# ATM – Weather and Data Integration 101

## Concept Overview and Examples

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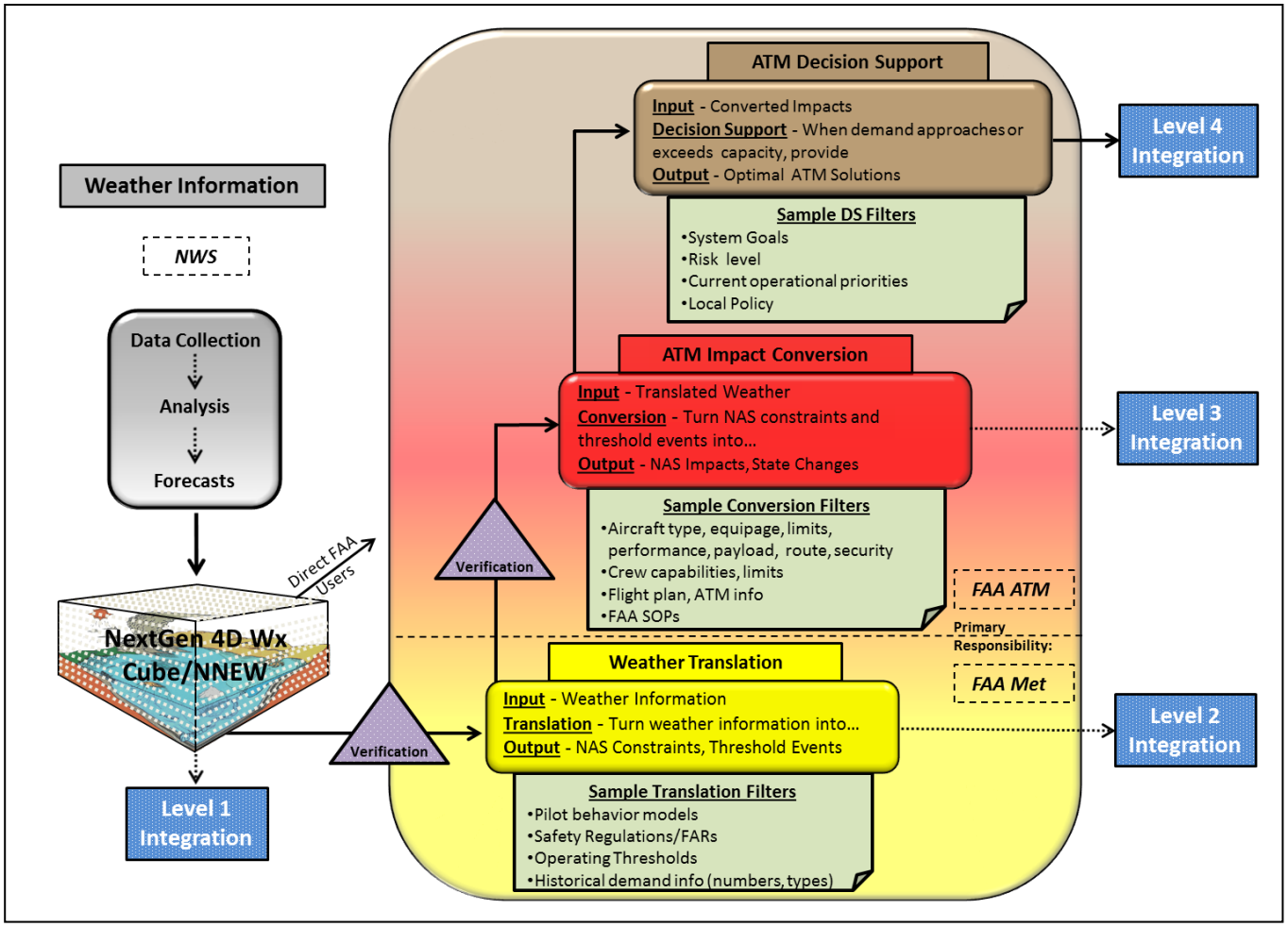
# Outline

- **Terms and Concept Explained**
  - Weather Integration
  - Levels of Integration
  - Weather Translation (getting beyond “weather”)
    - NAS Constraint:
      - Weather Avoidance Field (WAF)
    - Threshold Event
  - Impact Conversion (integrating air traffic)
  - Decision Support (optimizing solutions)
- **Examples**
  - Threshold Event
  - NAS Constraint

# What Is Weather Integration?


- Weather information, combined with other data elements, used in the logic of ATM decisions.



# Why Do We Need It?

- Weather disruptions are not off-nominal events, but rather cause the majority of NAS delays (estimated at 70%)
- The main goal of integrating weather into future decision support systems is to increase overall NAS efficiency by:
  - Standardizing the decision process and outcome (predictability)
  - Allowing full and continuous use of enhanced/automated tools during weather events
  - Lessening the burden on traffic management personnel who must manually process multiple information sources
  - Facilitating a more proactive approach to traffic management

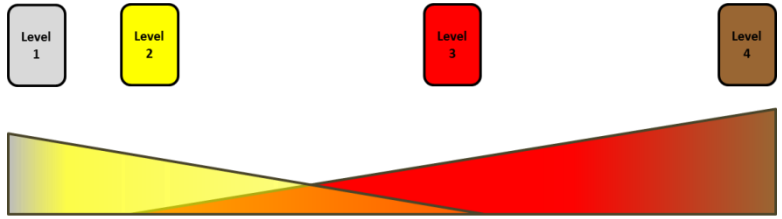
# What's the Big Deal?

## Why haven't we had Weather Integration in the past?

- Weather is everywhere: en route, terminal, the airport environment, and in space – no single domain "owns" it
- Weather will always have an element of uncertainty – although advancements in technology have vastly improved the accuracy of weather forecasting, it is still far from being an exact science
- Solutions to traffic management problems can be fundamentally complex in and of themselves – when system developers try to add probabilistic weather constraints to the mix while staying within budgetary and time limits, it is not uncommon for that work to be pushed off to the "next" phase.
- Bottom line - it's not simple to integrate weather, but it can and must be done!

# Who's Responsible for Weather Integration?

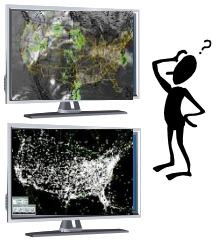
- The National Weather Service (NWS) and FAA Meteorology (FAA Met) are responsible for delivering weather "products"
- FAA Met owns "translating" that information into NAS Constraints and Threshold Events (must work with ATM community to incorporate additional data elements)
- FAA ATM is responsible for determining impact and developing optimized solutions (must provide operational requirements to FAA Met/NWS)
- **These are not stand-alone processes – they must be developed through partnerships and work seamlessly together**



# Questions About Weather Integration

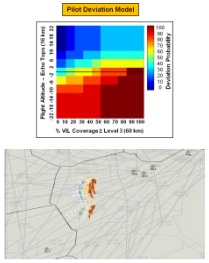
- Don't we just need better forecasts? Isn't that the main requirement for the NWS?
  - We will always need better forecasts and fidelity of weather data; however, simply having better information does not address the issues associated with needing weather integration (i.e., increased use of automation, allowing the continued use of NextGen automation systems, standardized decision making, and a reduced workload)
- Is having weather on the display weather integration? Do we need more than that?
  - Adding weather to the display increases situational awareness and is considered the first, preliminary stage of integration; however, all decision-making remains completely manual and at the discretion of the Traffic Manager (and this stops well short of weather integration goals)
- What is the first step in integrating weather?
  - There are different levels of integration….. (see next slide)

# Levels of ATM-Weather Integration

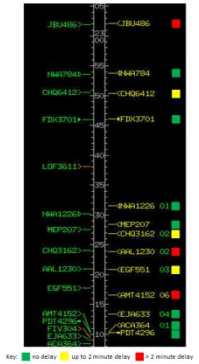


- Level Zero – No integration

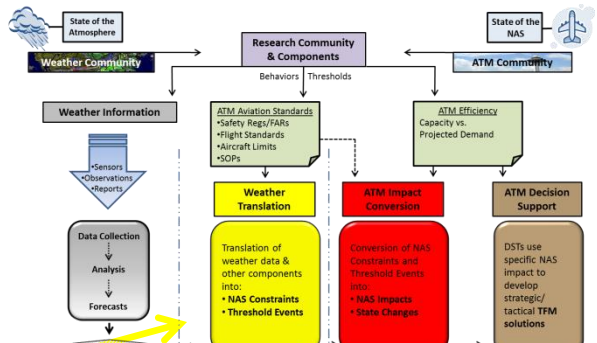
- Level One – “On-the-Glass”



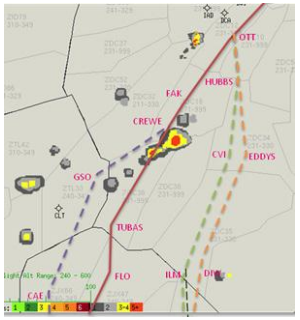

- Level Two – Translation



- Level Three – Impact

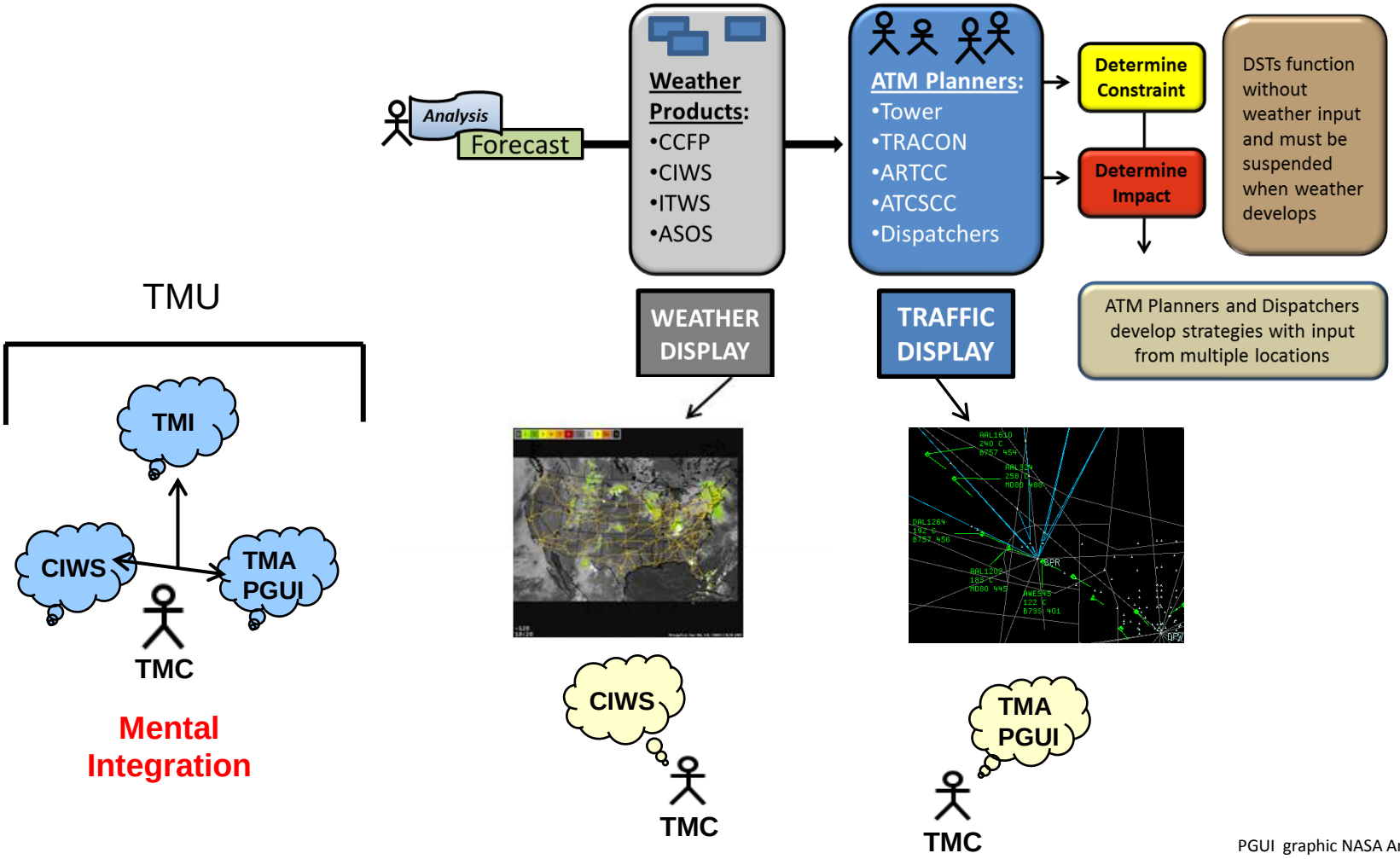



- Level Four – Decision Support



# ⊕ ATM-Weather Integration Level 0

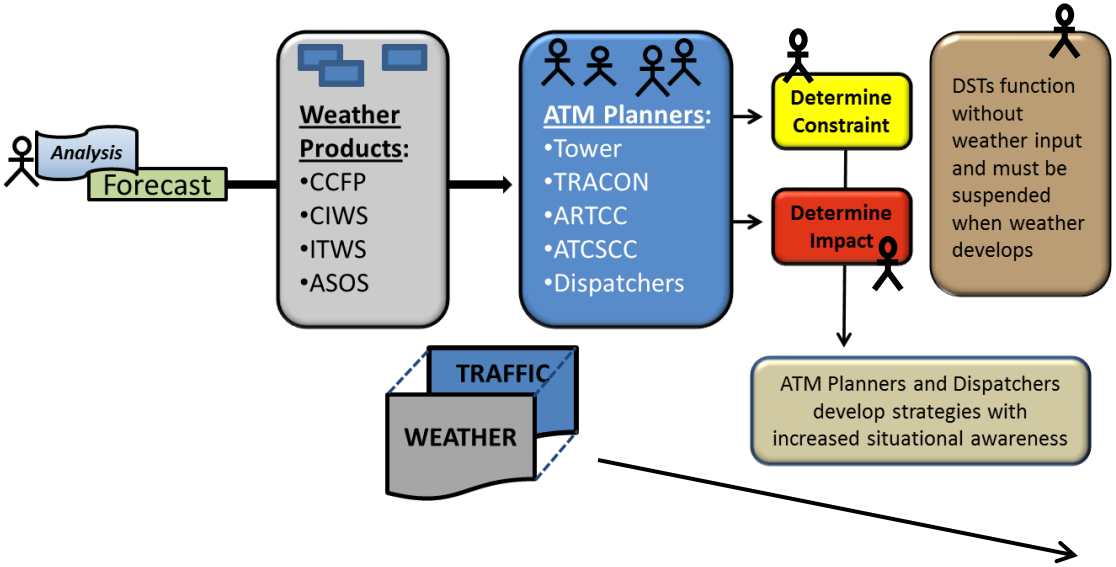
## Stand Alone Displays – Manually Intensive

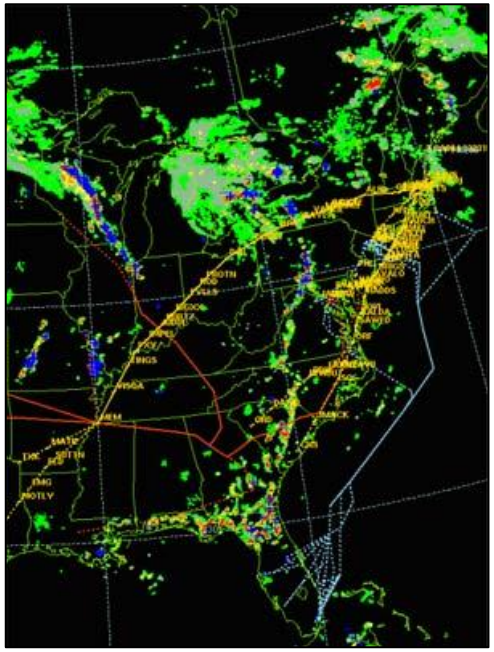



PGUI graphic NASA Ames, 2008
CIWS graphic NWS

# ATM-Weather Integration Level 1

## ”On-the-Glass” or Consolidated Weather Products - Provides Increased Situational Awareness



**Weather and traffic displayed on the same screen; provides <u>better situational awareness</u> but remains a manual, subjective, and <u>labor intensive</u> process.**

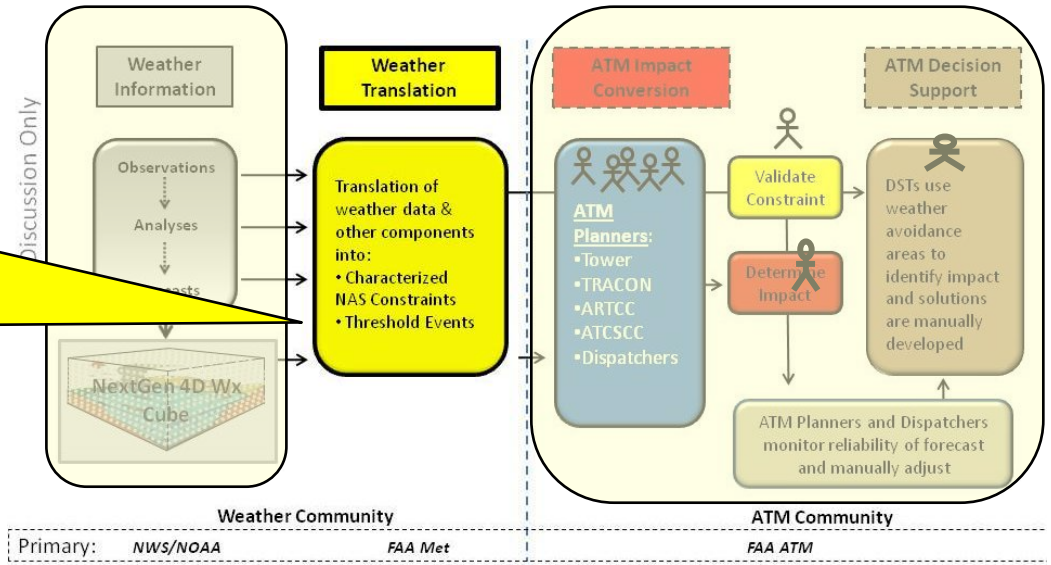
ETMS Graphic: Volpe

# ATM-Weather Integration Level 2a

## "NAS Constraints"

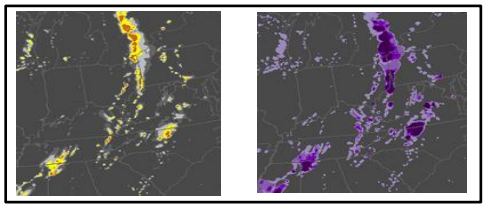
"Translation of weather data and other components into NAS Constraints."

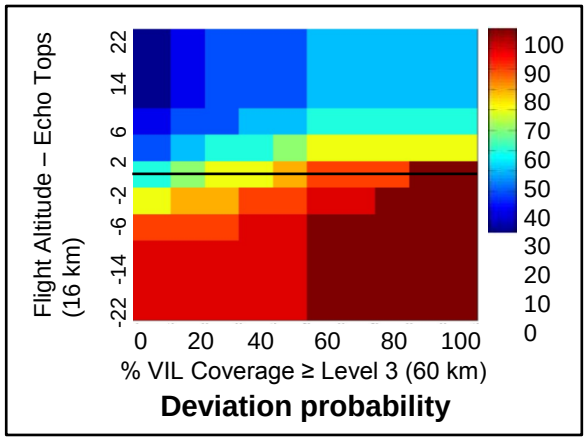
**(Capacity Estimation)**




**Example:**
**A WAF is used by RAPT, which identifies routes that are blocked but does not calculate actual impact**

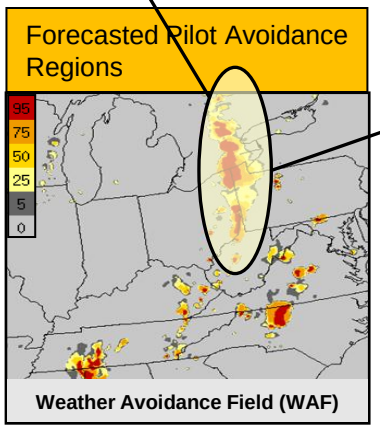
Precipitation & Echo Tops Forecast






Constrained areas with associated probabilities

No actual traffic has been applied to determine impact

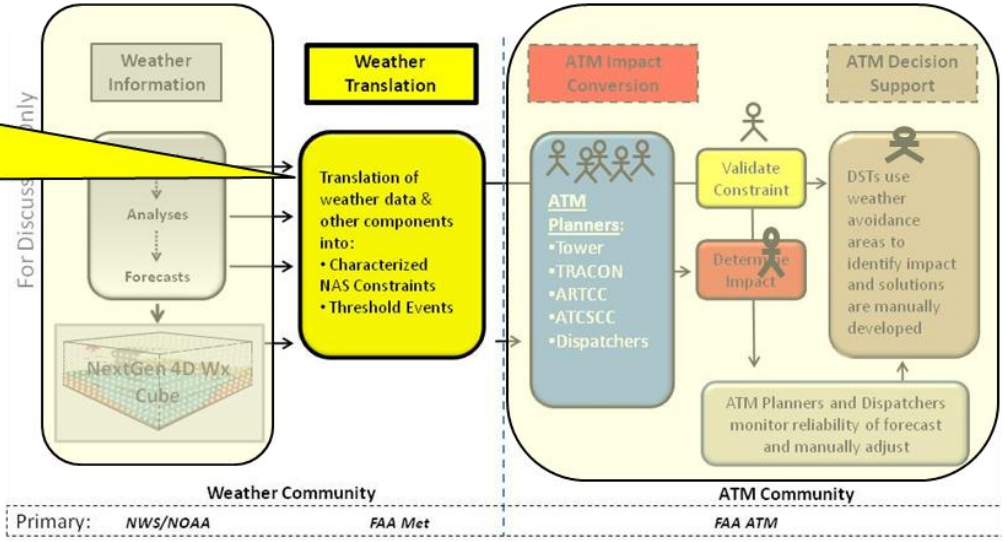



WAF Graphics MIT-LL

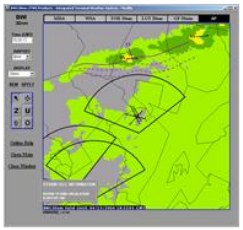
# ATM-Weather Integration Level 2b

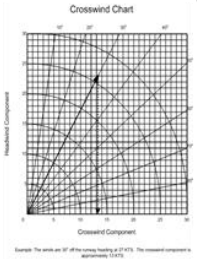
**"Threshold Events"**

"Translation of weather data and other components into Threshold Events"




**INPUT**




**OUTPUT**

**Notification that a <u>threshold is likely to be crossed</u> and a change may be required**

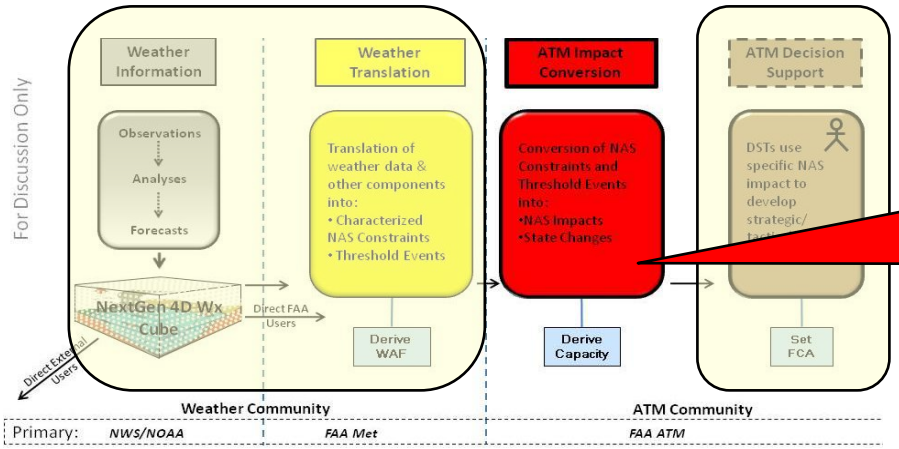
**Example:**
**ITWS takes weather information and matches it against predetermined values to provide a wind shear alert**

**Event times are determined with associated probabilities**

**No <u>actual</u> traffic has been applied to determine Impact**

# ATM-Weather Integration Level 3a

## "NAS Impacts"




"Conversion of NAS constraints into NAS impacts."

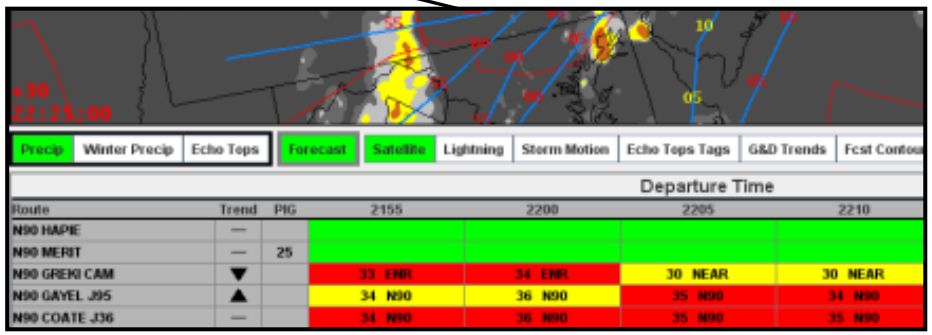
**Capacity, Demand, and Impact Calculation**

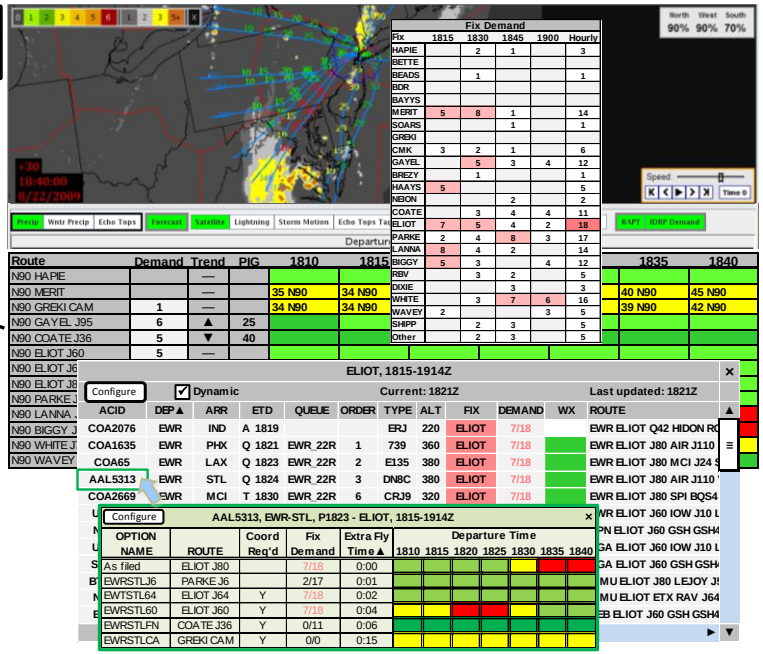
**Example:**
**IDRP applies known traffic to routes monitored by RAPT**

**Impact is represented as available capacity vs. demand. TMCs must still develop a plan**

**IDRP applies actual traffic projected through the constrained area to provide impact**

**RAPT applies constraint information to departure routes**

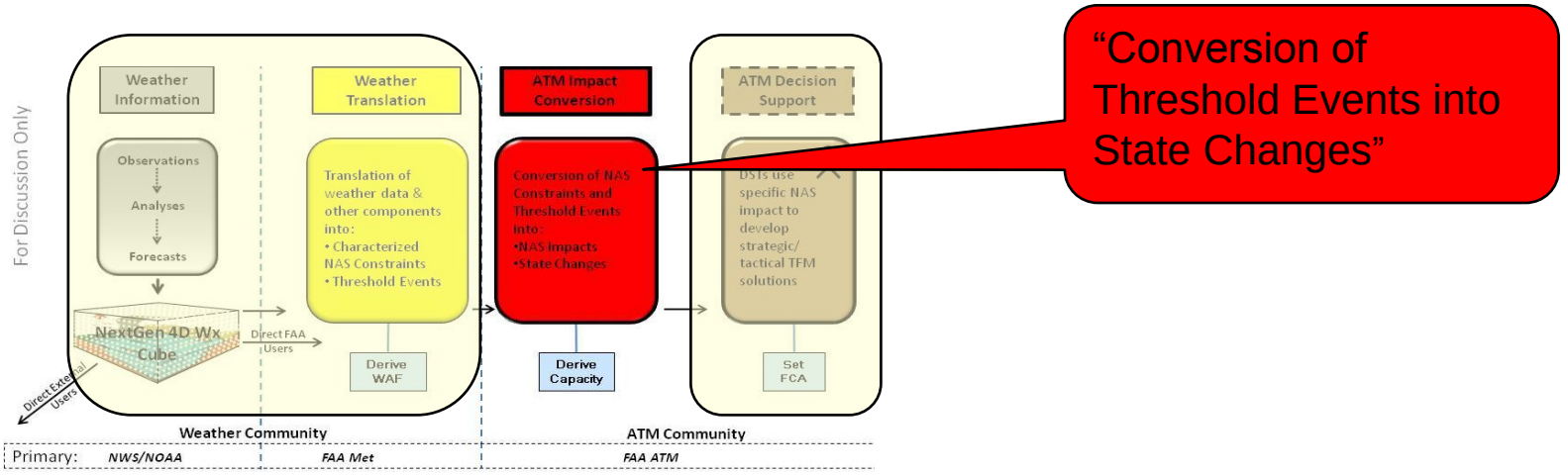



IDRP Graphics MITRE/ MIT LL

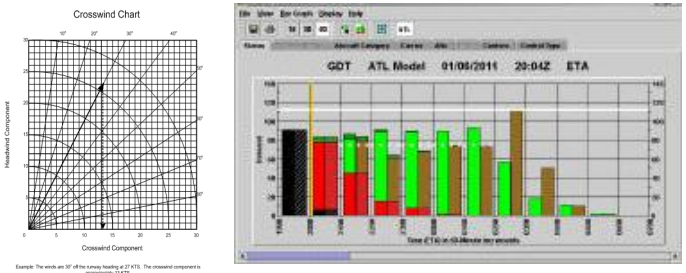
# ATM-Weather Integration Level 3b

**"State Changes"**




**INPUT**

ALERT +




+ =

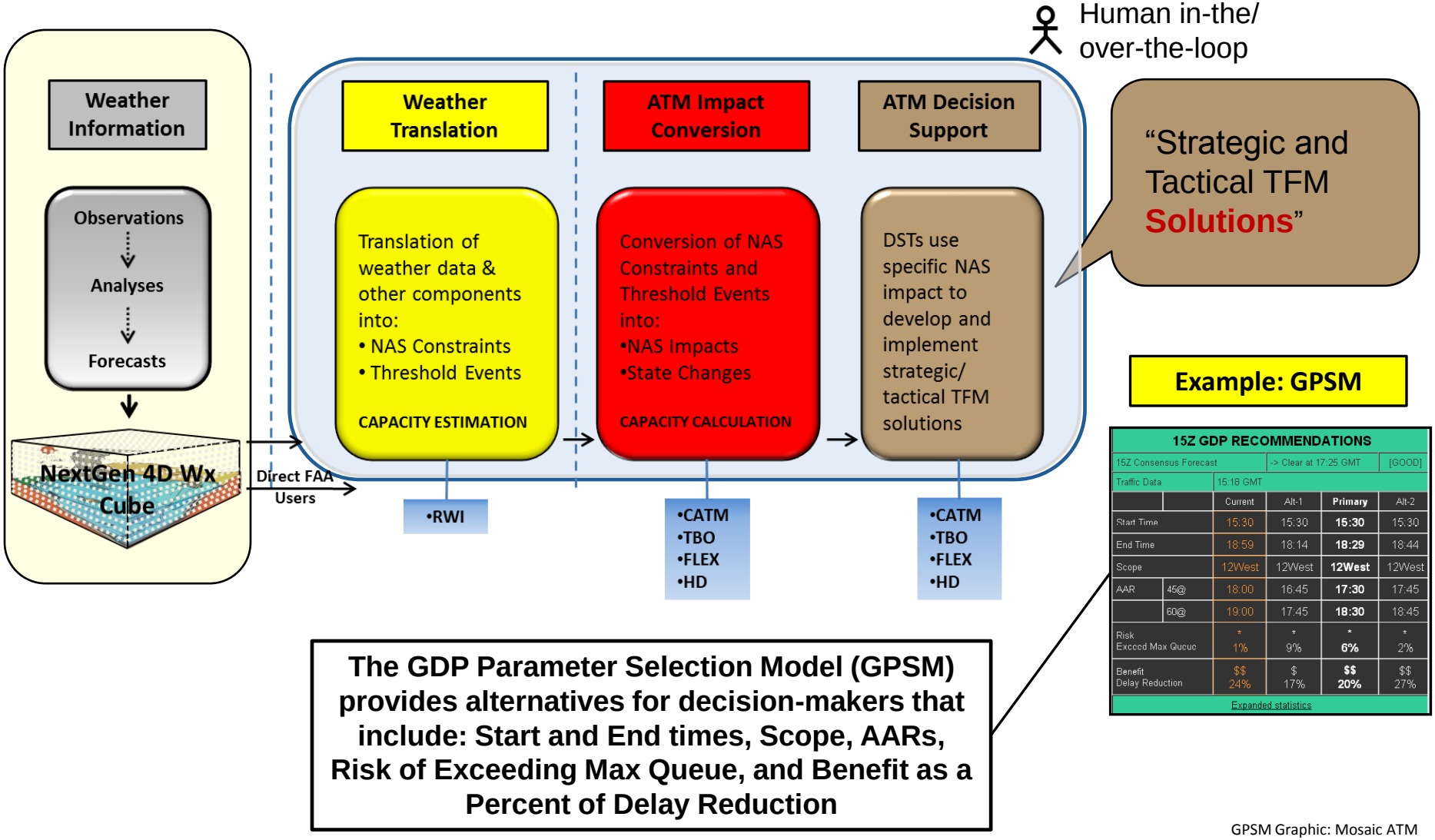
**OUTPUT**

**Addition of specific traffic and other data elements (aircraft type, limitations, user preferences) provides a measure of impact and optimized input for DSTs and human decision makers**

FSM Demand Graph FAA

# ATM-Weather Integration Level 4

## Machine-to-Machine Integration with Full "What-If" Decision Support




**Example: GPSM**

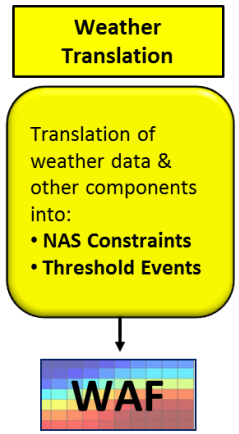
| 15Z GDP RECOMMENDATIONS | | | | | |
|---|---|---|---|---|---|
| 15Z Consensus Forecast | | -> Clear at 17:25 GMT | | | [GOOD] |
| Traffic Data | | 15:18 GMT | | | |
| | | Current | Alt-1 | **Primary** | Alt-2 |
| Start Time | | 15:30 | 15:30 | **15:30** | 15:30 |
| End Time | | 18:59 | 18:14 | **18:29** | 18:44 |
| Scope | | 12West | 12West | **12West** | 12West |
| AAR | 45@ | 18:00 | 16:45 | **17:30** | 17:45 |
| | 60@ | 19:00 | 17:45 | **18:30** | 18:45 |
| Risk Exceed Max Queue | | * 1% | * 9% | * **6%** | * 2% |
| Benefit Delay Reduction | | $$ 24% | $ 17% | $$ **20%** | $$ 27% |
| Expanded statistics | | | | | |

**The GDP Parameter Selection Model (GPSM) provides alternatives for decision-makers that include: Start and End times, Scope, AARs, Risk of Exceeding Max Queue, and Benefit as a Percent of Delay Reduction**

GPSM Graphic: Mosaic ATM


# Weather Translation

- ("Yellow Box") The process of taking weather data and combining it with other data elements such as pilot behavior models, safety regulations, operating thresholds, and historical demand information to arrive at a graphic depiction of where capacity will be reduced, or a threshold crossed. There are two outputs:




**Primary Responsibility: FAA MET**

  - **NAS Constraint**: (applies to airborne traffic and depicted as a WAF) Is currently

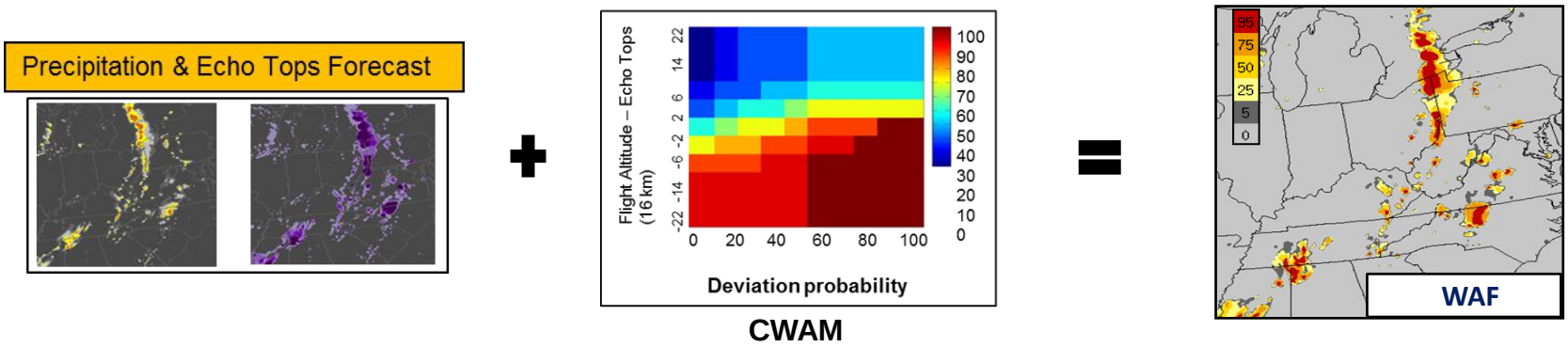
    The degree to which the weather hazard would constrain the affected NAS element in the presence of air traffic – permeability.

  - **Threshold Event**: (applies to the airport environment)

    When a non-hazardous atmospheric parameter such as ceiling, visibility, or wind speed crosses an operating threshold and may result in an associated change to configuration or arrival rate.

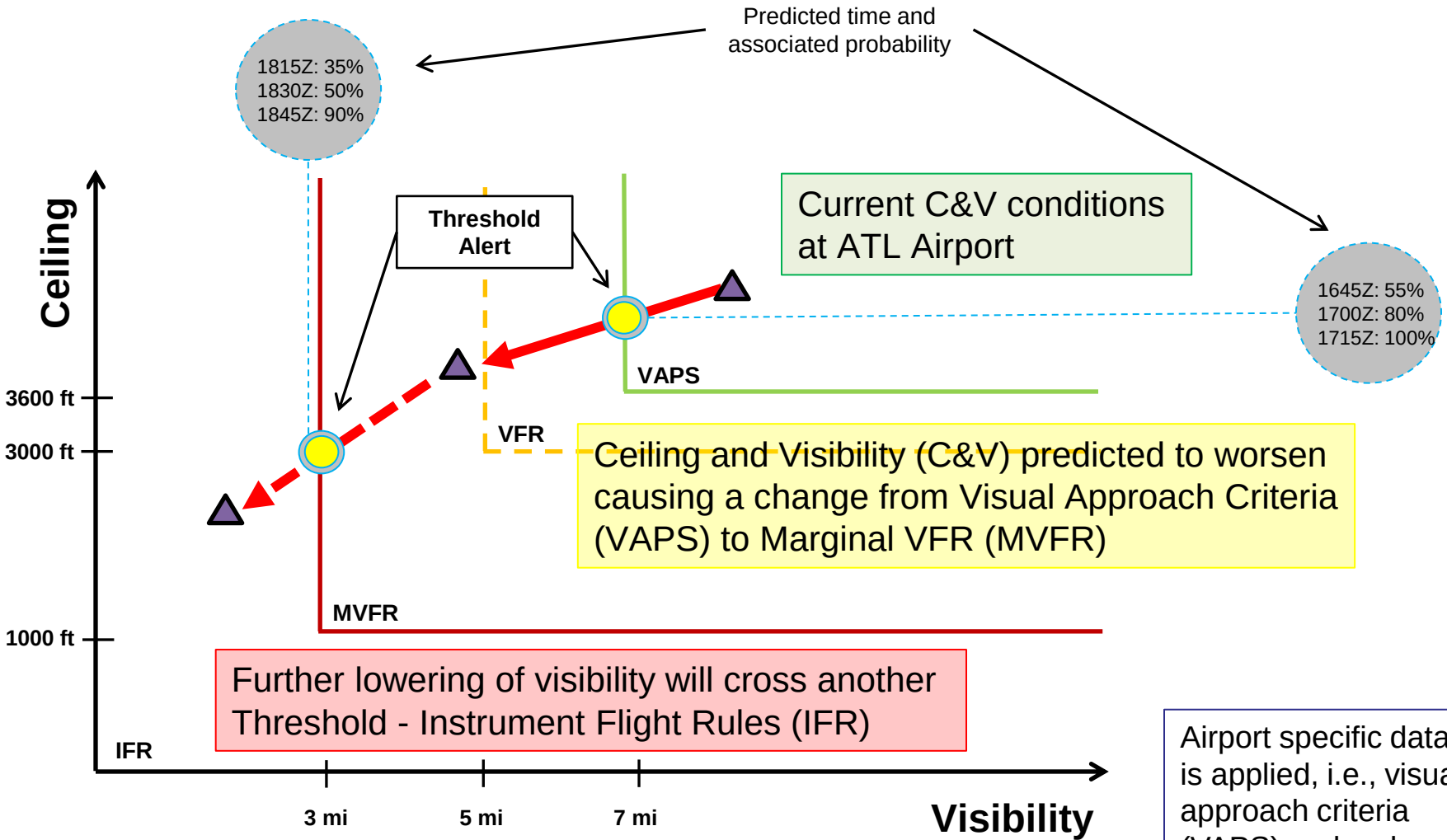
# Weather Avoidance Field (WAF)

- There are a growing number of WAF products, each with a slightly different name (think Kleenex). What is generally being depicted is the probable reduction to capacity, or Capacity Reduction Area (think tissue).
- The WAF should be considered an indication of airspace permeability as opposed to a “no fly” area. The WAF (or Capacity Reduction Area) associated with convective activity is the current output of Translation.




Weather, CWAM, and WAF Graphic MIT-LL

# Anatomy of a Threshold Event




Airport specific data is applied, i.e., visual approach criteria (VAPS), or local CSPO ceiling and visibility limits

Diagram credit: Metron Aviation


# ATM Impact Conversion

**ATM Impact Conversion**

Conversion of NAS Constraints and Threshold Events into:
- **NAS Impacts**
- **State Changes**

**Primary Responsibility: FAA ATM**

- ("Red box") This capability takes information from the weather Translation function, adds actual and projected demand, and other specific aircraft and ATM data elements, and converts it into potential NAS impacts (in the case of NAS constraints) or state changes (in the case of threshold events).
  - **NAS Impact**: (En route) The effect of the forecast weather constraint (capacity) on the individual aircraft (demand) projected to be in the affected NAS element at the same time.
  - **State Change**: (Airport) Examples include: runway configuration change, de-icing operations, longer runway occupancy times, etc. A state change may result in an increase or decrease in capacity.

# Decision Support

- ("Brown Box") The fundamental goal of Decision Support is to provide overall NAS optimization.

**ATM Decision Support**

DSTs use specific NAS impact to develop strategic/ tactical **TFM solutions**

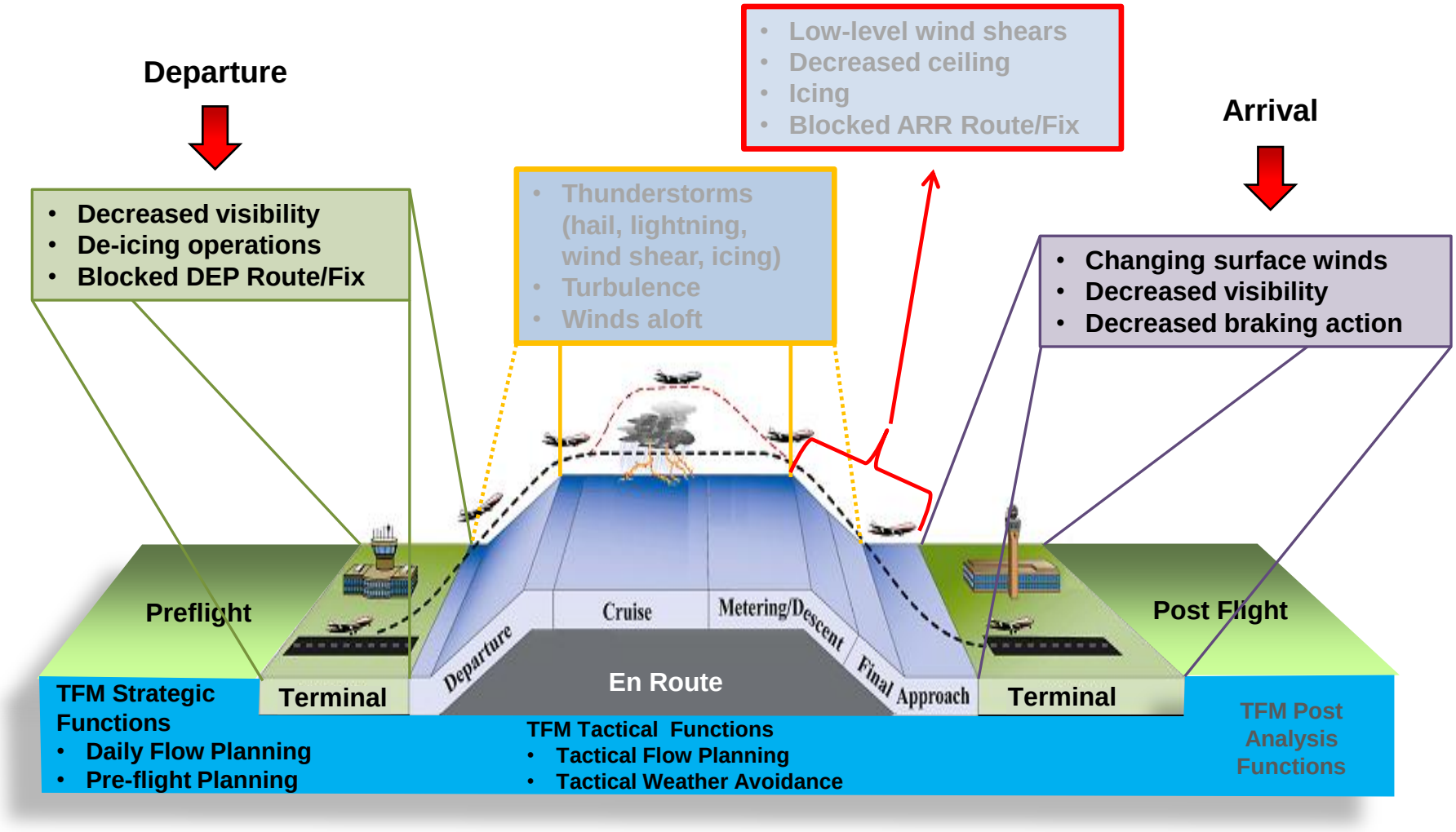
**Primary Responsibility: FAA ATM**

Impact data and state change information can be further enhanced by applying various "filters" such as sector loading figures, desired risk level, current priorities (AAR vs. DEP), current/updated constraint information, impact probabilities, local area information, and SOPs, etc. to derive mitigation options and provide "what-if" capability for traffic managers – both in the strategic and tactical time frames.

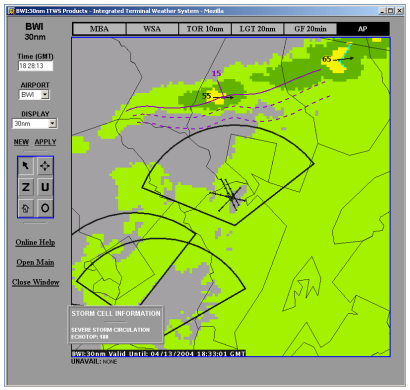
# Weather Integration Example 1: Airport Threshold Event

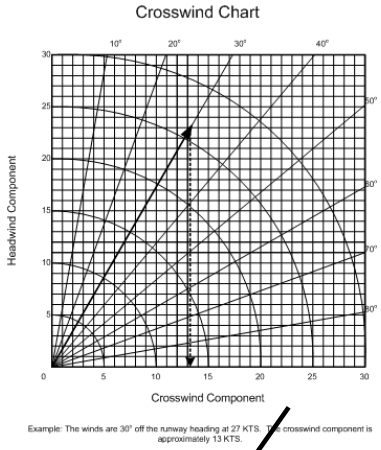
- **Solution Set –** High Density
- **Operational Improvement** – Initial Surface Traffic Management (2010-2017)
- **NSIP-B Increment** (104209-22) – Airport Configuration Management
- **Capability**: Provide continual impact assessment and recommendations for changes to airport configuration; including times that best serve the predicted demand and conditions.

# Weather Impacting Surface Operations



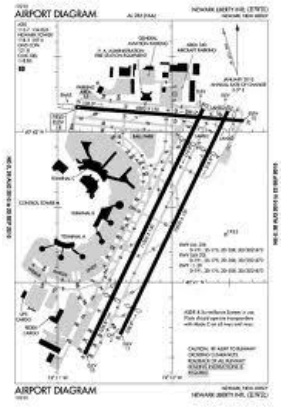
# Example of Runway Configuration Change without Weather Integration (Complex Manual Process)

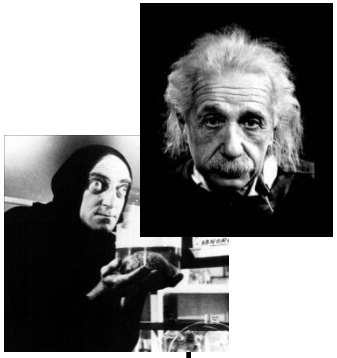


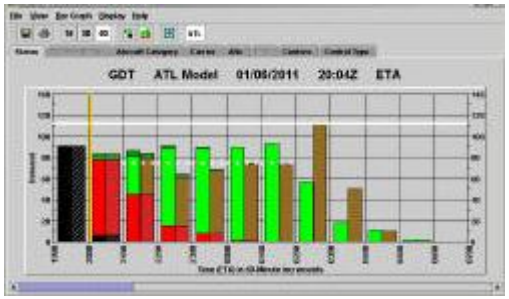





TMC



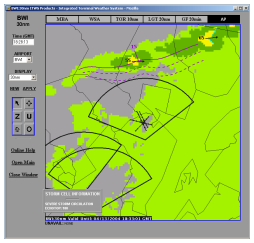



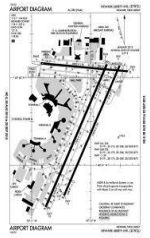


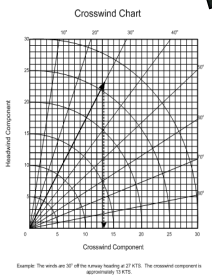

Decisions

FSM Graphic FAA
Einstein by Andrew Zimmerman Jones
Igor photo 20th Century Fox

# Example of Runway Configuration with Full Weather Integration







Amplifying Information
- Sector loading
- Risk level
- Priorities (AAR vs. DEP)
- Updated constraint info
- Local area SOPs

**Weather Translation (Level 2)**

Translation of weather data & other components into:
- **NAS Constraints**
- **Threshold Events**

**ATM Impact Conversion (Level 3)**

Conversion of NAS Constraints and Threshold Events into:
- **NAS Impacts**
- **State Changes**

**ATM Decision Support (Level 4)**

DSTs use specific NAS impact to develop strategic/ tactical **TFM solutions**

TMC

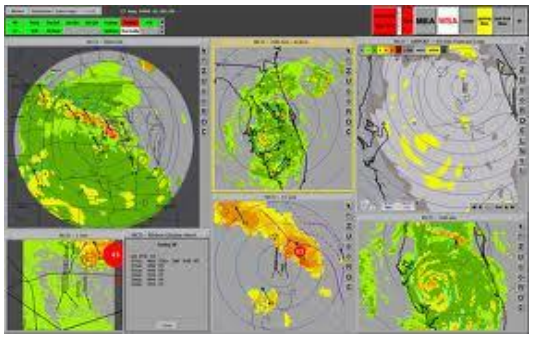
**Notification that a threshold will be crossed and a change may be required.**

**Addition of specific traffic provides impact alert and optimized input for Decision Support**

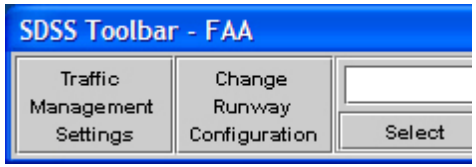
**Multiple recommendations with degrees of confidence and probability**

# Runway Configuration Change (Level 1)

- Monitor weather (**manually**):
  - Winds (speed, gust, direction)
  - Ceiling & Visibility

- Open Runway Configuration Dialog Box and manually input changes

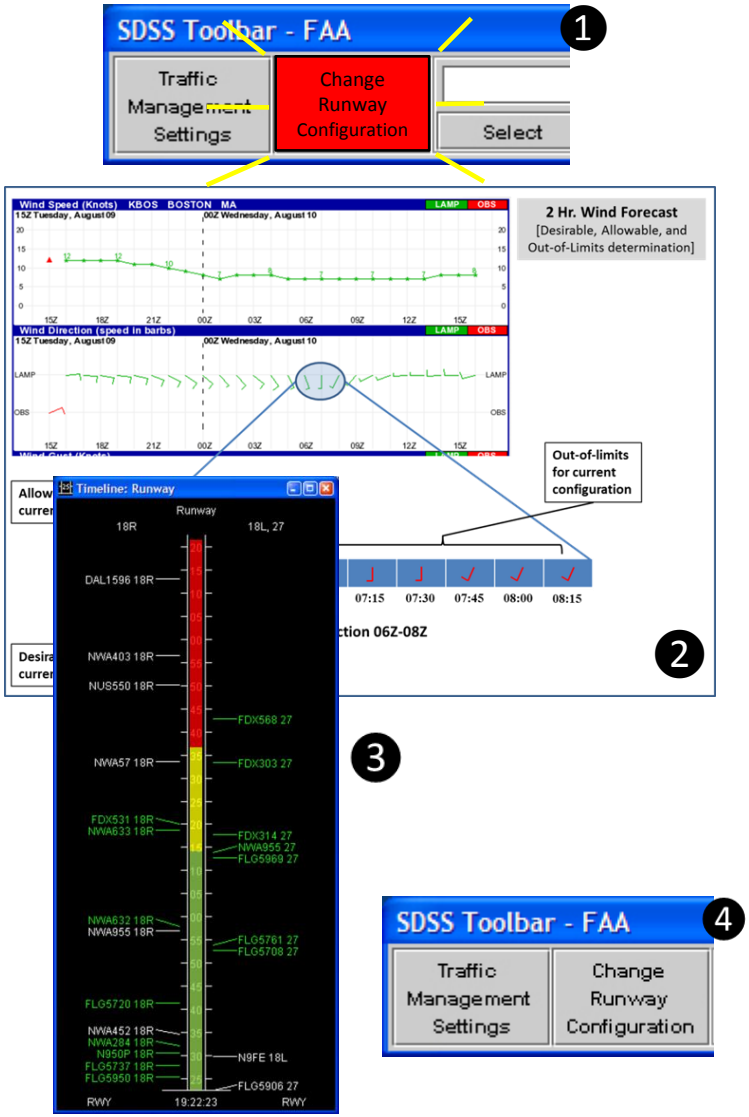



"SDSS predictions depend on knowledge of current or future airport runway configurations. SDSS does not receive this information electronically, thus users must manually enter the current runway configuration and planned future changes as soon as they are known." **SDSS User's Manual**

Graphics: SDSS User's Guide, Federal Aviation Administration (FAA), MIT Lincoln Labs.

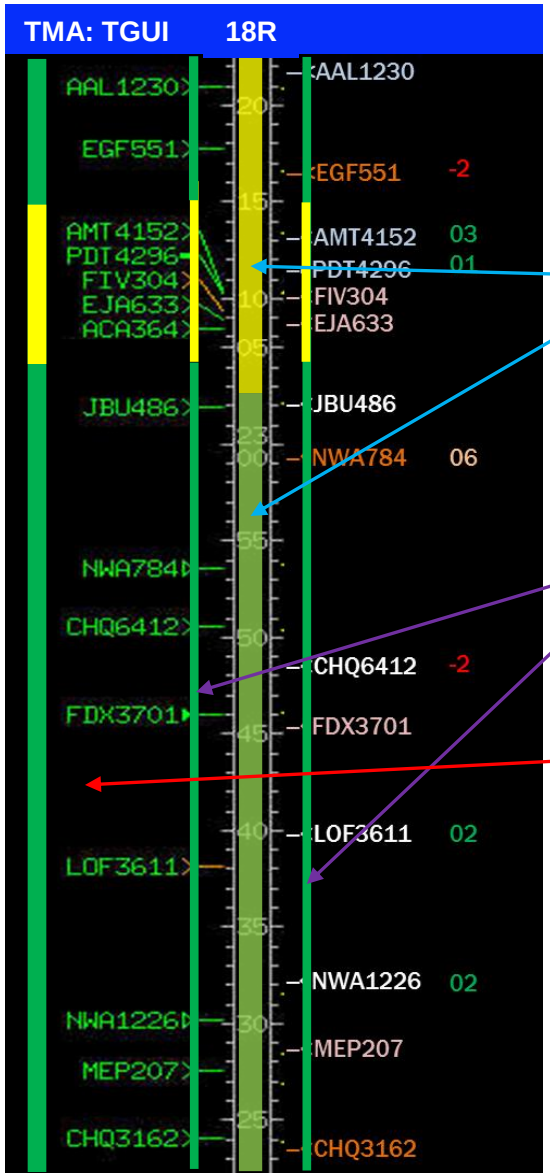
# Runway Configuration Change (Level 2)

- Forecast winds, ceiling, and visibility are **automatically** monitored along with other basic data elements (e.g., FAA regulations, local rules, runway headings and approach corridors)
- Threshold is triggered ❶ allowing:
  - Drill down of forecast ❷
  - Depiction of forecasted threshold change vs. projected runway traffic ❸
- Runway Configuration Dialog Box is manually configured ❹




Graphics: SDSS User's Guide and NWS GFS-LAMP station forecast,.

# Runway Configuration Change (Level 3)




**Weather Conditions As depicted on the TMA TGUI (l) and the SDSS rwy timeline (r)**

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**Traffic Conditions**

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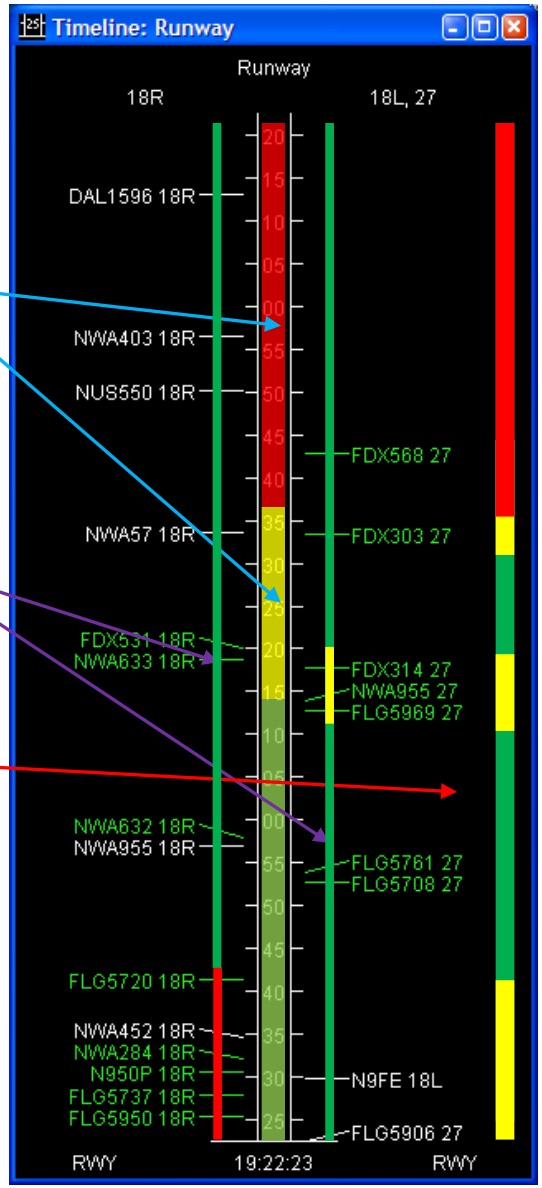
**IMPACT**

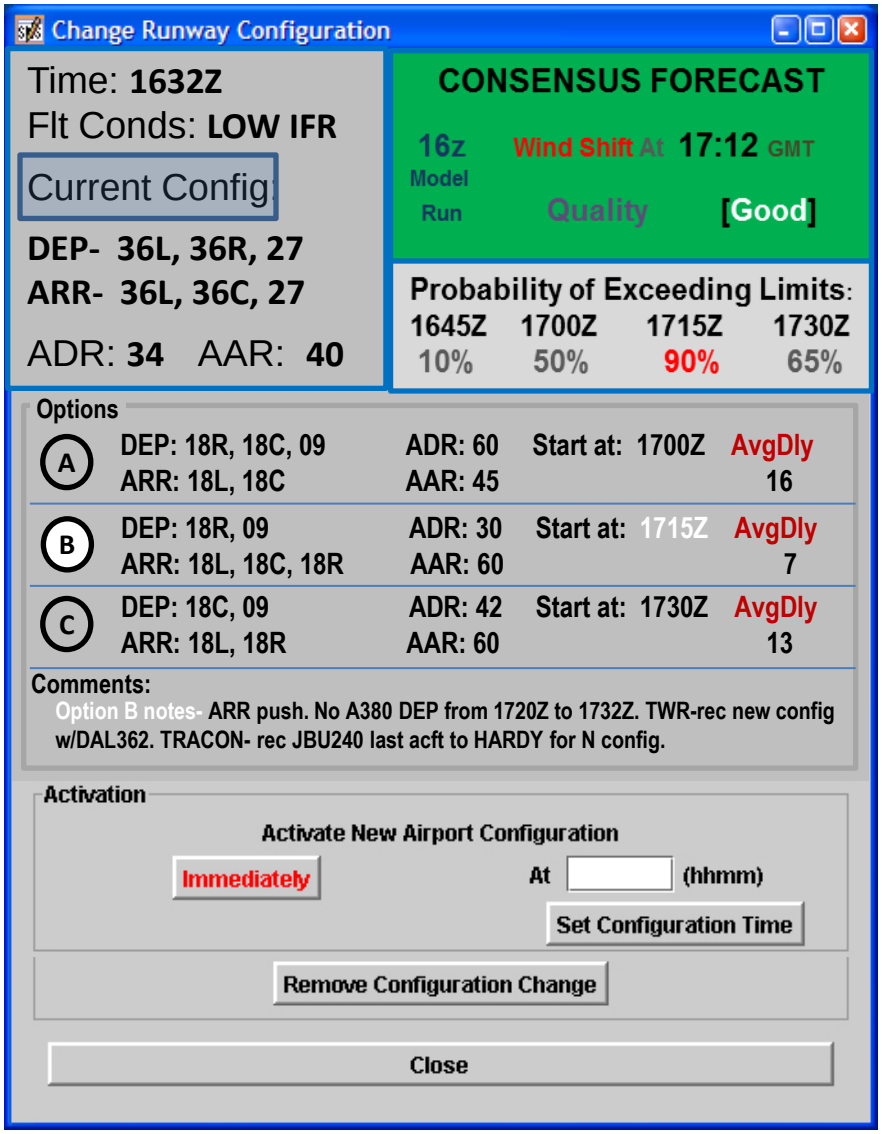
Manual judgment on if/when to change configuration




Graphics: SDSS User's Guide

# Runway Configuration Change (Level 4)

- Decision support provides optimized solutions and alternatives
- Additional data is considered by automation logic (e.g., time of impact vs. ARR/DEP demand)
- Human-in-the-loop options and “what-if” capability still available to traffic managers

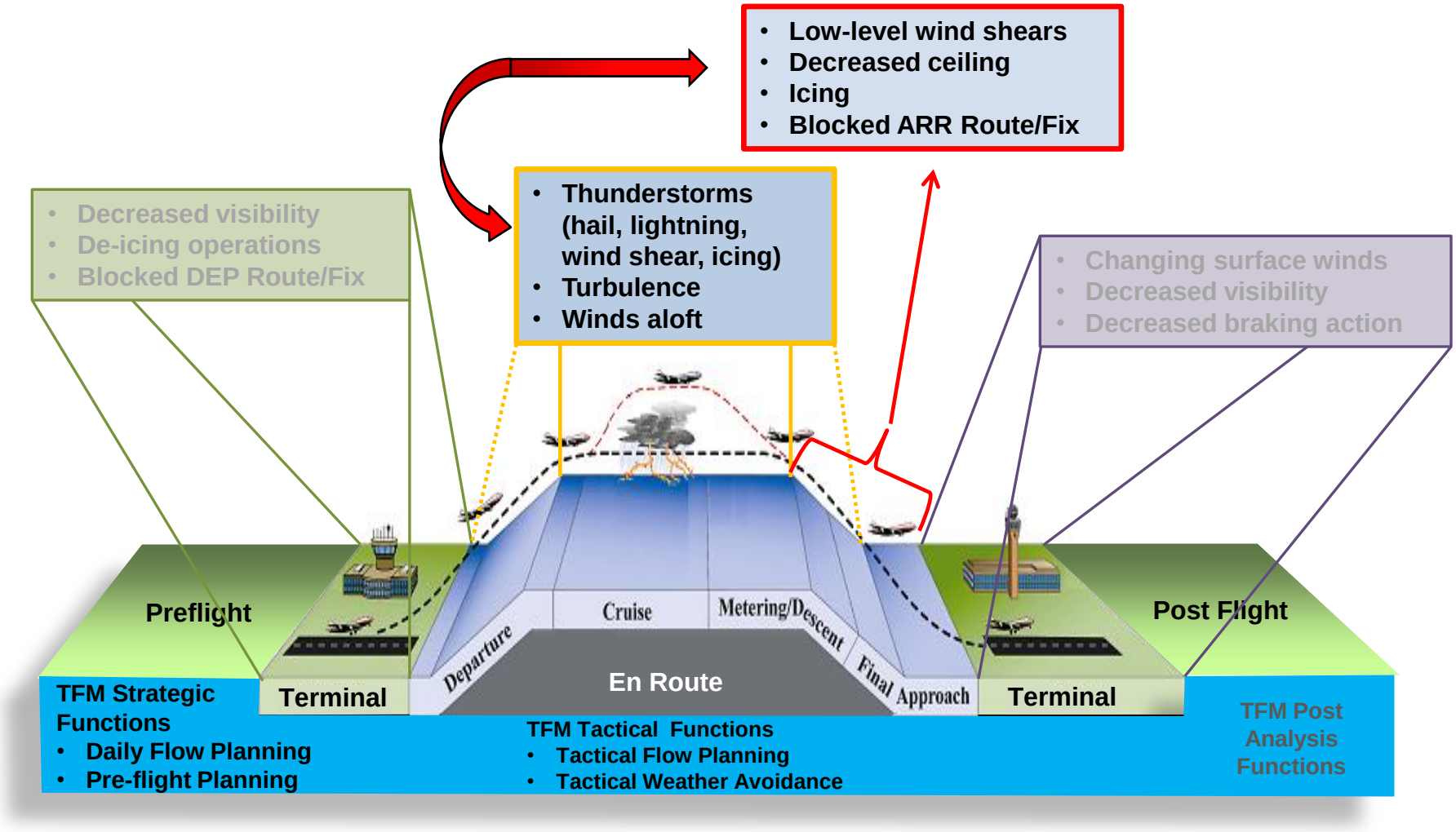



SDSS Graphic Mosaic ATM (modified)

# Weather Integration Example 2: En Route NAS Constraint

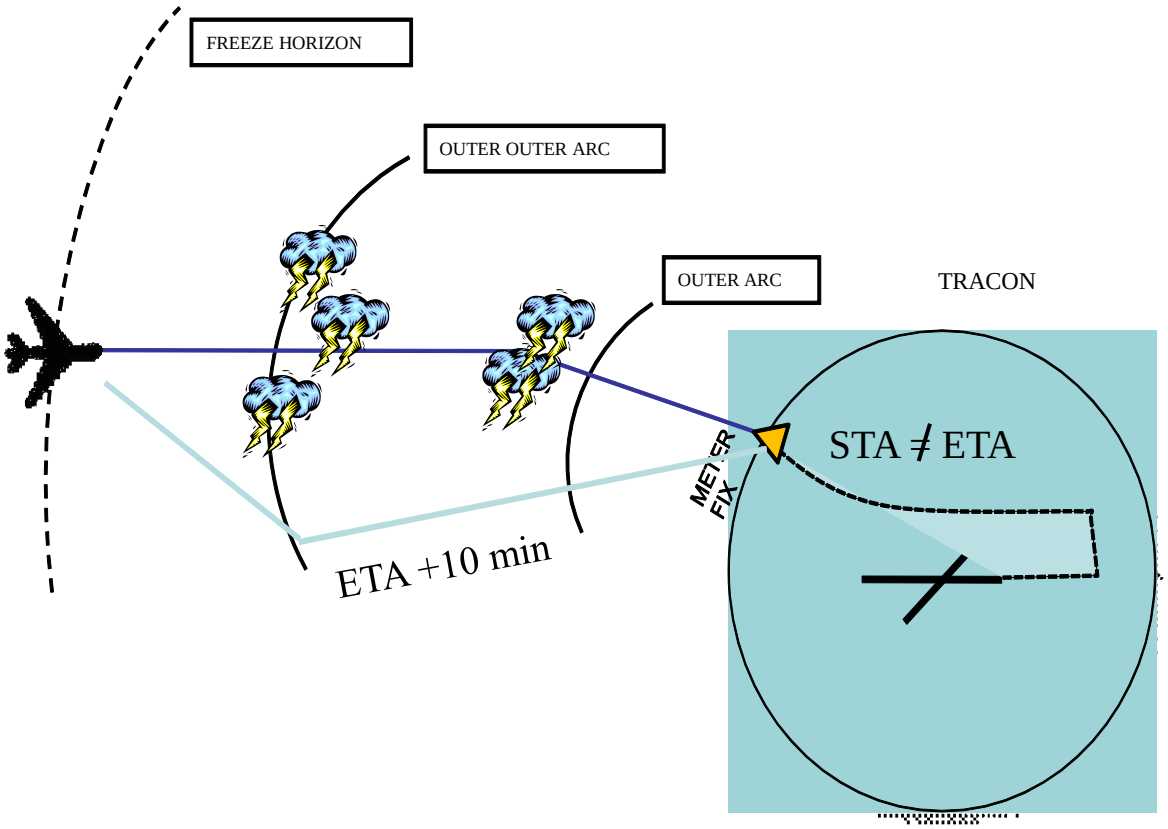
- **Solution Set –** Trajectory Based Operations (TBO)
- **Operational Improvement 102114** – Initial Conflict Resolution Advisories (2013-2017)
- **NSIP-B Increment 102114-29** – Aircraft-to-Weather Area Problem Resolution
- **Capability –** Predict intersecting aircraft-to-weather area trajectories; provide rank ordered resolutions which can be offered by the controller to the affected flight if requested

# Weather Impacting Airborne Traffic

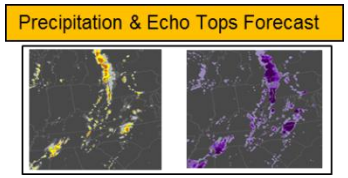


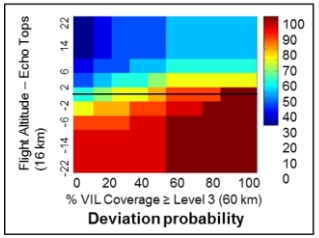
# TBFM and Hazardous Weather Today

- TBFM cannot anticipate the impact of hazardous weather on the trajectories of individual flights
- ETAs of flights diverting around hazardous weather fluctuate and STAs become unachievable
- Consequently, TBFM is discontinued in the presence of hazardous weather

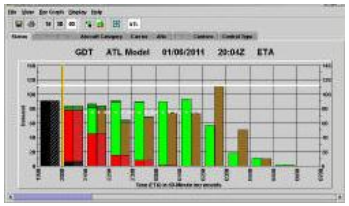


# Example of TBFM Use During Severe Weather with Full Weather Integration








Amplifying Information
- Sector loading
- Risk level
- STA/ETA deltas
- Updated constraint info
- Local area SOPs

**Weather Translation (Level 2)**

Translation of weather data & other components into:
- **NAS Constraints**
- **Threshold Events**

**ATM Impact Conversion (Level 3)**

Conversion of NAS Constraints and Threshold Events into:
- **NAS Impacts**
- **State Changes**

**ATM Decision Support (Level 4)**

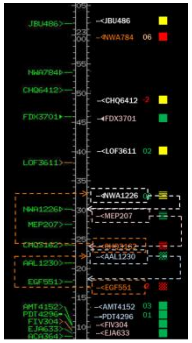
DSTs use specific NAS impact to develop strategic/ tactical **TFM solutions**

TMC

**A Weather Avoidance Field indicates an area with reduced capacity**

**Addition of specific traffic from the TGUI provides individual impact assessment**

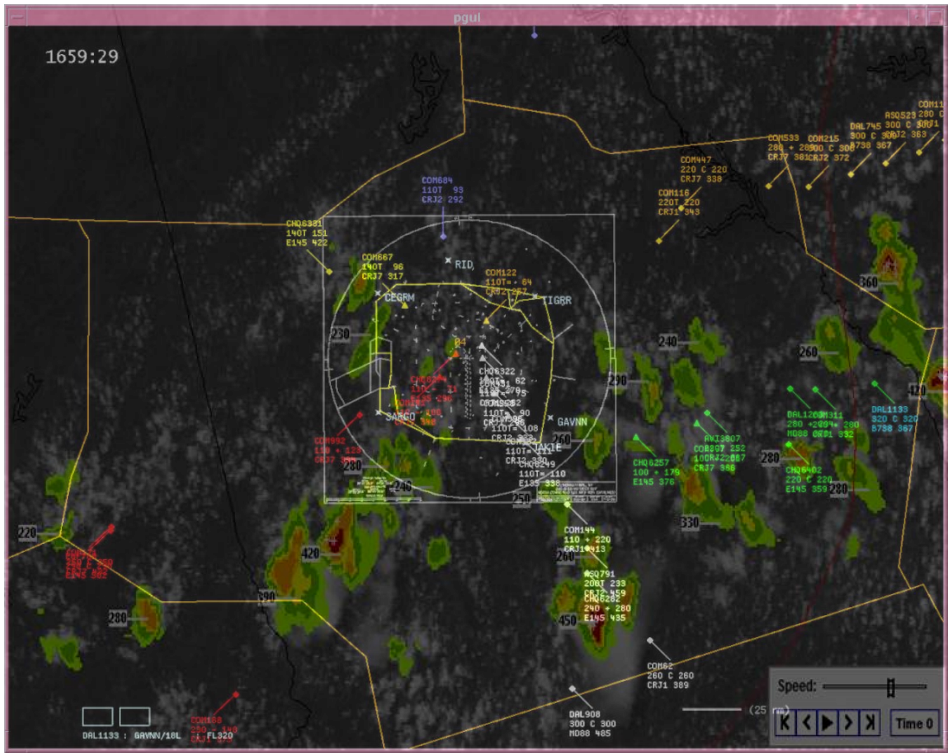
**Aircraft are considered for reordering based on weather impact and ETA/STA timing**



CWAM Graphic MIT LL

# TBFM Weather Integration Level 1: "weather on the glass"

- CIWS imagery overlay on TMA PGUI
- Schedule: Spring 2013
- Benefits
  - Increased situation awareness
  - Better understanding of relationship between traffic and weather
- Shortfalls
  - Manual impact c[illegible] ulation
  - Manual solution development

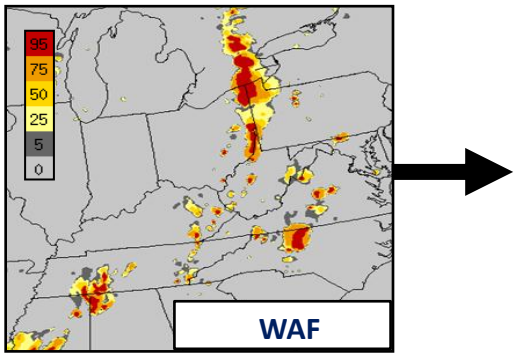


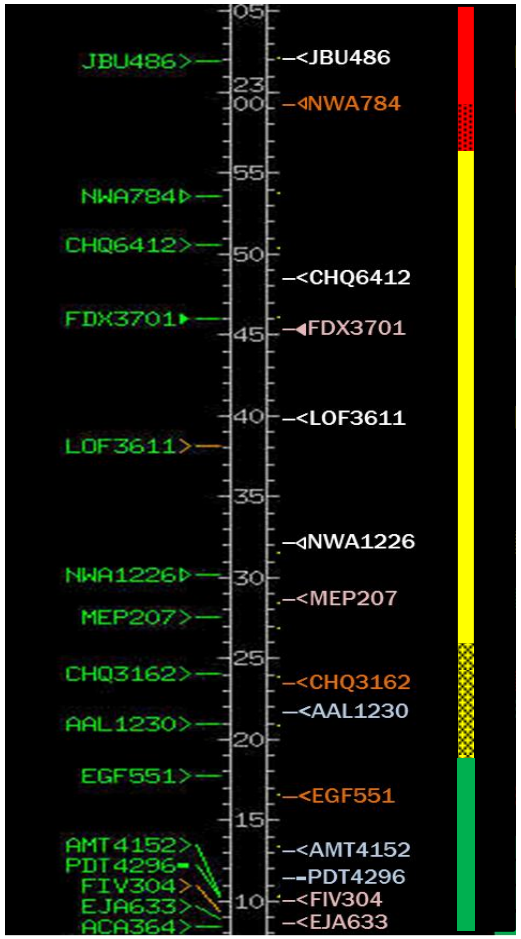

Notional illustration of TBFM PGUI with CIWS imagery overlay

TBFM Graphic FAA

# TBFM Weather Integration Level 2: Constraint Indicators

- **Weather Constraint Information**: Predicted route blockage information (from weather translation) is calculated for time and probability of occurrence
- That information is then displayed on the TMA TGUI via “stoplight” indicators
- Benefits: increased awareness of potential constraints
- Shortfalls: manual impact calculation and solution development

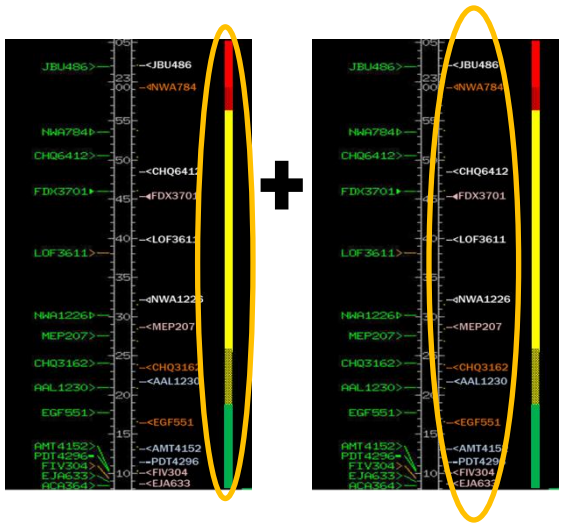


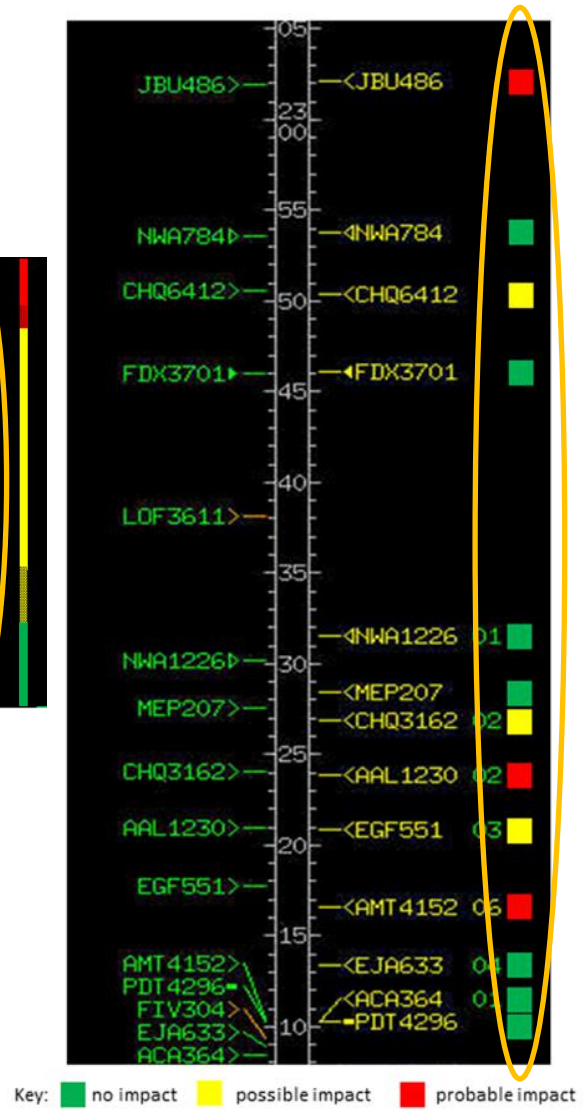




Notional illustration of TBFM TGUI with “stoplight” constraint indicators

# TBFM Weather Integration Level 3: Impact Indicators

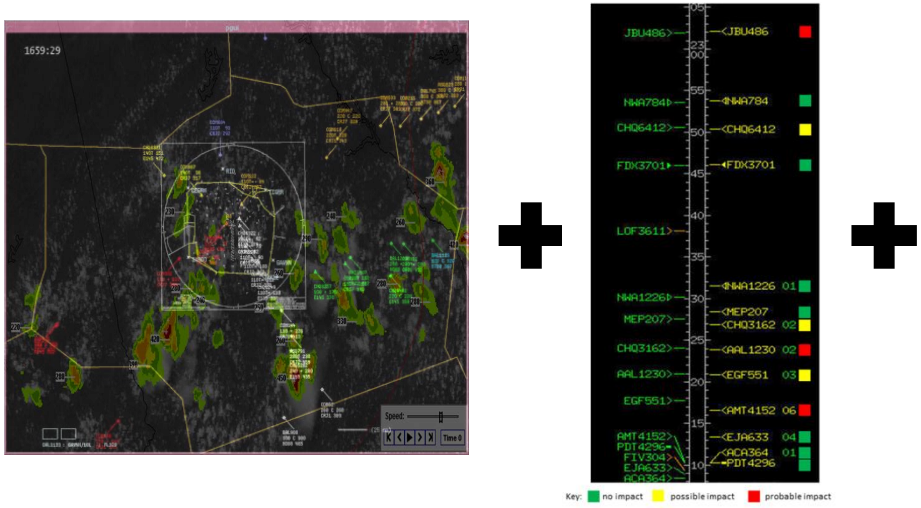
- **Impact Conversion**: Route blockage information is applied to individual flights and flows (converted from constraints to impact)
- That information is then displayed on the TBFM TGUI via individual aircraft "stoplight" indicators
- Benefits: automatic impact calculation
- Shortfalls: manual solution development

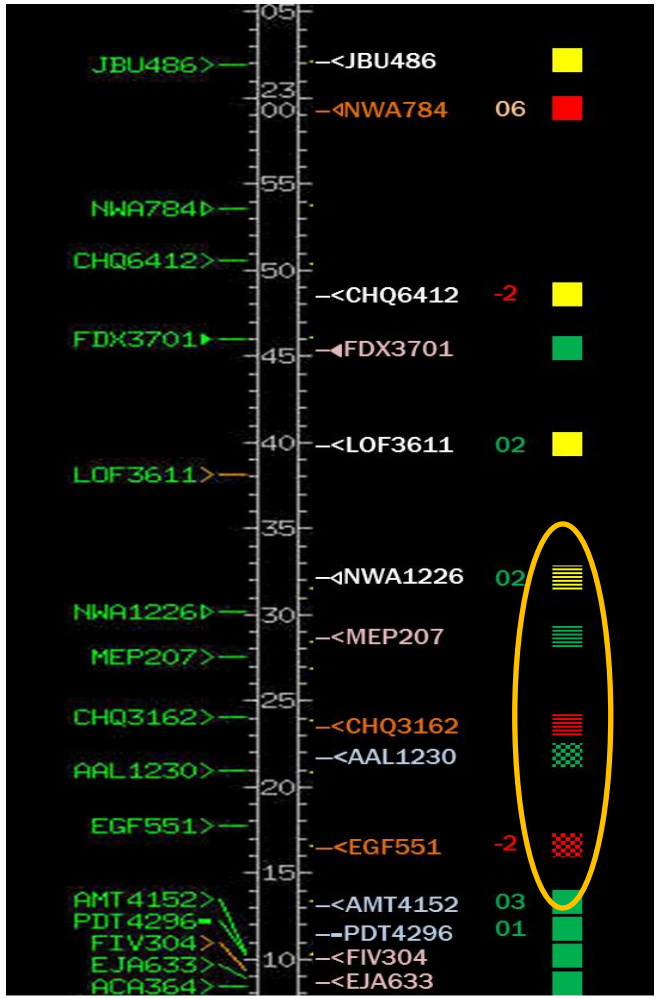





Notional illustration of TMA TGUI with "stoplight" impact indicators

# TBFM Weather Integration Level 4: Full DST Functionality (Convection)



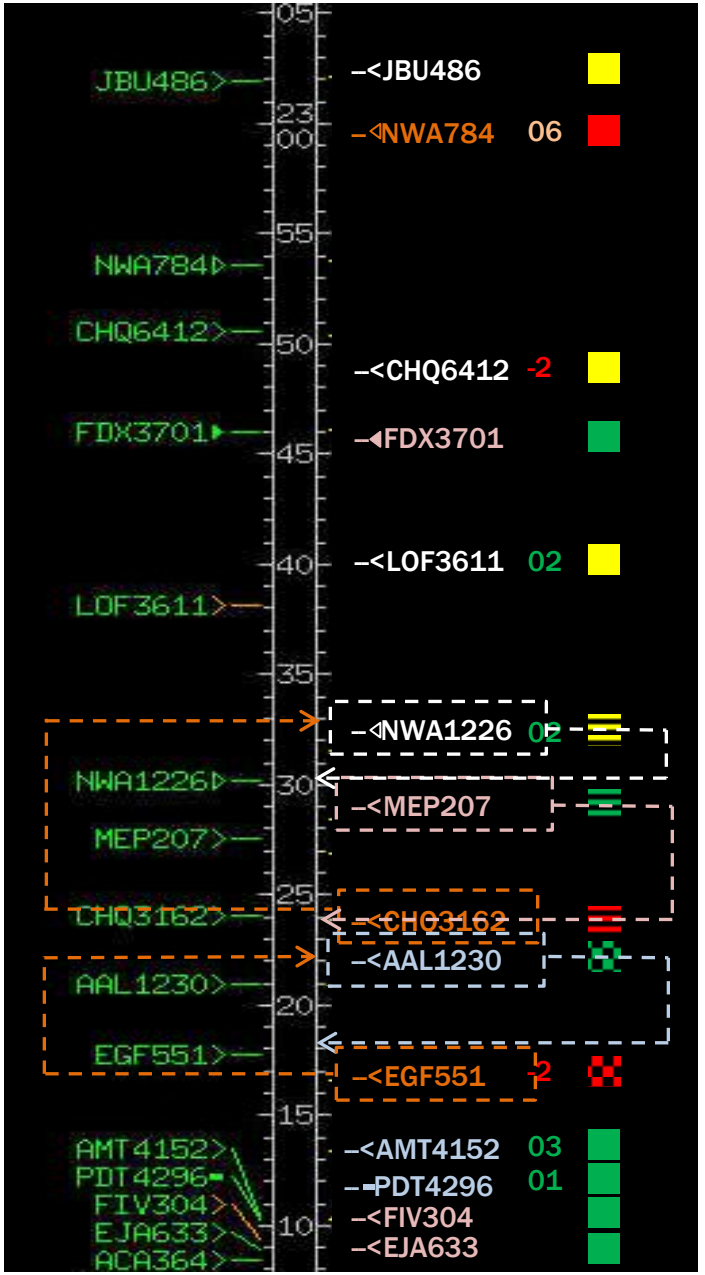




- **Full Decision Support System**
- Benefits: automated optimized solution recommendations (including reordering of flights)

Notional illustration of TMA TGUI with flight list swap recommendations

# TBFM Weather Notional Operations – Level 4

- A mouse click on any of the special impact symbols causes the DST recommendations to be graphically displayed
- A look at the TBFM PGUI with CIWS overlays suggests that both of the recommendations appear to be good solutions
- One more click on one of the special impact symbols executes the flight list changes




Notional illustration of TMA TGUI – times and positions are not to scale

# Overall Benefits of Weather Integration

- Improved efficiency and standardization due to objective vs. subjective decision making; more consistent and predictable
  - Computers can monitor a complex set of business rules (e.g., if the wind is from X direction, at Y speed, and the field is VFR…)
  - Allows decision makers to take advantage of automation
- Proactive decision making (even a short lead time can yield great benefits)
- Full use of automation tools during weather events
- Cost savings!

# Coming Soon…

## ATM – Weather and Data Integration 201

An In-depth Look at Inputs and Outputs to Translation, Conversion, and Decision Support

## ATM – Weather and Data Integration 501

Advanced Concepts, Research Opportunities, Partnerships