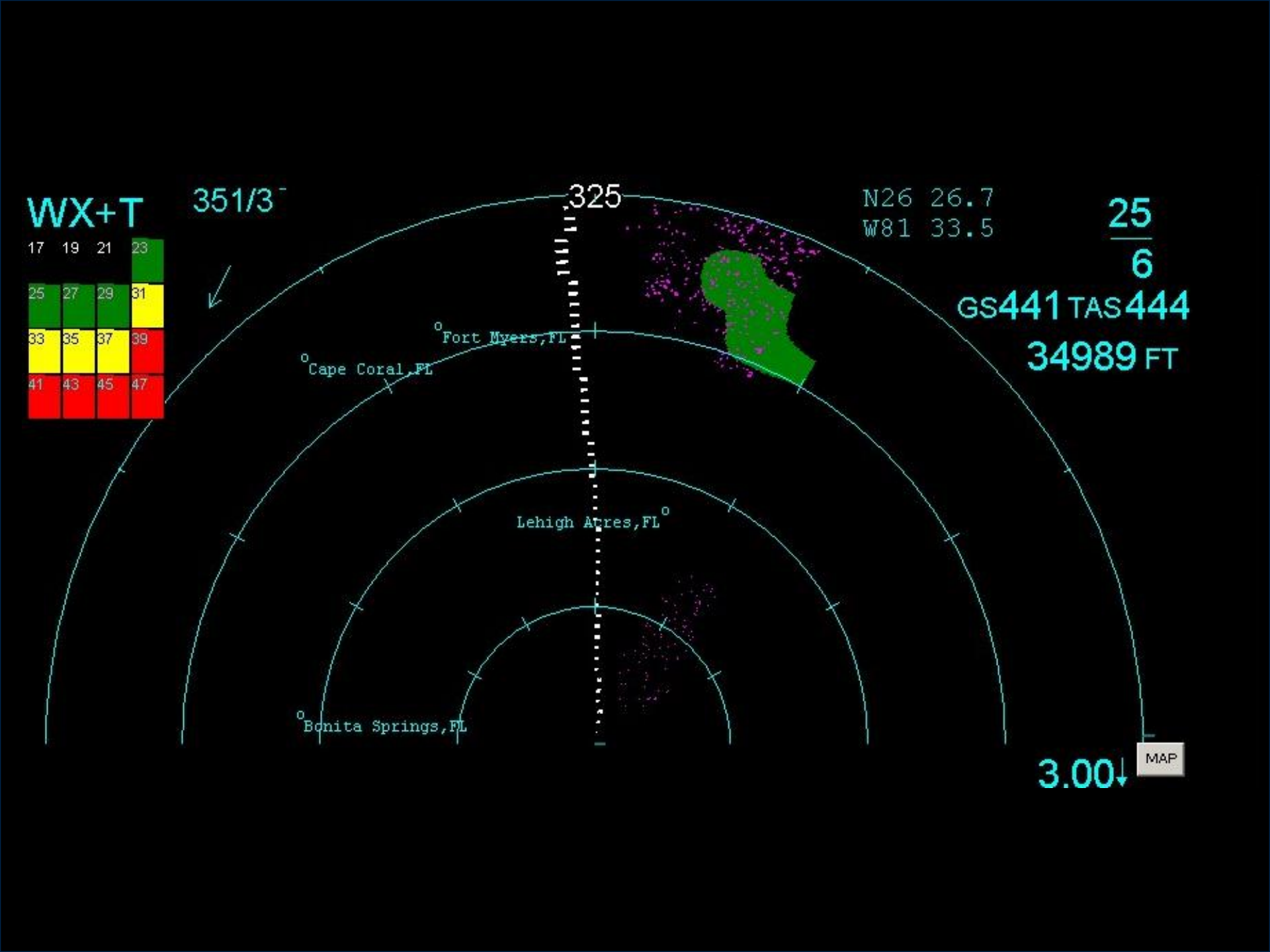
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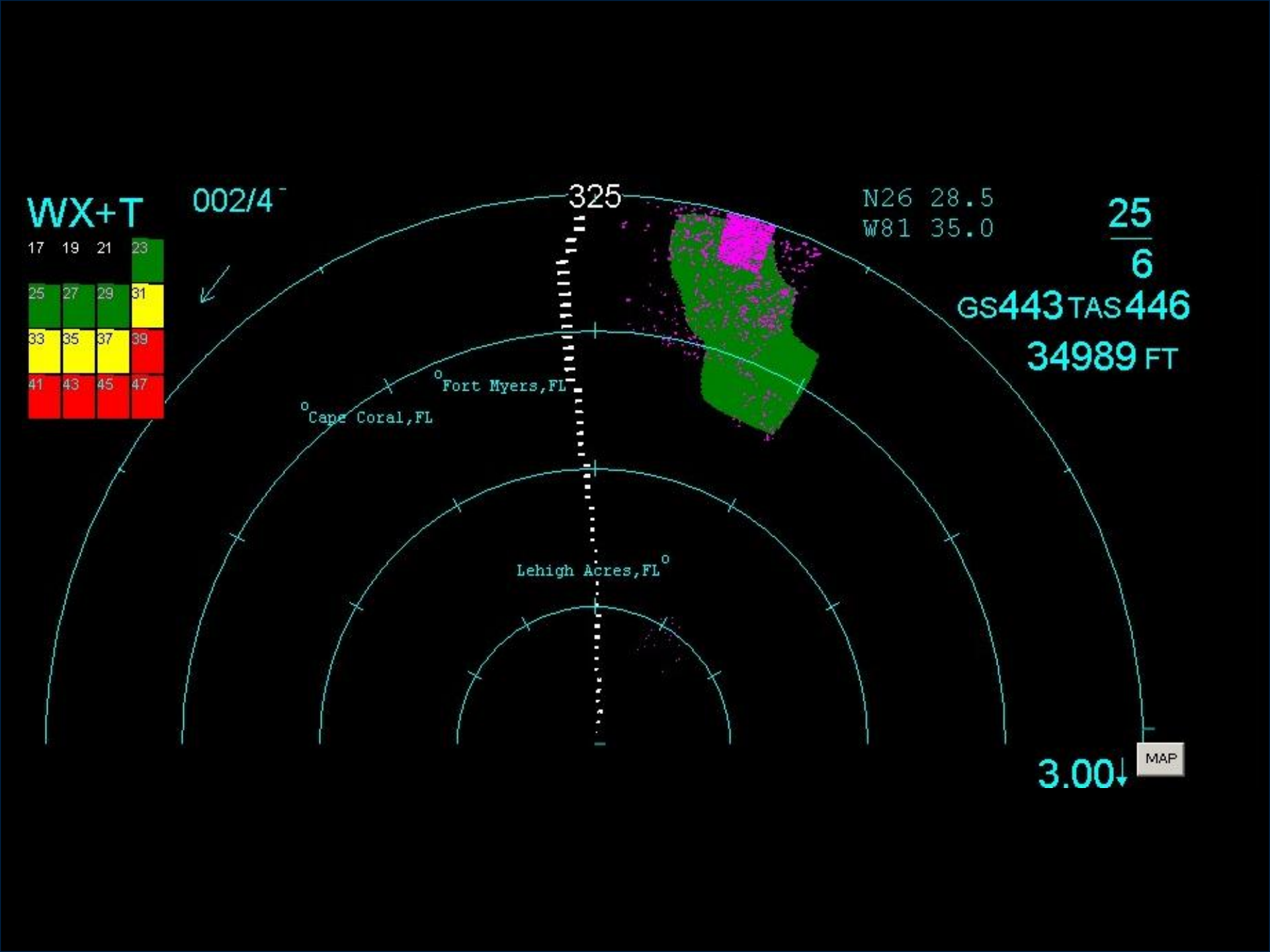
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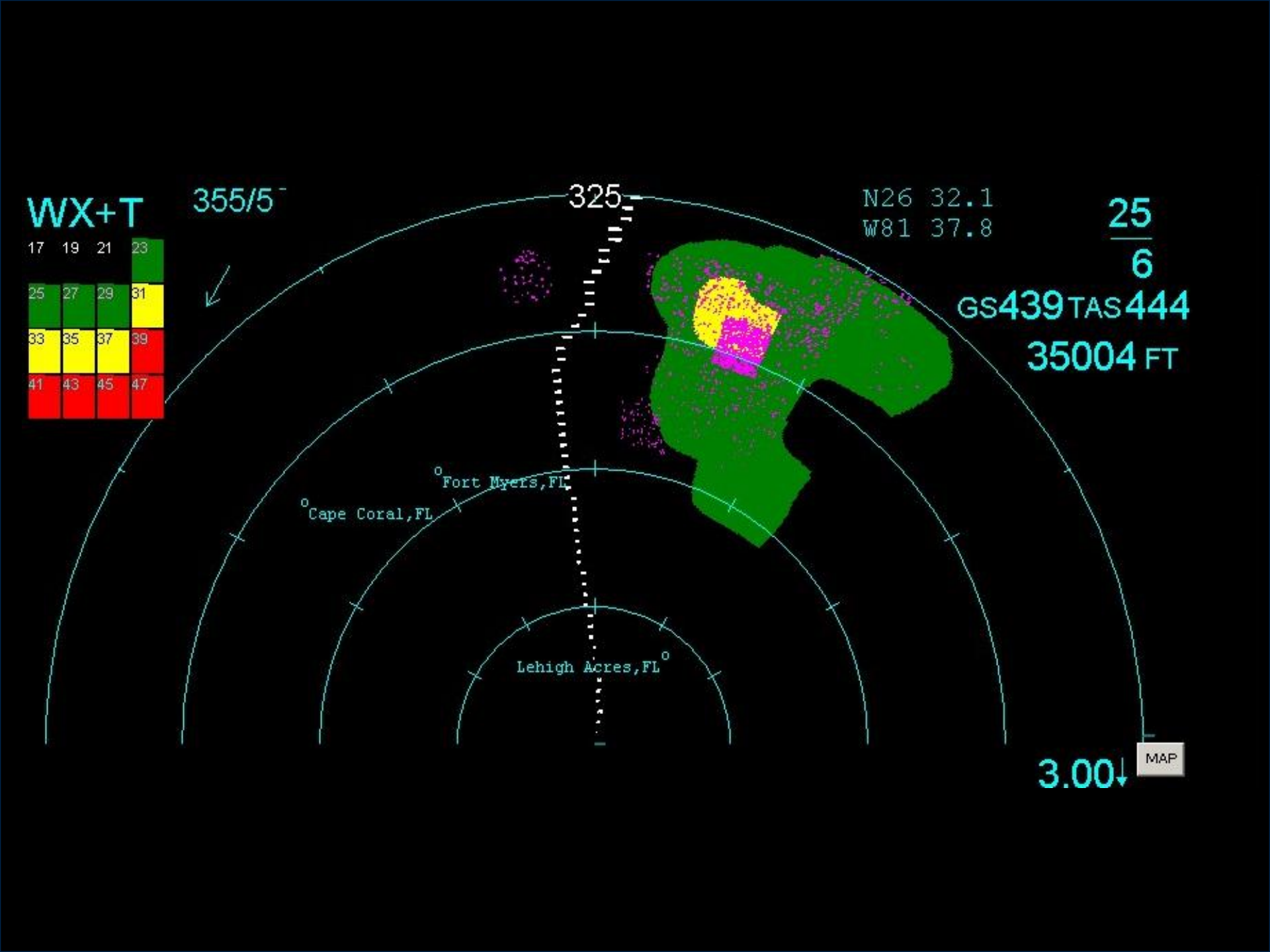
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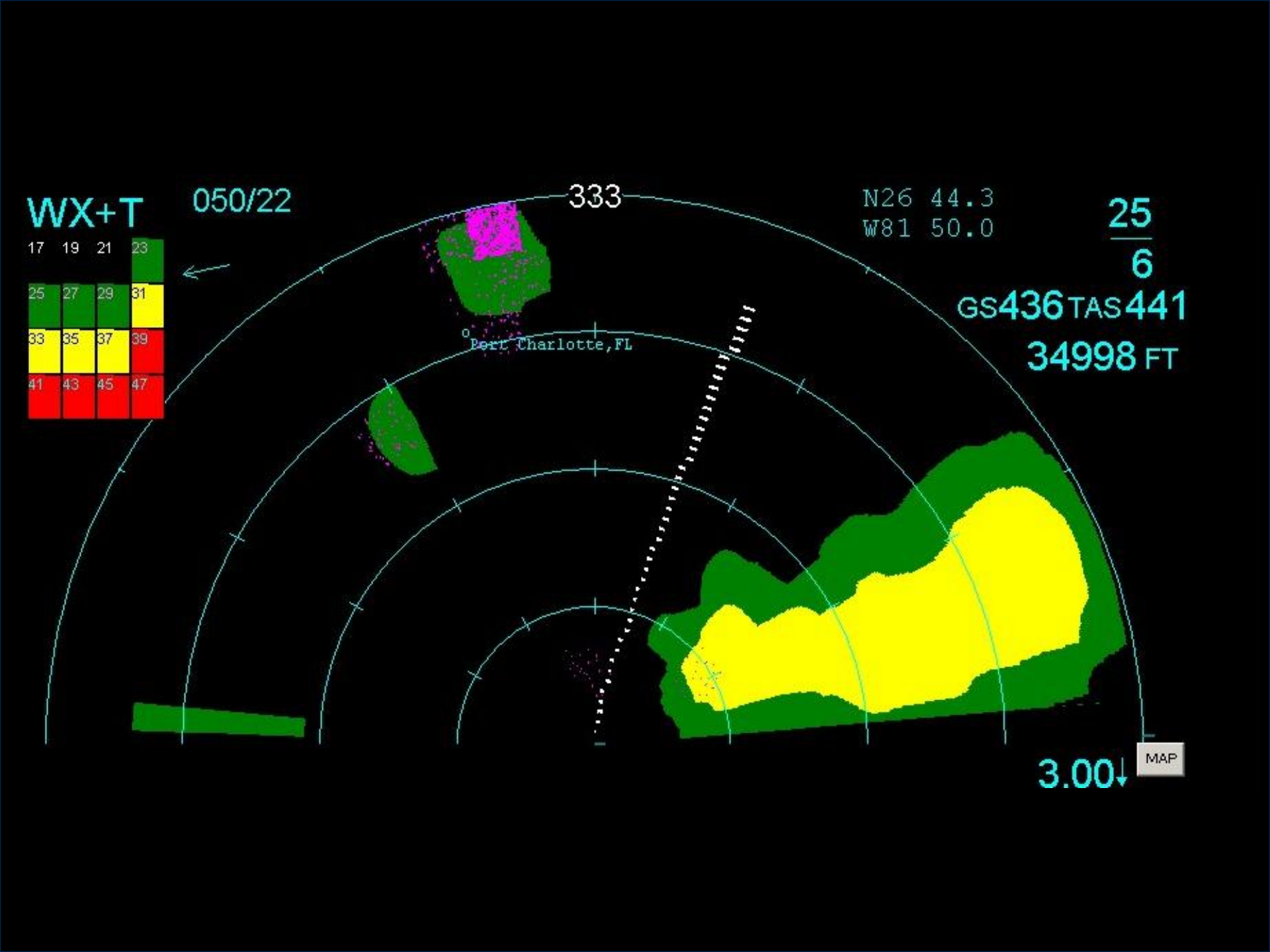
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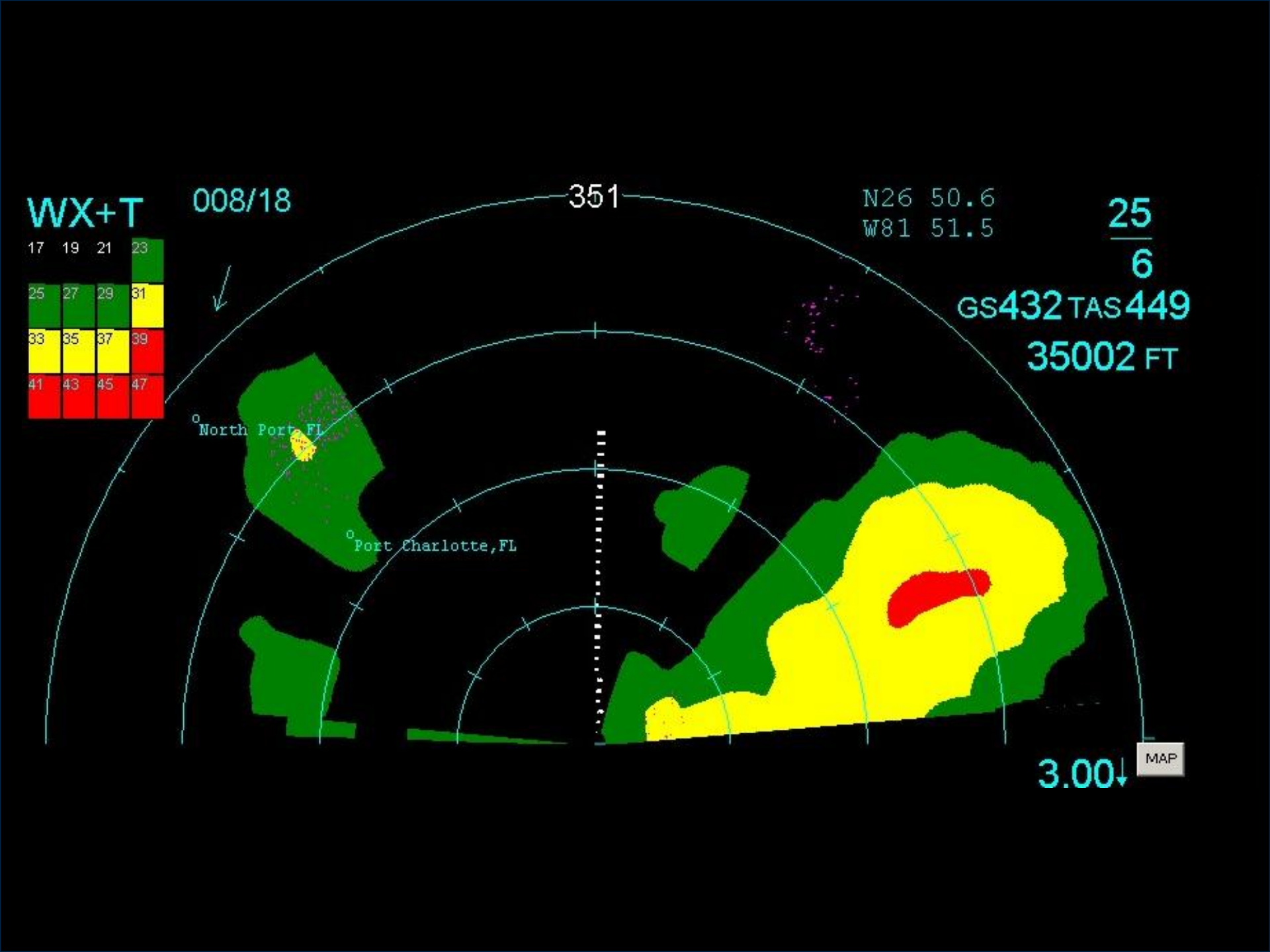
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N26 50.6
W81 51.5
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35002 FT
North Port, FL
Port Charlotte,FL
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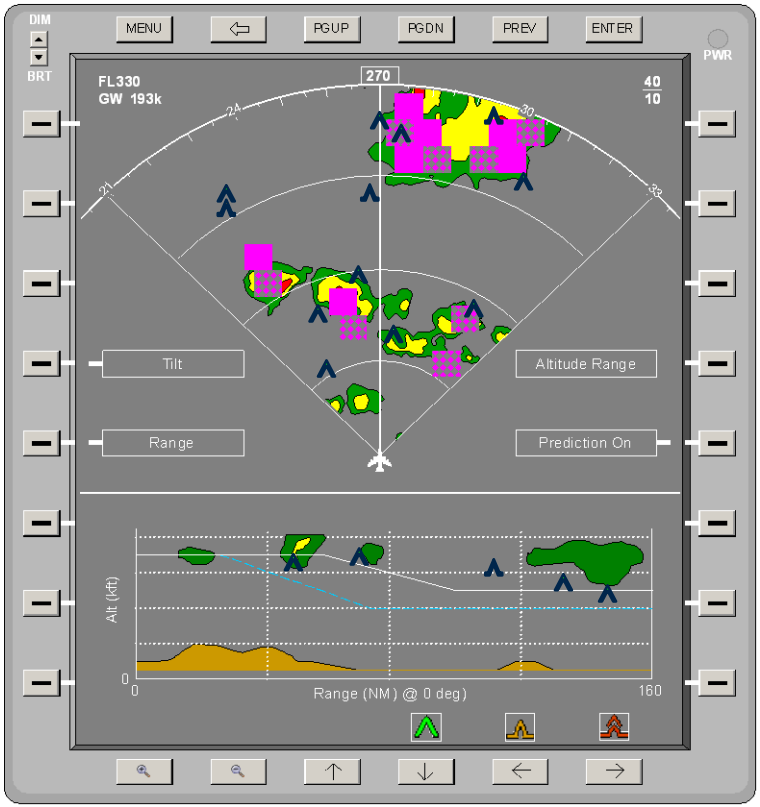
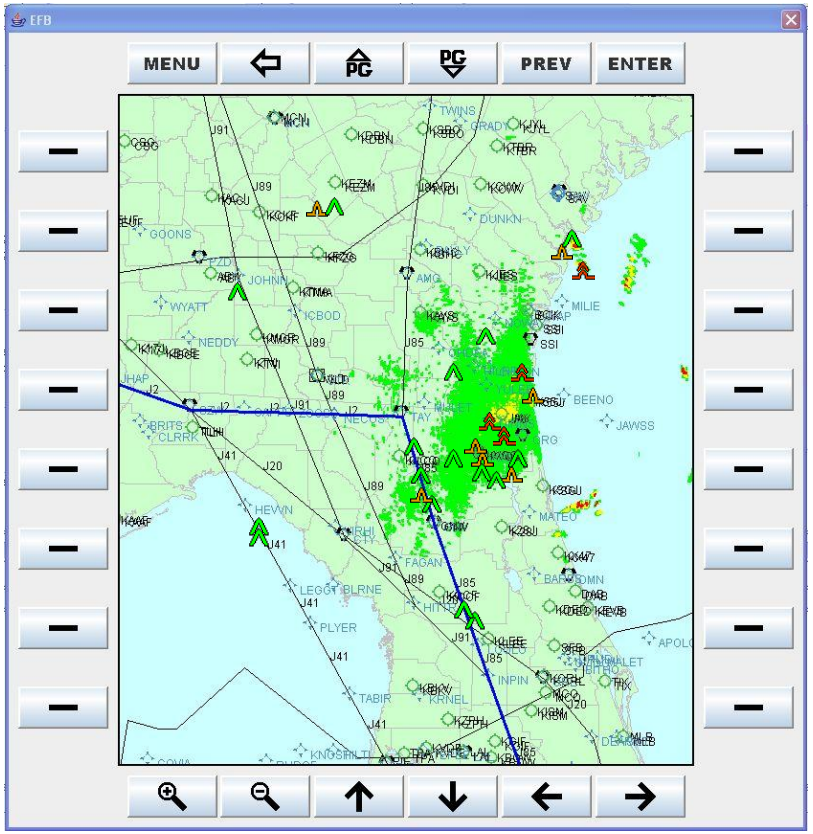
MAP

Prototype Cockpit Displays

TAPS + E-Turb Sector PPI with VPD (Nav display)



Overhead Map (Class II EFB)



NASA funded R & D efforts

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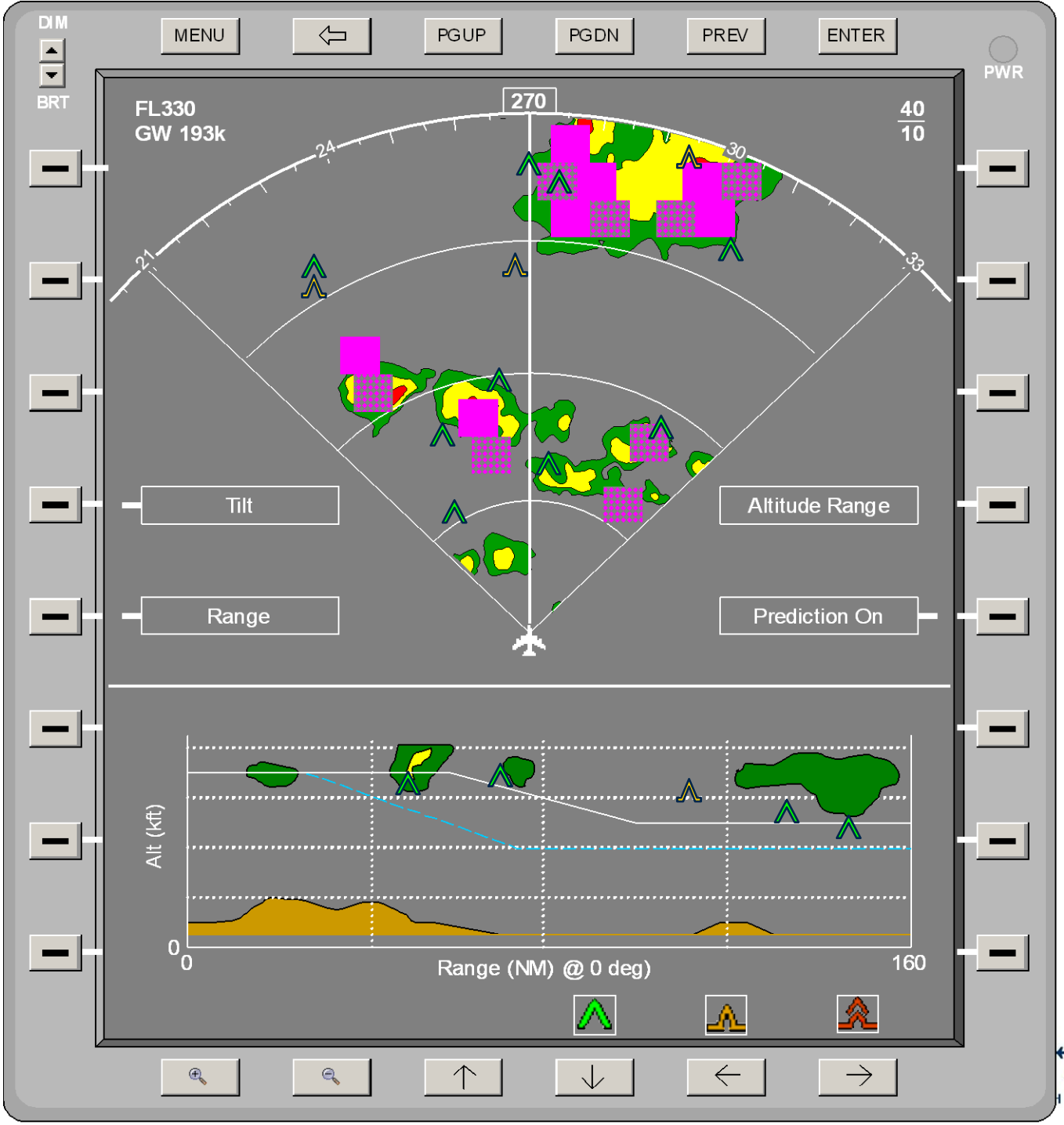

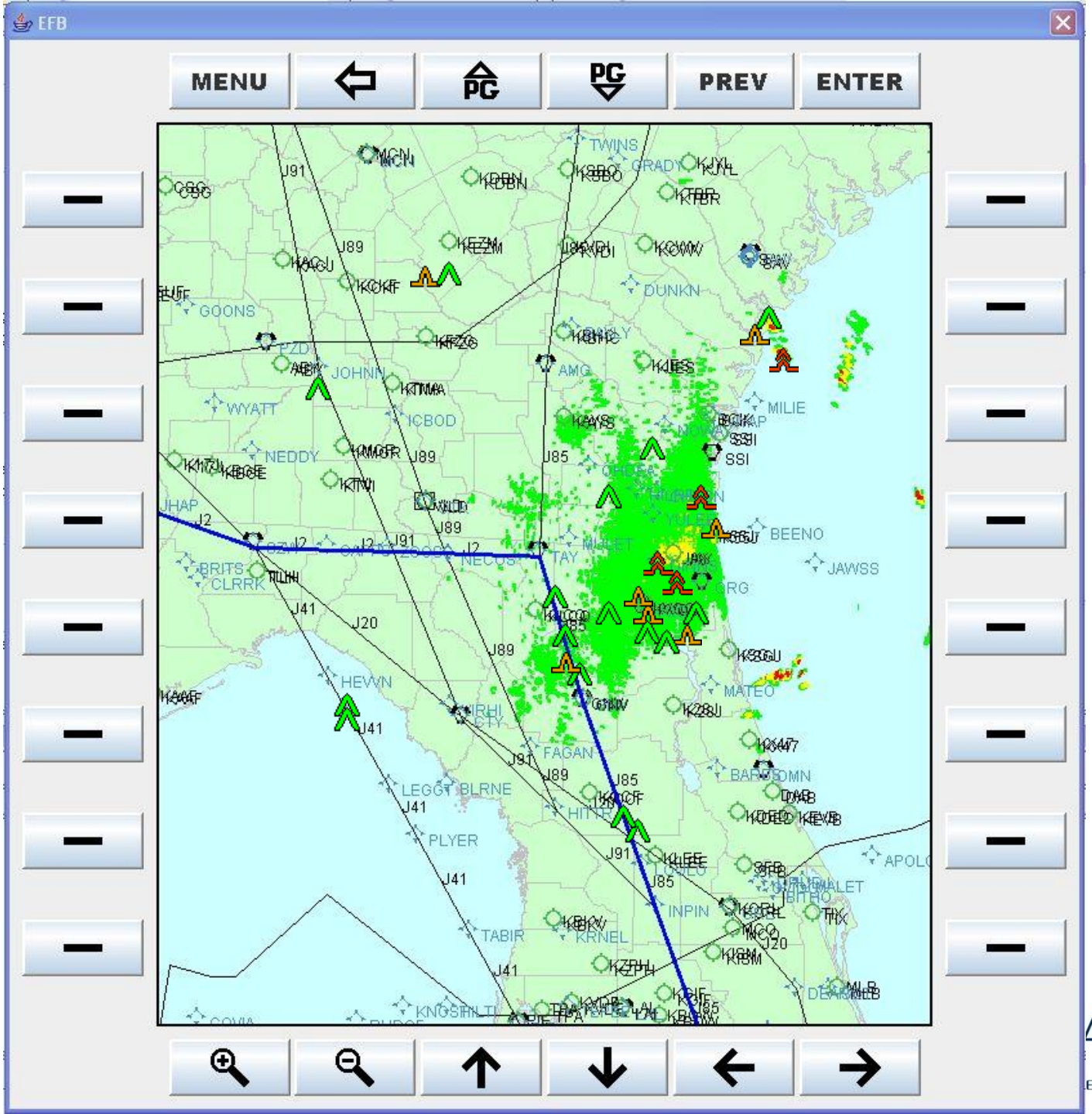
EFB
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WYATT
NEDDY
ICBOD
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BEENO
JAWSS
BRITS
CLRRK
NECOS
TAY
HEVVN
LEGGT
BLRNE
PLYER
FAGAN
MATEO
INPIN
TABIR
KRNEL
J91
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J20
J2

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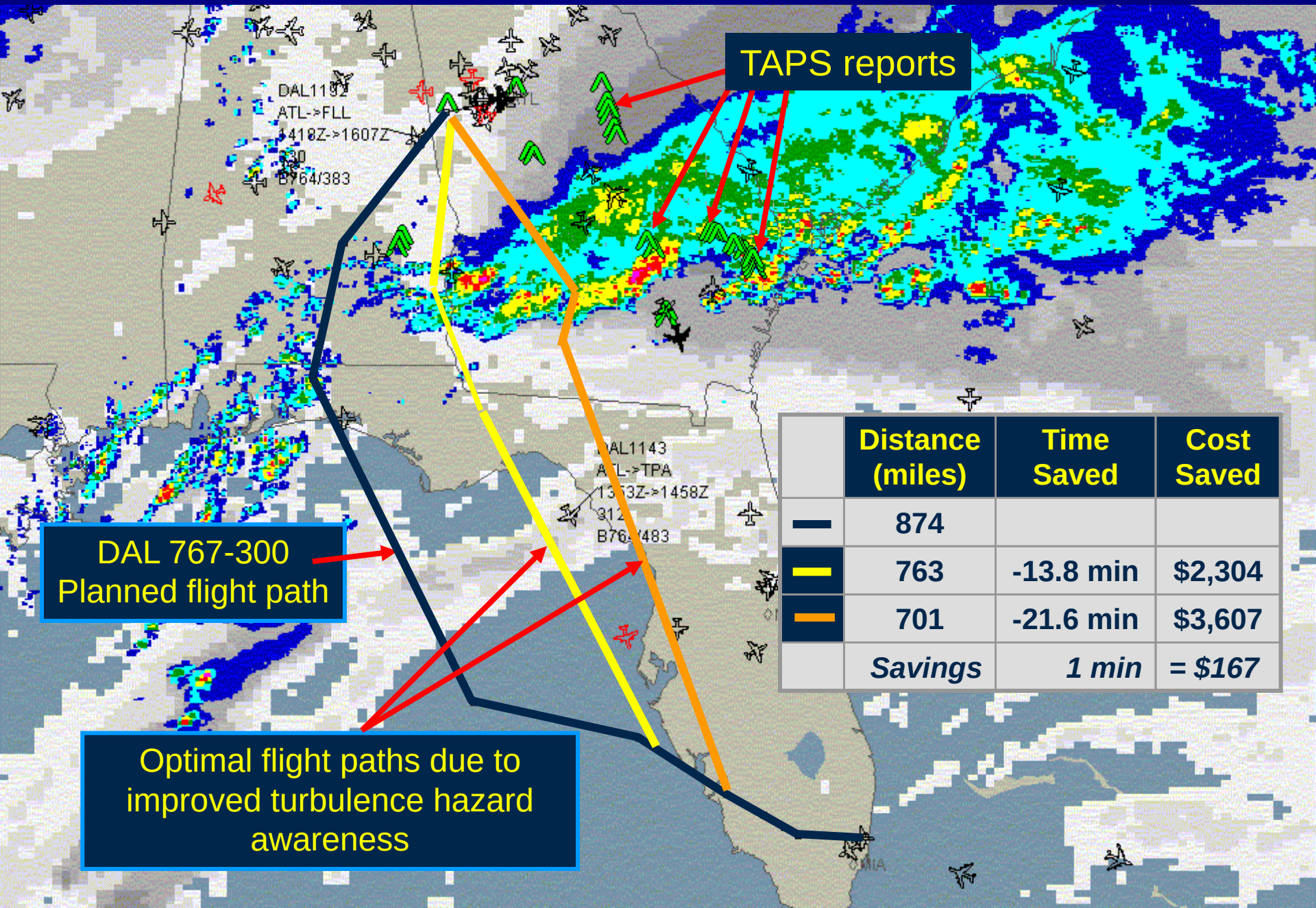
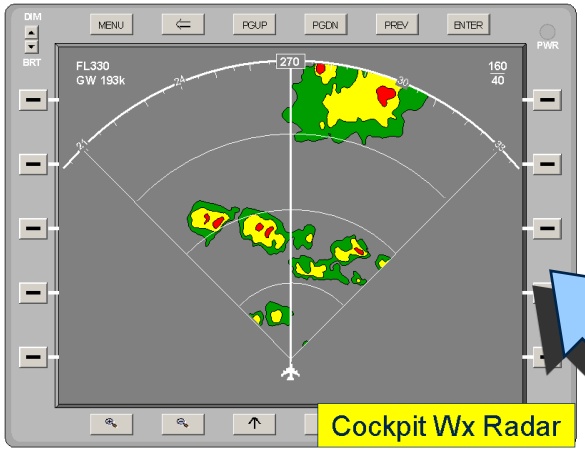
Other TAPS/E-Turb Applications

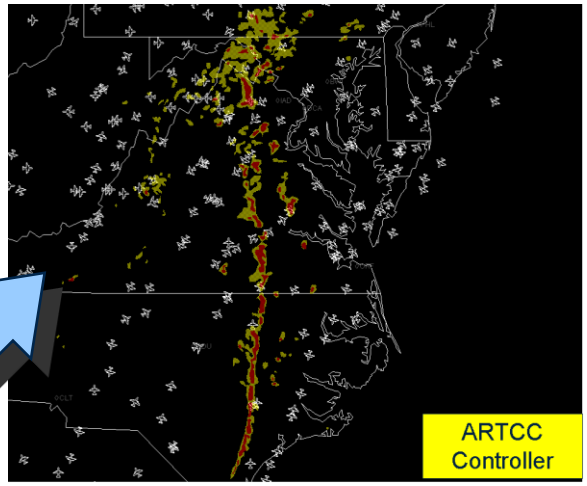
Potential Time/Distance/Cost Savings



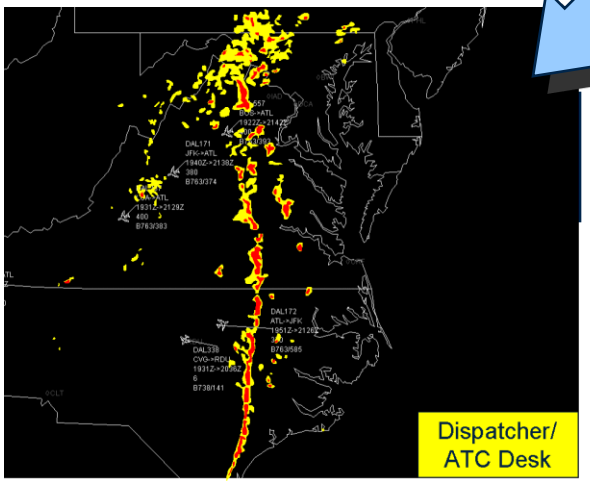
	Distance (miles)	Time Saved	Cost Saved
	874		
	763	-13.8 min	$2,304
	701	-21.6 min	$3,607
	Savings	*1 min*	*= $167*

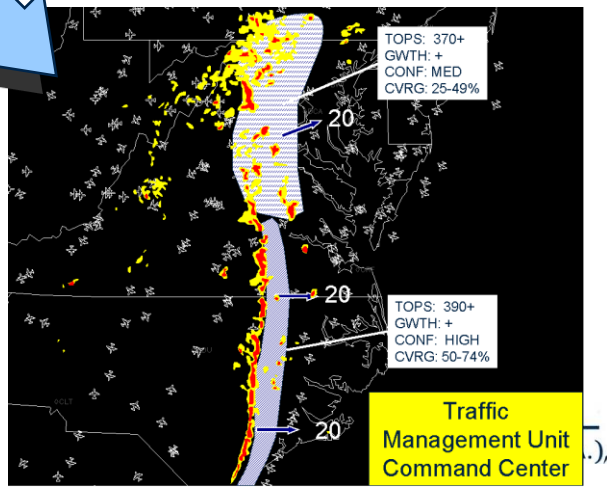
Turbulence Information Flow - Present



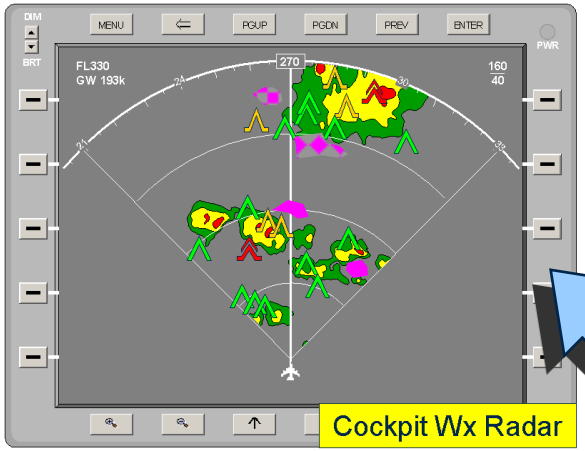


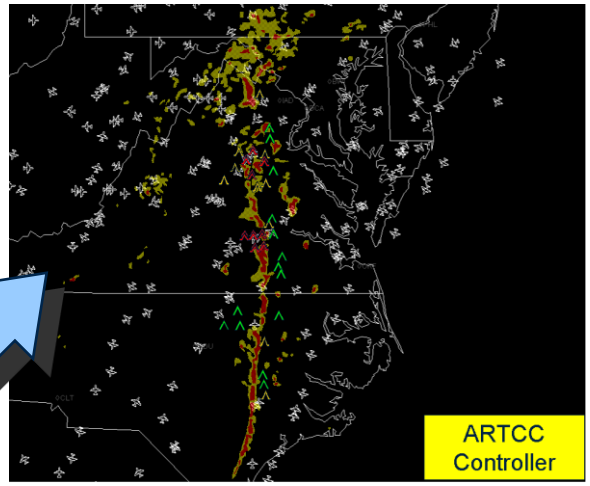
Where is the hazard?



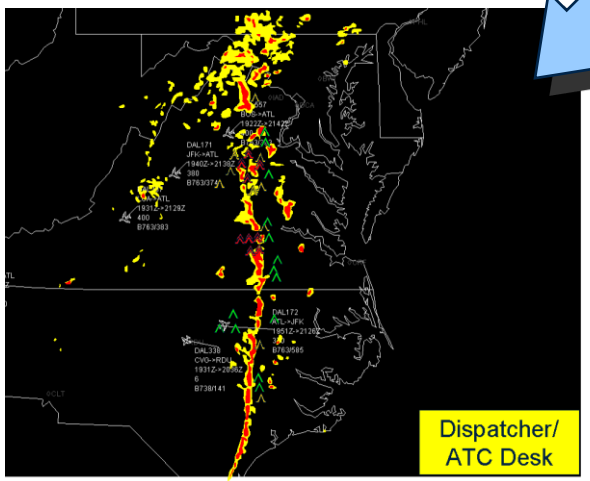


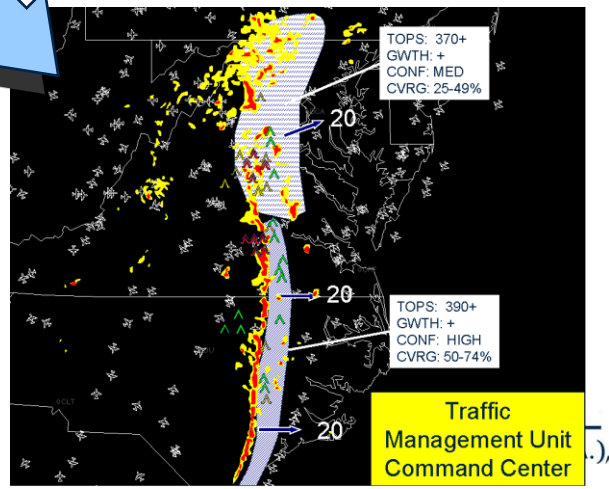
Turbulence Information Flow - Future





TAPS & other products





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