



Choosing Colors for Work-Centered Support Systems for Command and Control Using a Visual Search Task

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Introduction



- **Complexity of displays has increased with availability of new technology**
 - **Information technology**
 - **Ease of color display**
- **Human factors guidelines**
 - **Hard to keep pace with rapidly increasing technology**
 - **Complex displays particularly challenging**



Work-Centered Support Systems



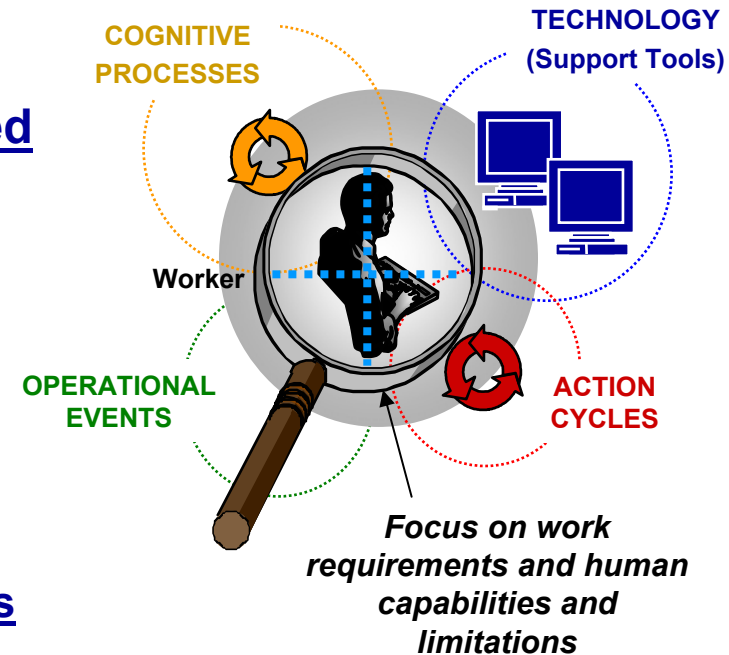
- **Replace “Windows-based” desktop with arrangement more suited to work needs**
- **Incorporates intelligent technology to retrieve data and automate functions where it makes sense to do so**
- **Continuous and work-specific display of status information**
- **Detailed, work-specific information easily accessed**



Work-Centered Support System Technology Summary



- **New** human-computer interface technology
- Highly efficient support for **work as practiced**
- **Uses:**
 - Cognitive work & task **analyses**
 - Cognitive-based **design techniques**
 - **Intelligent agents**
- **Provides:**
 - Cognitively compatible, “actionable” **displays**
 - Rapid user **adaptation to unanticipated events**
 - Agents to automatically **monitor, retrieve & fuse information**
 - ***User remains focused on “core” work activities, NOT “overhead” activities of data monitoring, retrieval & fusion***
- **Provides:**
 - ***Proactive problem identification***
 - ***Better, faster decisions/work actions***
 - ***Reduced training and operating costs***

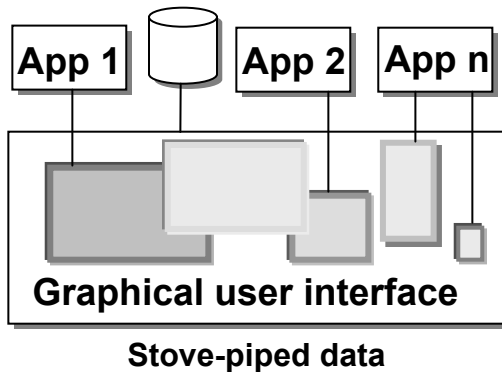




Historical Perspective: User Interface as Work Support System

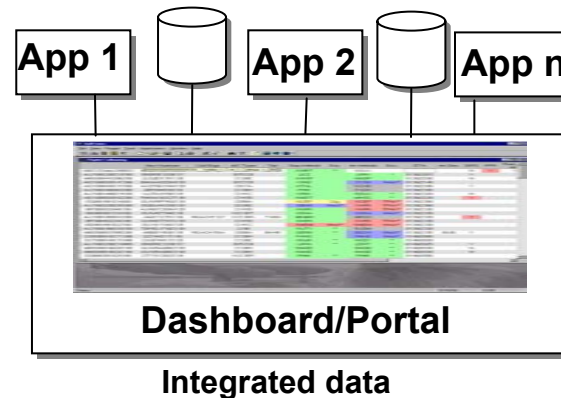


Traditional



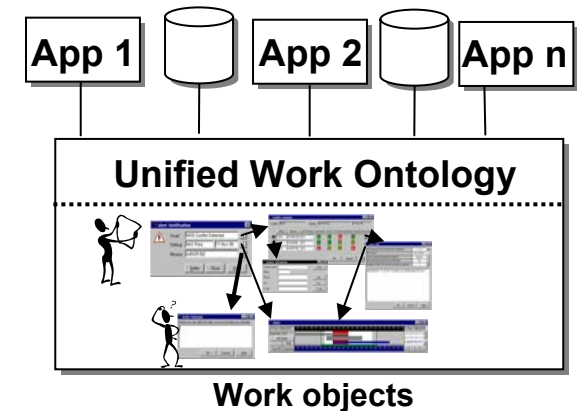
- UI as a desktop
- One window per application
- High procedural cost
- High cognitive burden

Modern



- UI as a portal
- Data-centric
- Moderate procedural cost
- High cognitive burden

Future



- UI as a work aiding system
- Single organizing framework
- Work-centered aiding collaboration; decision making; product development; work management
- Low procedural cost
- Low cognitive burden

*Next generation
User Interface technology*



Work-Centered Design Principles



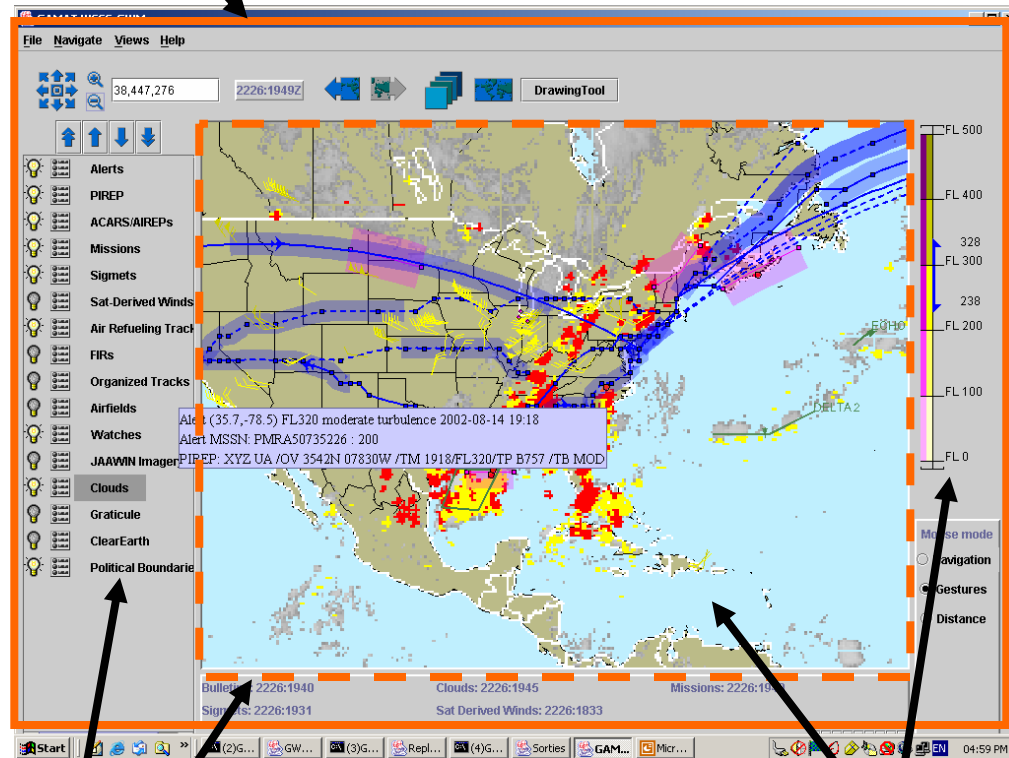
(1) Work-context space/panel
(work management)

(2) Context space
coordination

(1) Work-context space/panel
(decision support & product development)

Sorties	Sorties In DB	Sorties Shown	Sorties In Air	Sortie Agents	Unack Alerts
438	16	9	16	2	

Highlight	Sortie	Time
Highlight	EGUN-KWRI	149:1425
	PVM778198147: 250	149:2243
	SAAM	C005A
Highlight	KADW-KTCM	149:1430
	PVM88802147: 300	149:2030
	SAAM	C017A
Highlight	KDOV-KTCM	149:1500
	AJRA5599914: 100	149:2030
	ONTIN	C005B
Highlight	KADW-KSUU	149:1615
	PVM783002146: 300	149:2145
	SAAM	C005B
Highlight	PGUA-PHI	149:1730
	ABC027100148: 300	150:0100
	CHANNE	C005A
Highlight	KADW-KSUU	149:1800
	PVM787502148: 300	150:0000
	SAAM	C005A
Highlight	KADW-KSUU	149:1915
	PVM787002148: 300	150:0045
	SAAM	C005B
Highlight	ETAR-KADW	149:2000
	PAM783202148: 200	150:0450
	SAAM	C005B



(3) Problem –
Vantage –
Frame

(5) Joint aiding throughout

(6) First person principle (Work ontology) throughout ⁶

(4) Central - Peripheral

WCSS- Global Weather Management (GWM)



Overall alert status

Agent alert due to weather

Selection areas for geo-spatial fusion of real time weather, mission, route, port and other info

Flight path

PIREPs, AIREPs

Air refueling track

Agent alert due to weather

Current aircraft position

Agents continuously monitor user-definable "box" around flight paths

NOTAMs

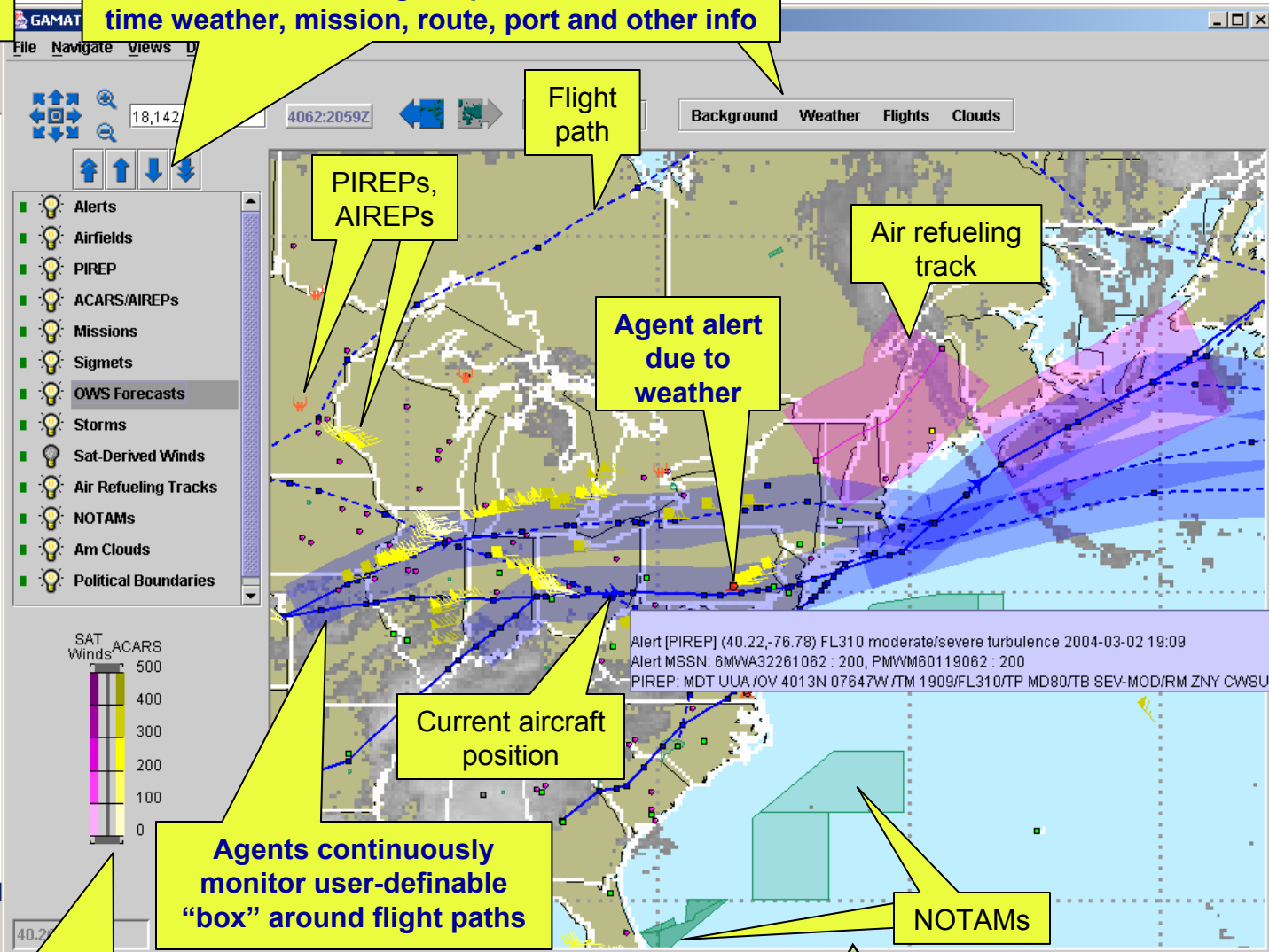
Sortie summary display

ORM ratings

Altitude range filter; Weather images color coded based on altitude

Sortie detail display

Sortie	Reorder	Filter	Alerts																																																																																																												
Sorties	Sorties	Used																																																																																																													
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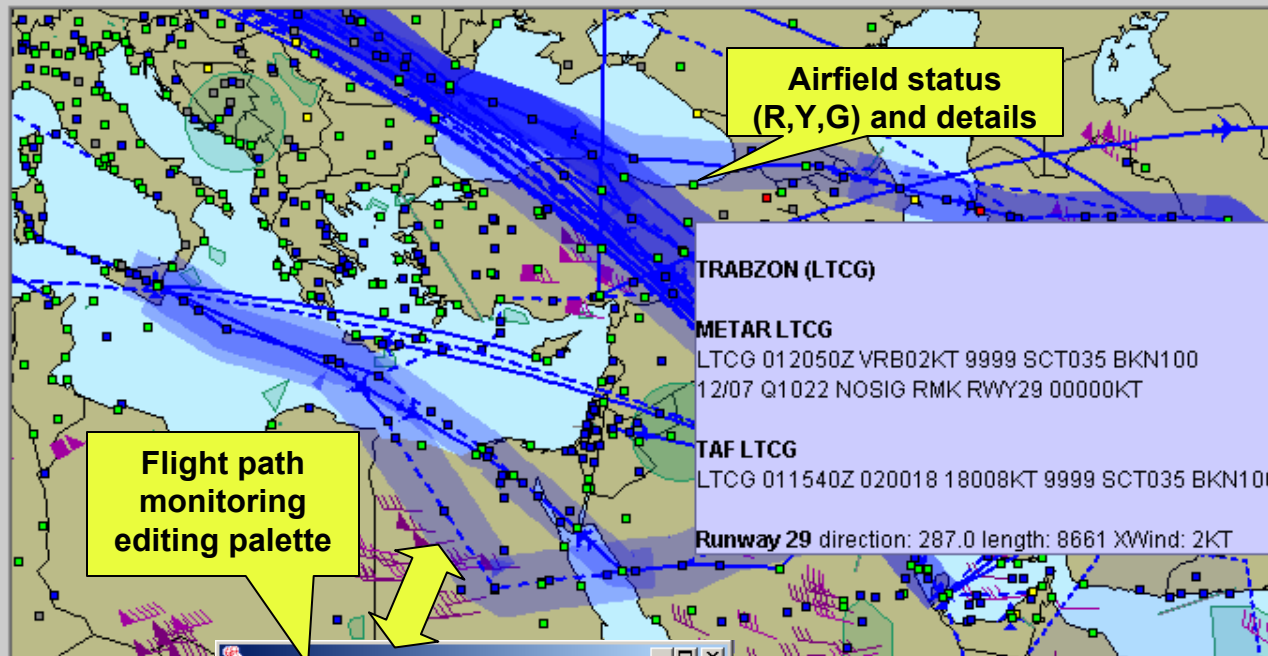
31,609,358

4061:2109Z

MetWatch Area

Background Weather Flights Clouds

- Alerts
- Airfields
- PIREP
- ACARS/AIREPs
- Missions
- Sigmet
- OWS Forecasts
- Storms
- Sat-Derived Winds
- Watches
- NOTAMS
- Am Clouds
- Political Boundaries



Airfield status (R,Y,G) and details

TRABZON (LTCG)
METAR LTCG
 LTCG 012050Z VRB02KT 9999 SCT035 BKN100
 12/07 Q1022 NOSIG RMK RWY29 00000KT
TAF LTCG
 LTCG 011540Z 020018 18008KT 9999 SCT035 BKN100
Runway 29 direction: 287.0 length: 8661 XWind: 2KT

Flight path monitoring editing palette

Edit Agent Parameters

Parameter Set:	Close Watch
Feet under FL	10000.0
Feet above FL	10000.0
Range (nm)	75.0
Min turbulence	2
Min Icing severity	3
Wind Direction Delta	100.0
Wind Speed Delta	20.0
Wind Speed Delta %	0.2
Time Bubble Lower	1.0
Time Bubble Upper	4.0

Ok Edit Cancel

Create Area

Watch or Exclusion Zone:
 Watch

Hazard:
 Turbulence

Severity:
 Moderate

Start Date/Time:
 2004-03-01 20:59

Duration (HH:MM):
 02:30

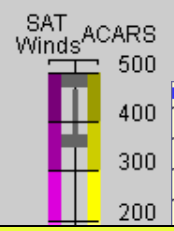
Min Altitude (FL):
 0

Max Altitude (FL):
 300

Annotation:
 N Arabian Turb

Make Public

Create Area
 Cancel
 Commit



- Bulletins: 4061:2030
 - Sigmet: 4061:2002
 - OWS Forecasts: 4061:1857
 - Tropical Storms: 4061:1957
 - Sat Derived Winds: 4061:1804
 - Missions: 4061:2028
 - Am Clouds: 4061:2030
 - Pac Clouds: 4061:2030
 - NOTAMS: 4061:1745 (checked@4061:2030)
- [Click button for details]

Data currency indicator (e.g. all data current except for NOTAMS)

USER-DEFINED AGENTS- Watch Areas for turbulence and icing

Moderate Turbulence
 FLO-300
 N Arabian Turb

Light/Moderate Icing
 FL200-500
 NE Indian Ocean Icing

41.01, 39.85

Data Status



20,318,550

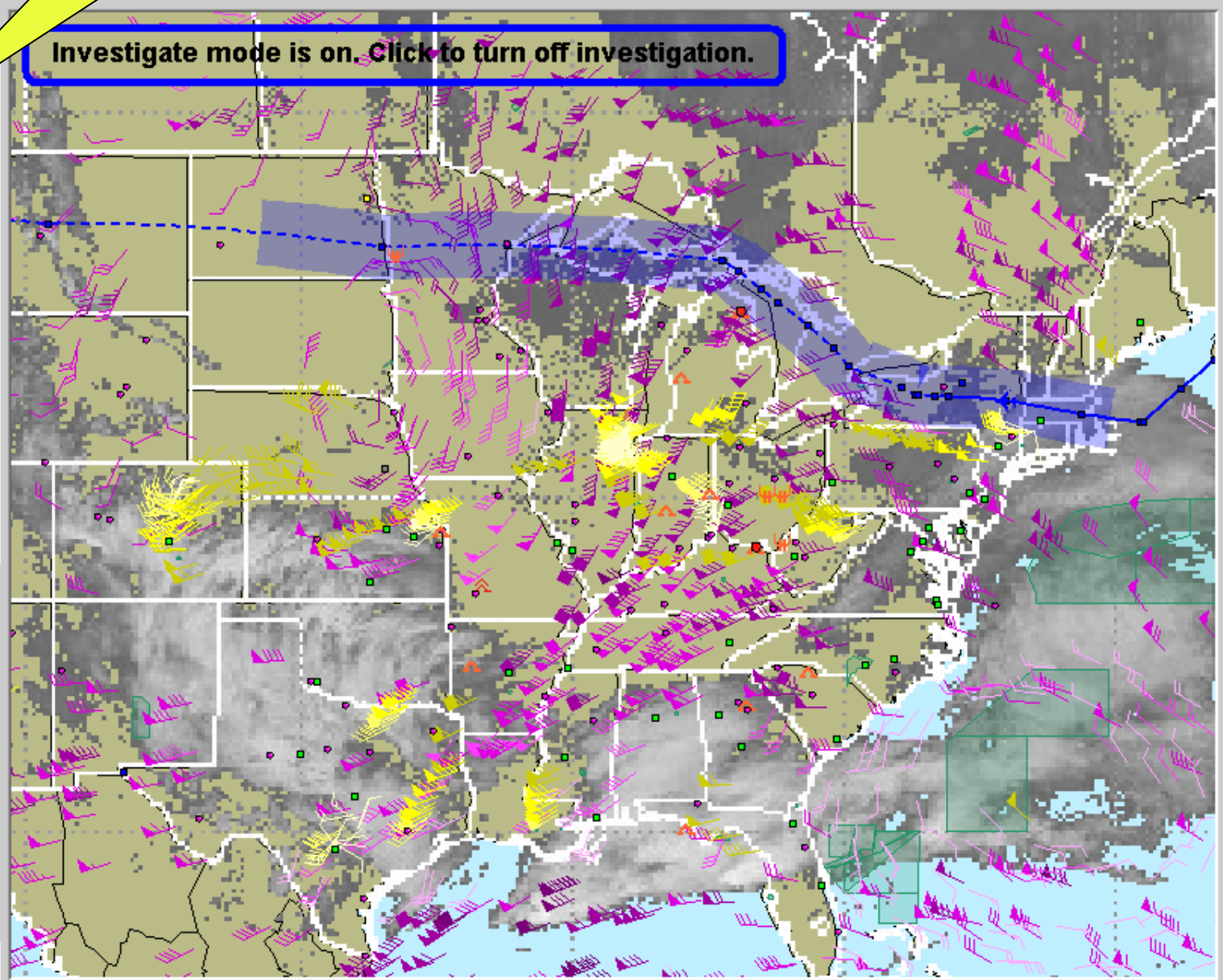
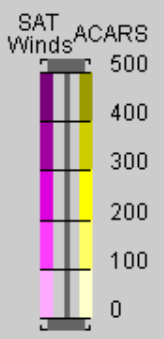
MetWatch Area

Background Weather Flights Clouds

“Layer” selections used to rapidly fuse info

Investigate mode is on. Click to turn off investigation.

- Alerts
- Airfields
- PIREP
- ACARS/AIREPs
- Missions
- Sigmet
- OWS Forecasts
- Storms
- Sat-Derived Winds
- Watches
- NOTAMS
- Am Clouds
- Political Boundaries



28.57, -110.57

Data Status



Display Color Guidelines (Helander, 1987)



- **Limit use of color to 10 or less**
- **Reserve color use for drawing attention or means of quickly categorizing data**
- **Reserve red, green, & yellow for warning, safe, and caution, respectively**



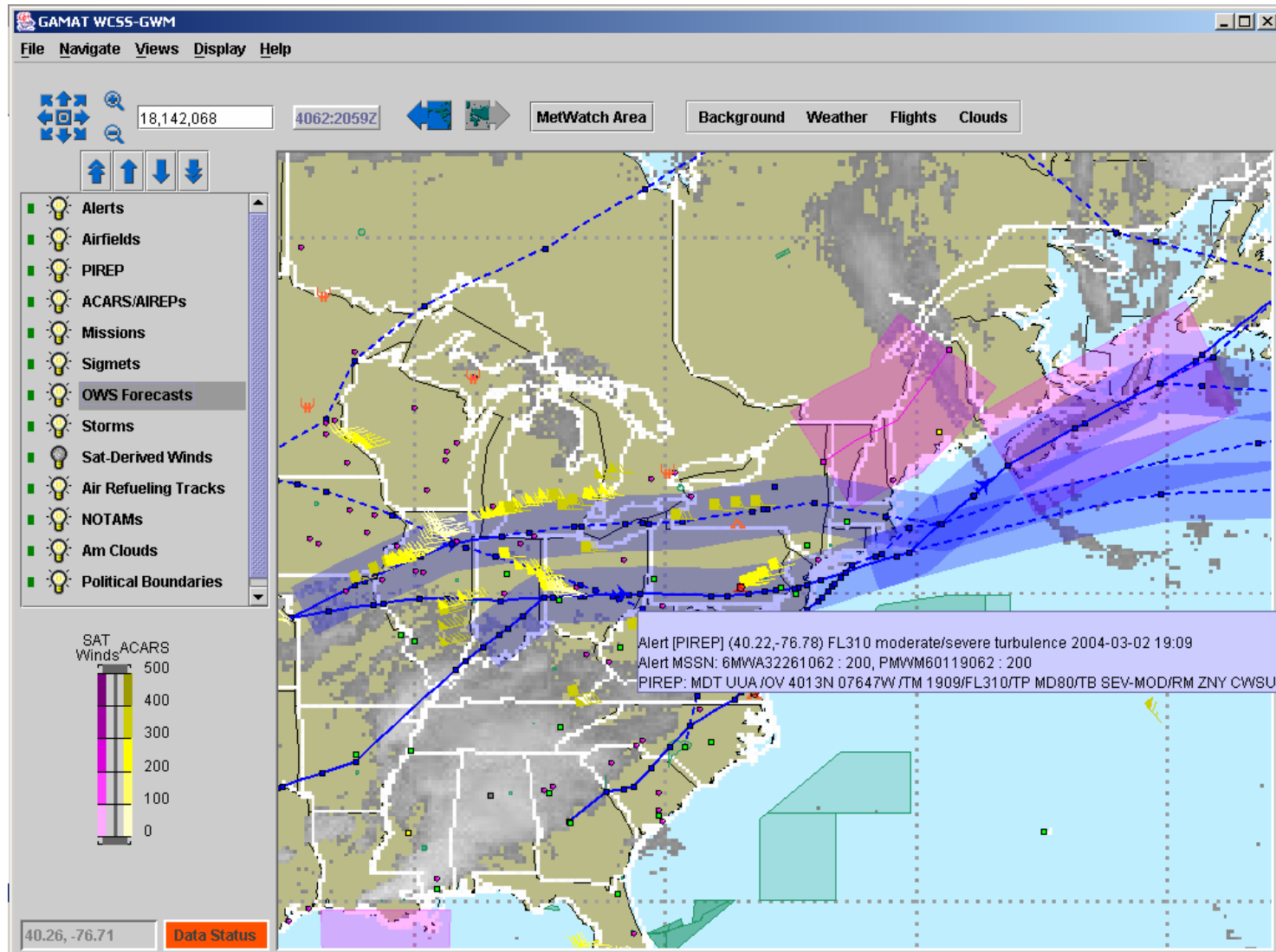
Display Color Guidelines (DoD, 1989)



- **Emergency – flashing red**
- **Alert – red**
- **Marginal or caution – yellow**
- **Satisfactory – green**
- **Advisory may be blue**
- **May use color to differentiate between classes of information BUT must not conflict with above color use**

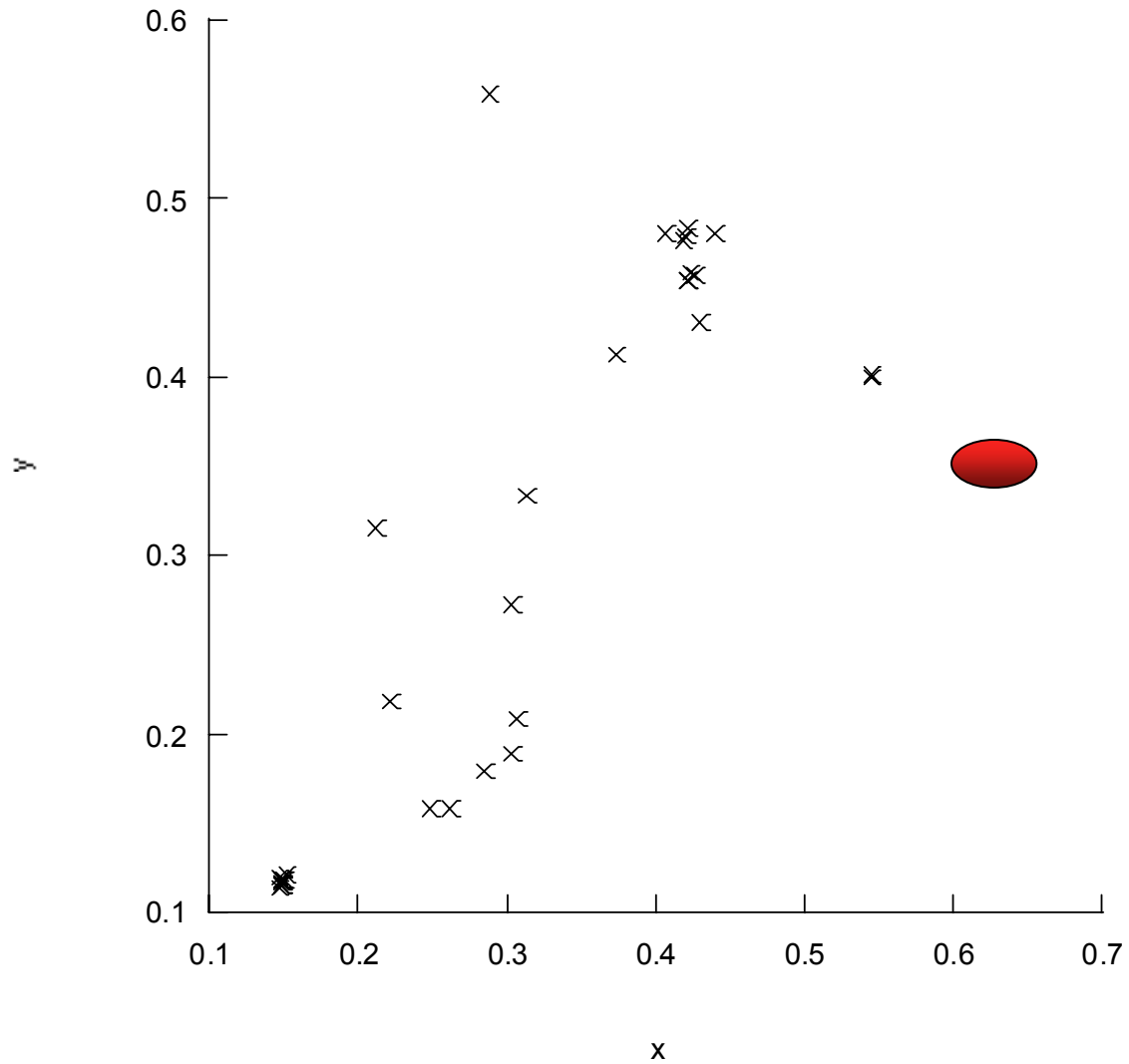


The GWM Map Display





GWM Colors





“No matter how intelligent the choice of information, no matter how ingenious the encoding . . . the graph is a failure if the visual decoding fails.” (Cleveland, 1985)



Display Element Criteria Levels



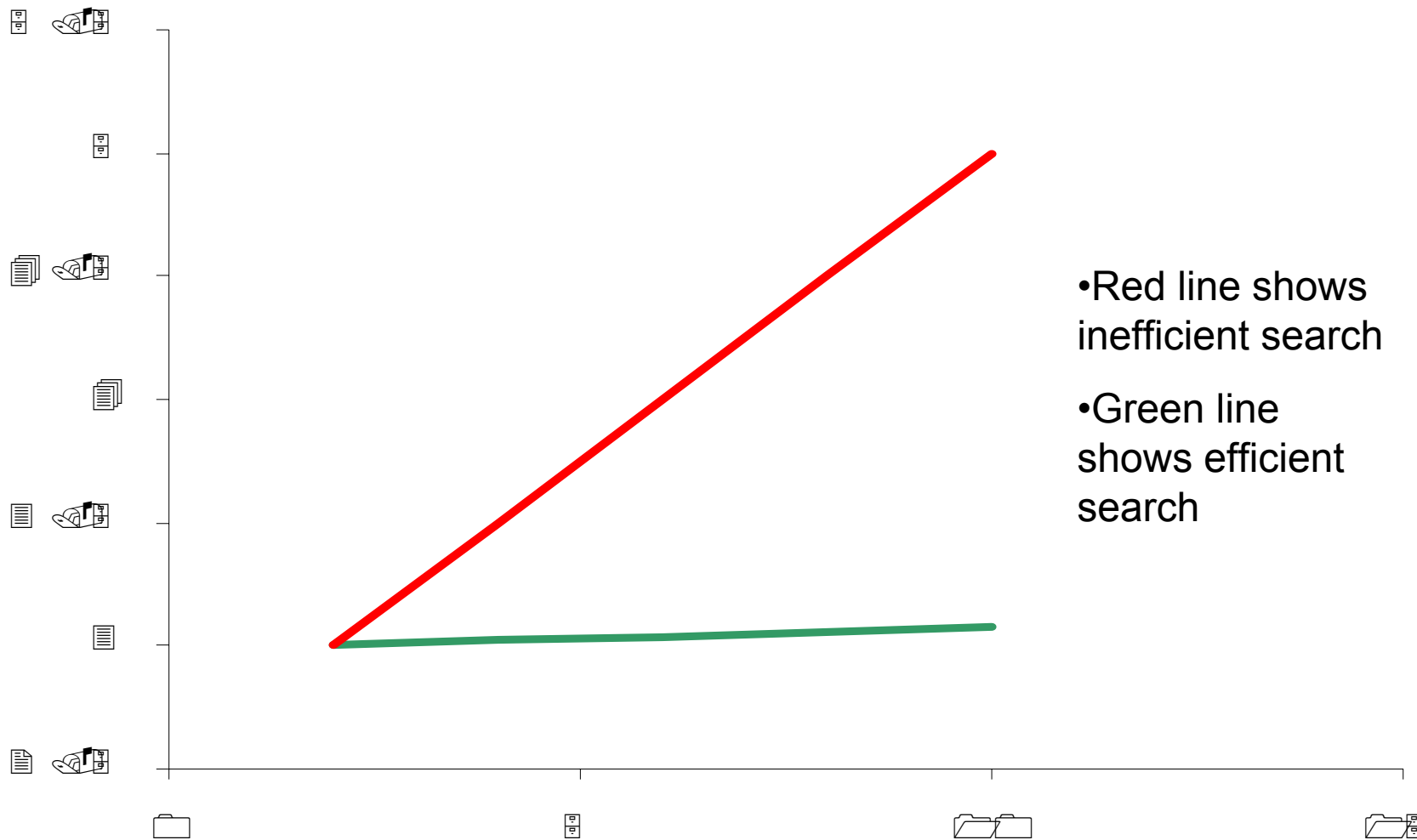
- **Visibility**
- **Discriminability**
- **Conspicuity**



Efficient Search



REACTION TIME



•Red line shows inefficient search

•Green line shows efficient search

SET SIZE



Research Goals of this Pilot Work



- **Combine basic methodology with applied display to demonstrate usefulness for designing and evaluating display coding**
- **Compare expected outcomes to results of using this methodology**
- **Verify expected effects of changing the GWM display color scheme**
- **Collect pilot data for future research testing use of transparency as a visual feature**
- **Recommend color sets to test in future evaluation**



Experimental Design



		Block	
		Experimental Design	
Background color	original	Set size	Set size
		2	6
		(2 repetitions)	(2 repetitions)
		Set size	Set size
	recommended	18	54
		(2 repetitions)	(2 repetitions)
		Set size	Set size
		2	6
(2 repetitions)	(2 repetitions)		
Set size	Set size		
18	54		
(2 repetitions)	(2 repetitions)		

Trials within each block

		Low Level of Clutter	
Background Clutter	Symbol colors	Original	
		Symbol Colors	
		(10 trials)	
		Recommended	
	Symbol colors	Symbol Colors	
		(10 trials)	
		Moderate Level of Clutter	
		Symbol colors	Original
	Symbol Colors		
	(10 trials)		
	Recommended		
	Symbol colors	Symbol Colors	
(10 trials)			
High Level of Clutter			
Symbol colors		Original	
	Symbol Colors		
	(10 trials)		
	Recommended		
Symbol colors	Symbol Colors		
	(10 trials)		

Note: Paper (page 9) reports 8 blocks instead of 16 completed & set size of 3 rather than 2.



Method



- **Participant**
 - Female, age 46, normal color vision
- **Apparatus**
 - Dell PC with flat panel display
 - Stimuli generated by JAVA / JYTHON program
 - Office setting
- **Procedure**
 - Fixation cross presented at the center of the display background
 - Mouse click to signal “ready”
 - Target and distractors appear
 - Press “enter” or mouse click when target is found
 - Target and distractors disappear (background remains)
 - Position cursor over the quadrant where the target had been – mouse click
 - Next background appears with fixation cross



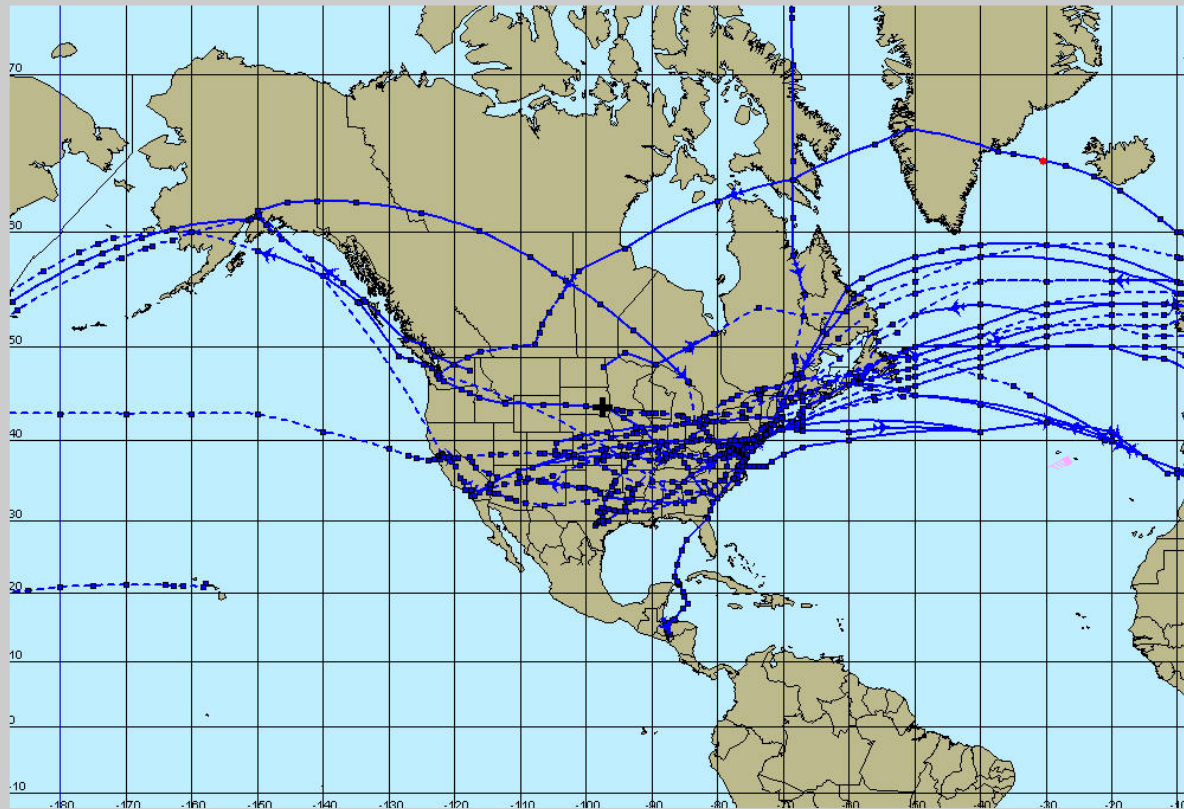
Set Size 2



Testing Frame

File

Started new trial



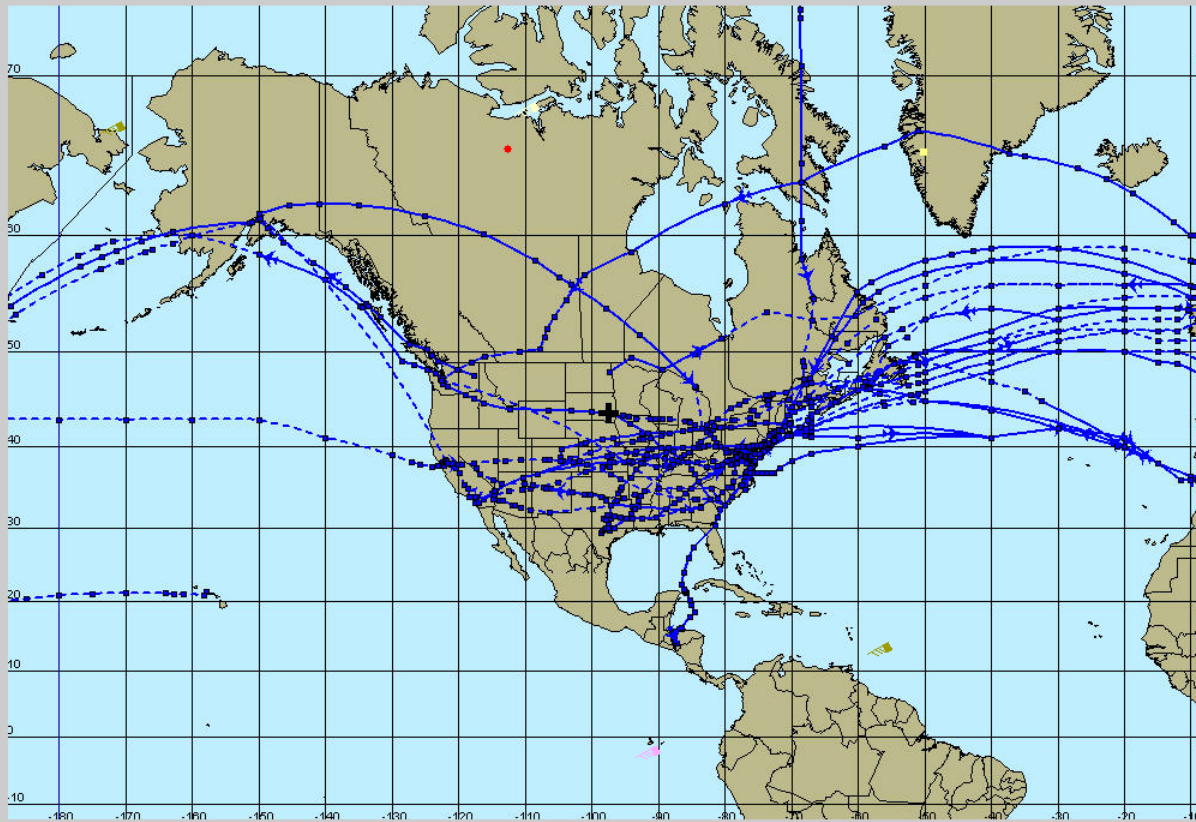


Set Size 6



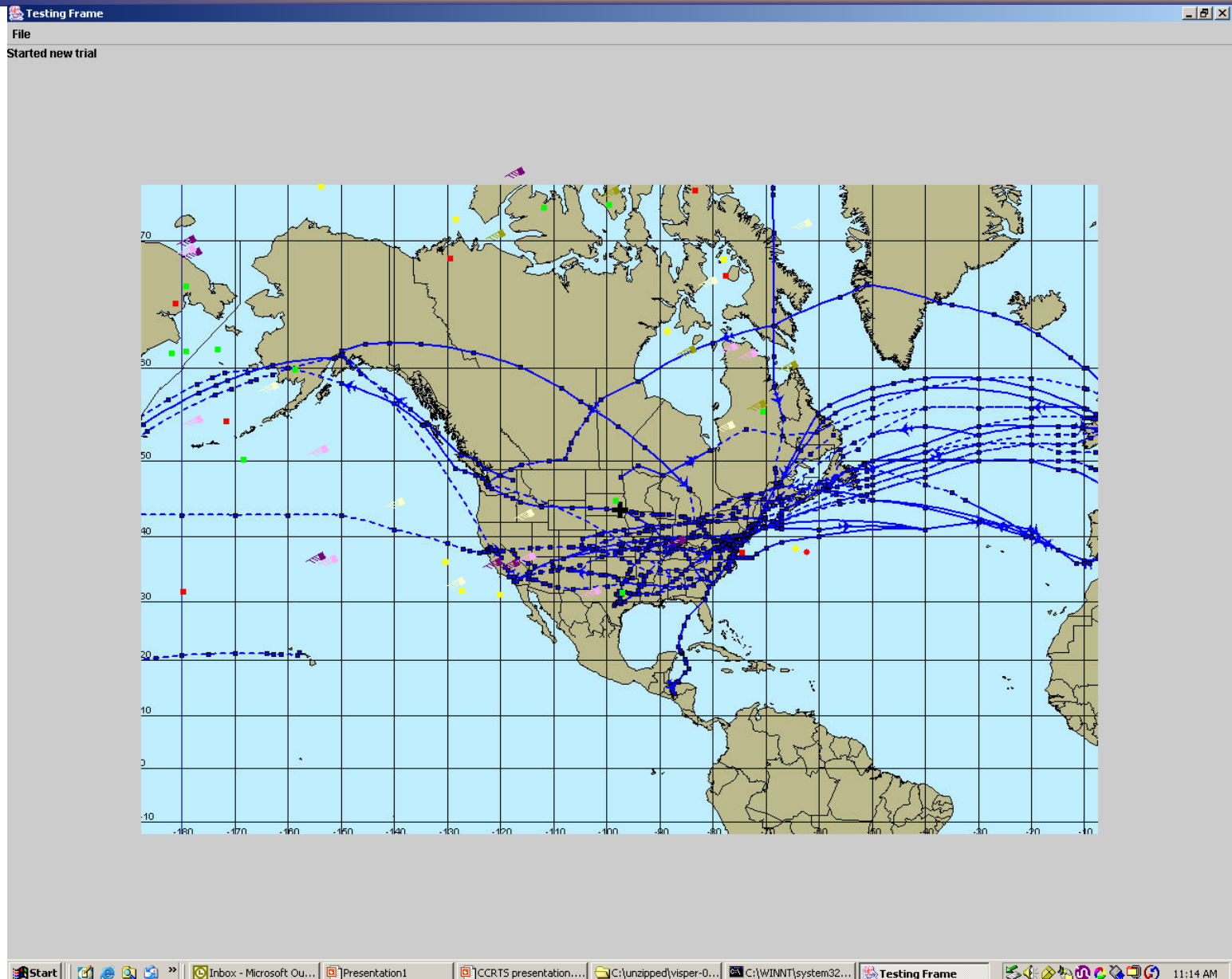
Testing Frame

File
Started new trial



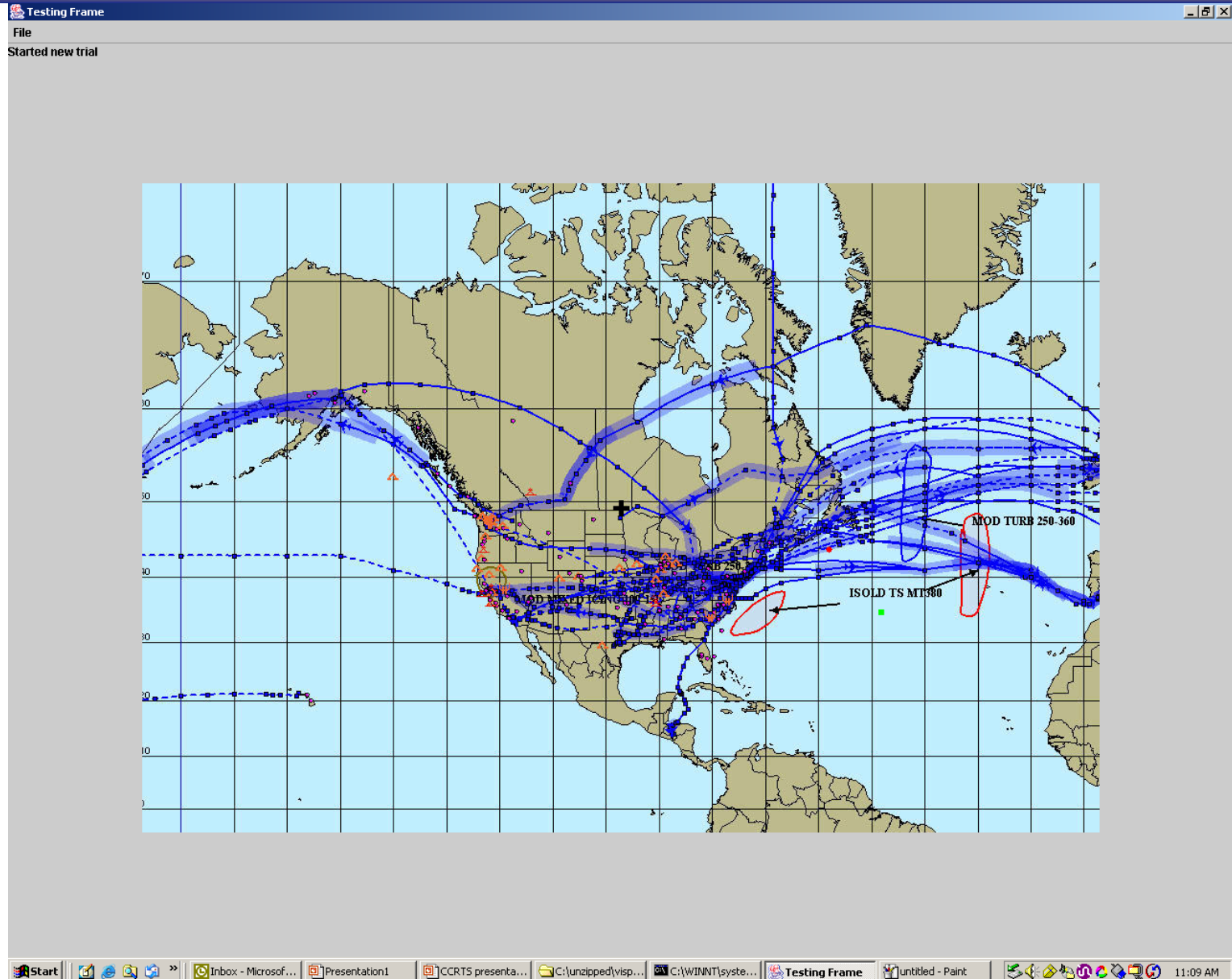


Set Size 54





Moderate Clutter





High Clutter

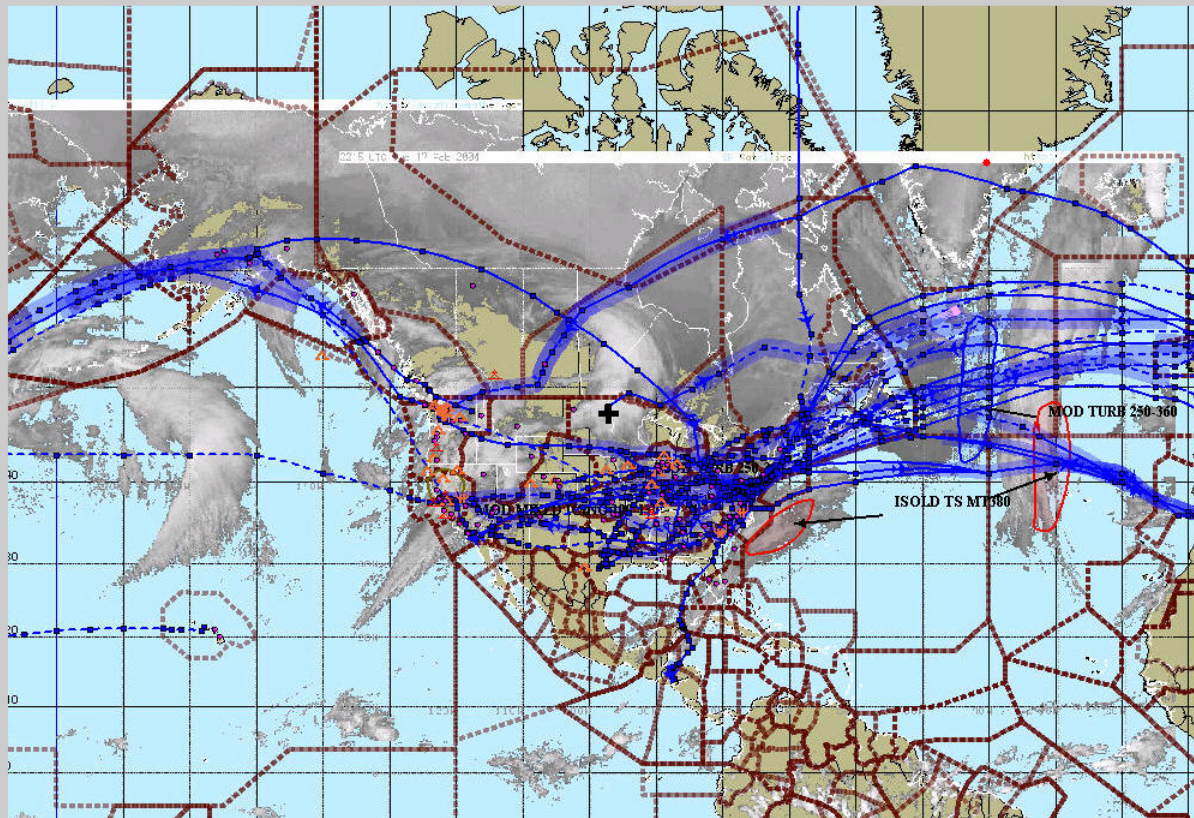


Testing Frame



File

Started new trial





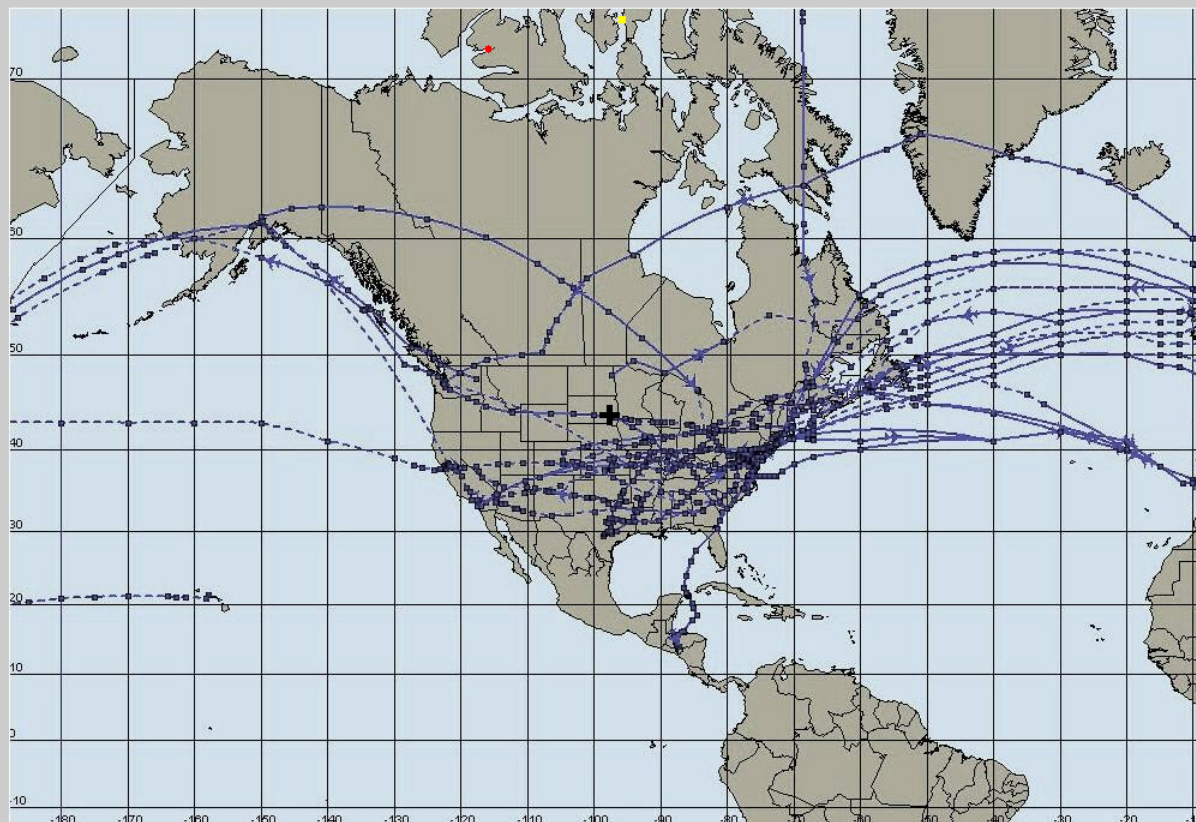
De-saturated Background



Testing Frame

File

Started new trial





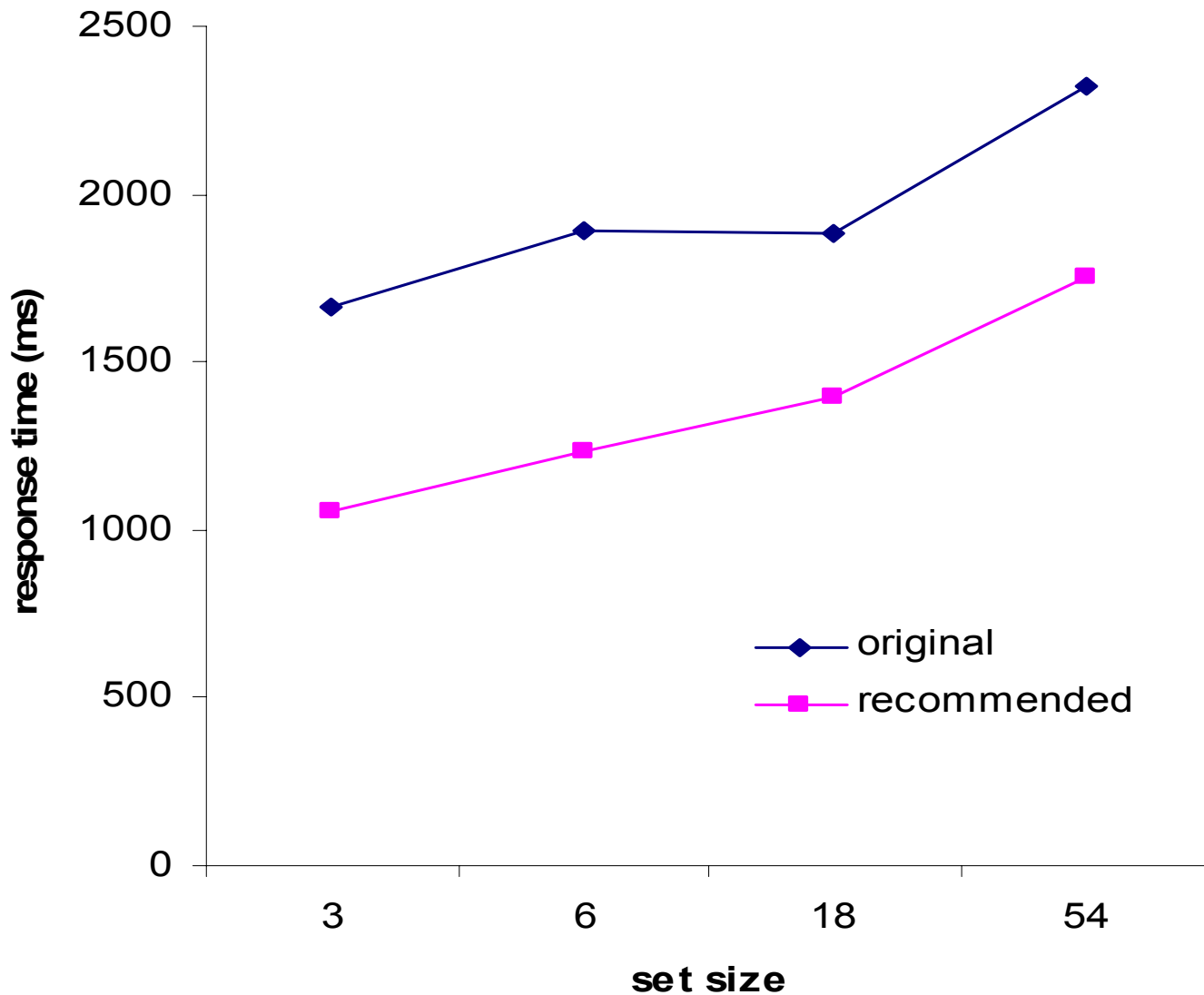
Results



- No effect of distractor symbol color
- Set size effect, $F(3, 29) = 5.9, p < 0.05$
- Effect of Clutter, $F(2, 39) = 7.1, p < 0.05$
- **Effect of de-saturation of background, $F(1, 119) = 24.6, p < 0.05$**



Background Color



Background

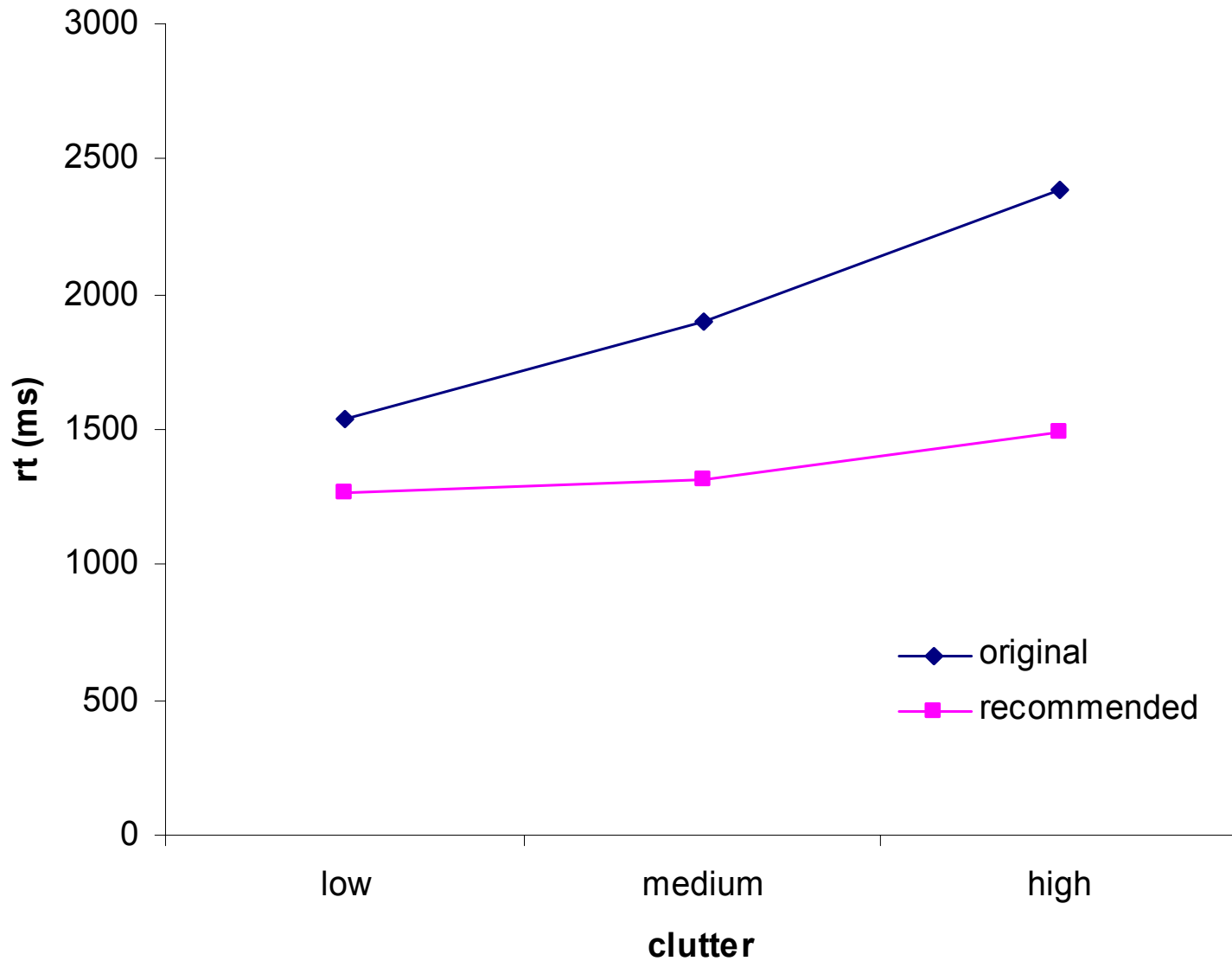
$F(1, 119) = 24.6,$
 $p < 0.05$

Set Size

$F(3, 29) = 5.9,$
 $p < 0.05$



Background Color



Background

$F(1, 59) = 24.6,$
 $p < 0.05$

Clutter

$F(2, 39) = 7.1,$
 $p < 0.05$



Discussion



- **Search task felt to be effective method of testing color sets in this type of display**
- **Verified that background color de-saturation was effective in speeding search for target**
- **Method was sensitive to set size effects and effects of clutter**
- **Selected task for future research with color sets and transparency**



Future Research



- **TRANSPARENCY**
 - Perceptual phenomenon
 - Factors leading to / improving the perception of transparency much studied
 - Perception of transparency as a visual feature not studied
- **MORE COLOR SETS**



??? QUESTIONS ???

