Weather Effects Embedded within Net-Centric C2 System Workflows

Topic 10: Collaborative Technologies for Network-Centric Operations

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Background:
Weather impact examples

- **Effects/impacts are hard to quantify and analyze**
- **Strategic Decision**
  - Wait until after monsoon rainy season.
  - Win before severe winter sets in.
  - Build weapons that work in extreme cold.
- **Operational Decision**
  - Ensure parkas arrive in desert AOR before August (gets cold at night!).
  - Use PGM sensor X in morning (fog); sensor Y in afternoon (clear).
  - Expect/plan on slow sortie regeneration rates because it's so hot.
  - Reserve airspace to east of city to ensure sensor cloud free line of sight.
  - Reserve air refueling airspace to east in morning and west in afternoon to synchronize with frontal passage (aviation hazards).
- **Tactical Decision**
  - Swing left around fields because the ground is soaked.
  - Ascend to get out of the icing; descending would be worse.
  - Move UAV south to avoid the approaching line of thunderstorms.
  - Descend to find favorable tailwind (fuel consumption).
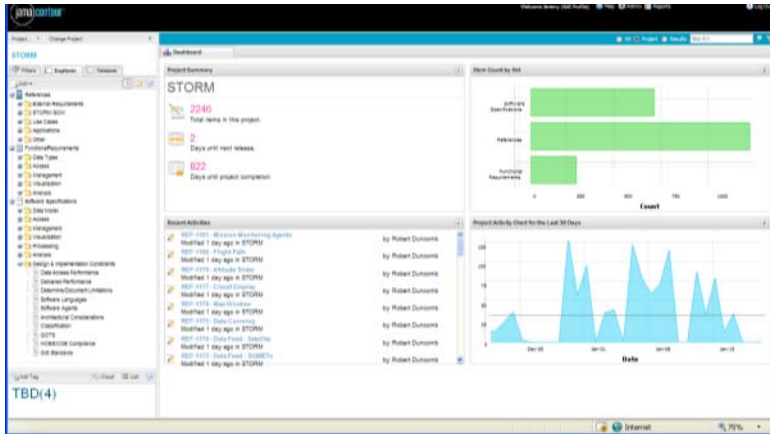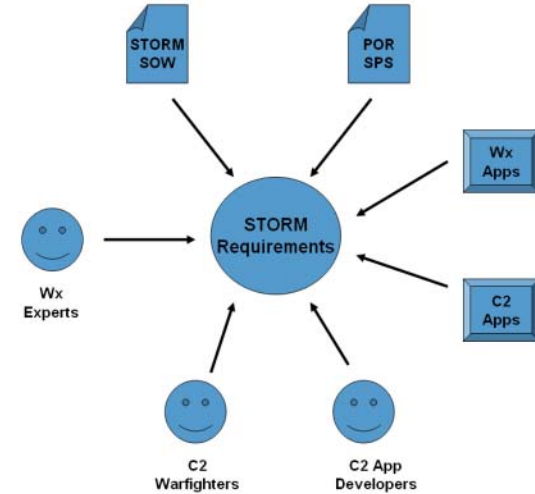

Trafficability?

Requirements Specification Completed

Reviewed 2,250 pages in 23 C2 requirements documents and extracted 1,170 weather incorporation requirements
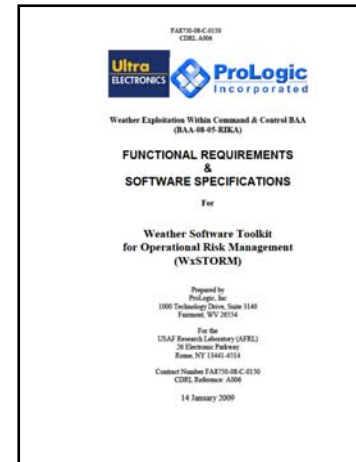
Evaluated weather integration in existing C2 applications and documented best of breed

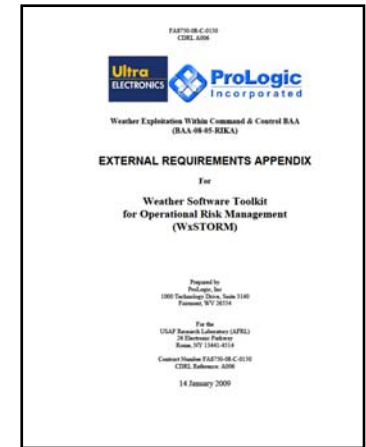Interviewed C2 warfighters to obtain over 100 use cases
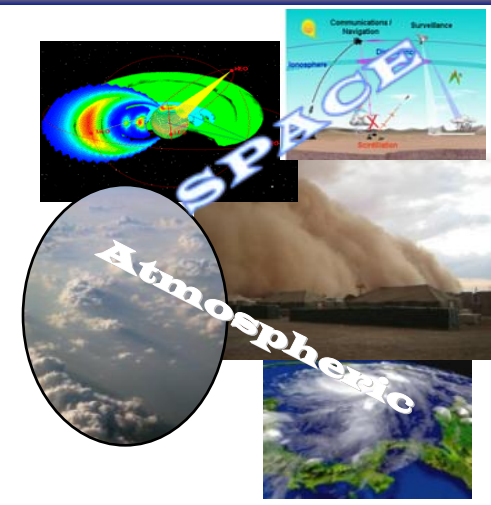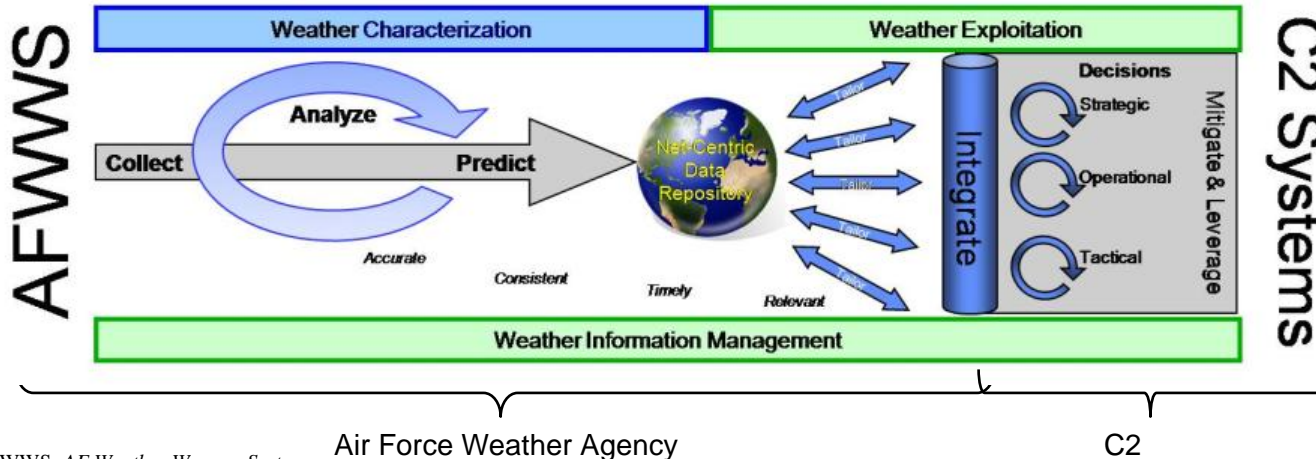
On-line Requirements Database
- Total Derived Functional Requirements: 241
- Total Derived Software Specifications: 627

Specification Document
176 pages

Requirements Collection Document
110 pages

Challenge

Weather Characterization | Weather Exploitation

AFWWS
Collect → Analyze → Predict → Net-Centric Data Repository → Integrate → Decisions (Strategic, Operational, Tactical) — Mitigate & Leverage — C2 Systems

Accurate • Consistent • Timely • Relevant

Weather Information Management

Air Force Weather Agency — C2

AFWWS: *AF Weather Weapon System*
Air Force Doctrine 2-9.1, Weather Operations, 3 May 2006, pg. 15

- **Much progress has been made in**

  – Forecast accuracy

  – Dissemination

  – Machine to machine exchange

  Joint **E**nvironmental **T**oolkit

- **But not much progress has been made in incorporating weather risk management into our computer-augmented decision-making processes**

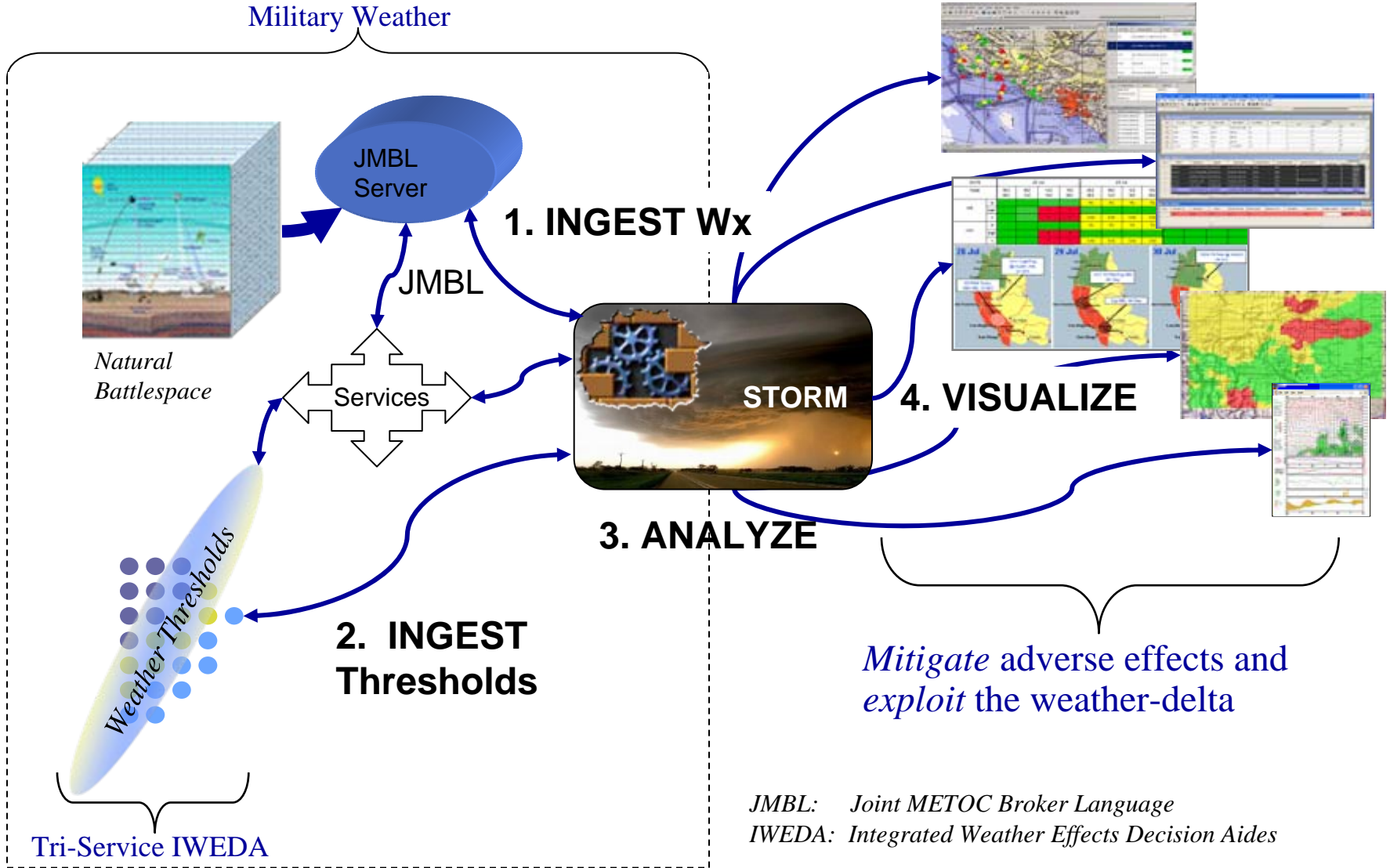**Objective:** Incorporate weather advice in C2 Systems.

Computer Augmented Weather Advice

- **C2ISR applications are starting to ingest weather data/advice but efforts have mostly been cumbersome and 'raw'**

  - Converting 'raw weather data'

    (e.g., winds, rain, and clouds)

    into 'actionable information' for C2ISR

    (e.g., fuel consumption, lock-on range, cloud-free LOS)

    is not trivial

    (NBE effects are hard to quantify and analyze, data is complex)

- **To incorporate actionable advice within their applications, C2ISR developers require functionality that can:**

  - Retrieve, manage, analyze, and display weather data/rules

  - Compute, optimize, and support exploration of effects

- **A "weather effects" software toolkit would enable developers to integrate verified, validated weather advice**

  - Within their cost and schedule and with minimal developer training

WxSTORM Toolkit Brings Weather Advice into C2 Applications

Military Weather

JMBL Server

1. INGEST Wx

JMBL

Natural Battlespace

Services

STORM

4. VISUALIZE

3. ANALYZE

Weather Thresholds

2. INGEST Thresholds

Tri-Service IWEDA

Mitigate adverse effects and *exploit* the weather-delta

JMBL: *Joint METOC Broker Language*
IWEDA: *Integrated Weather Effects Decision Aides*

Why Hard: Weather Data Model

- **Forecast data is extremely complex**
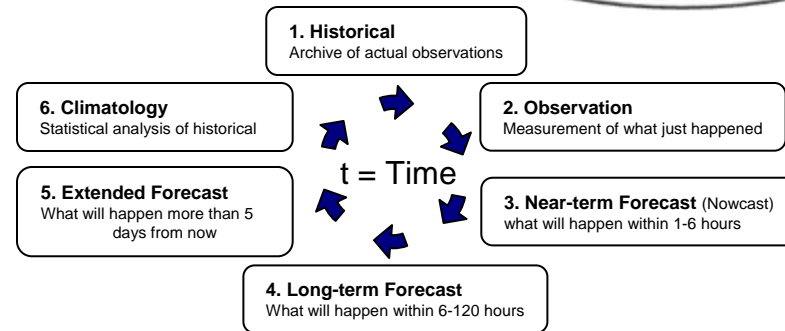 - 3-D Location
    - Latitude, longitude, level/altitude
    - Global scope
    - Multiple projections

  - Compound Time
    - Past/ "Present" / Future
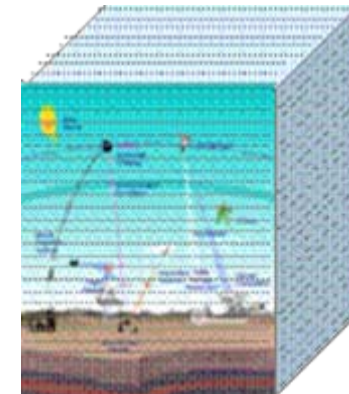   - Model run time

  - Thousands of Attributes (state and derived)
    - Examples: Temperature, humidity, salinity, pressure, rain, clouds
    - Units of measure
    - Text, imagery, numerical, raster, vector

  - Resolution
    - Nested, overlapping, multi-resolution (spatial and temporal)
    - Update frequency
    - Coordinate systems
    - Points not areas
    - Units, interpolation issues

1. Historical
Archive of actual observations

6. Climatology
Statistical analysis of historical

2. Observation
Measurement of what just happened

t = Time

5. Extended Forecast
What will happen more than 5 days from now

3. Near-term Forecast (Nowcast)
what will happen within 1-6 hours

4. Long-term Forecast
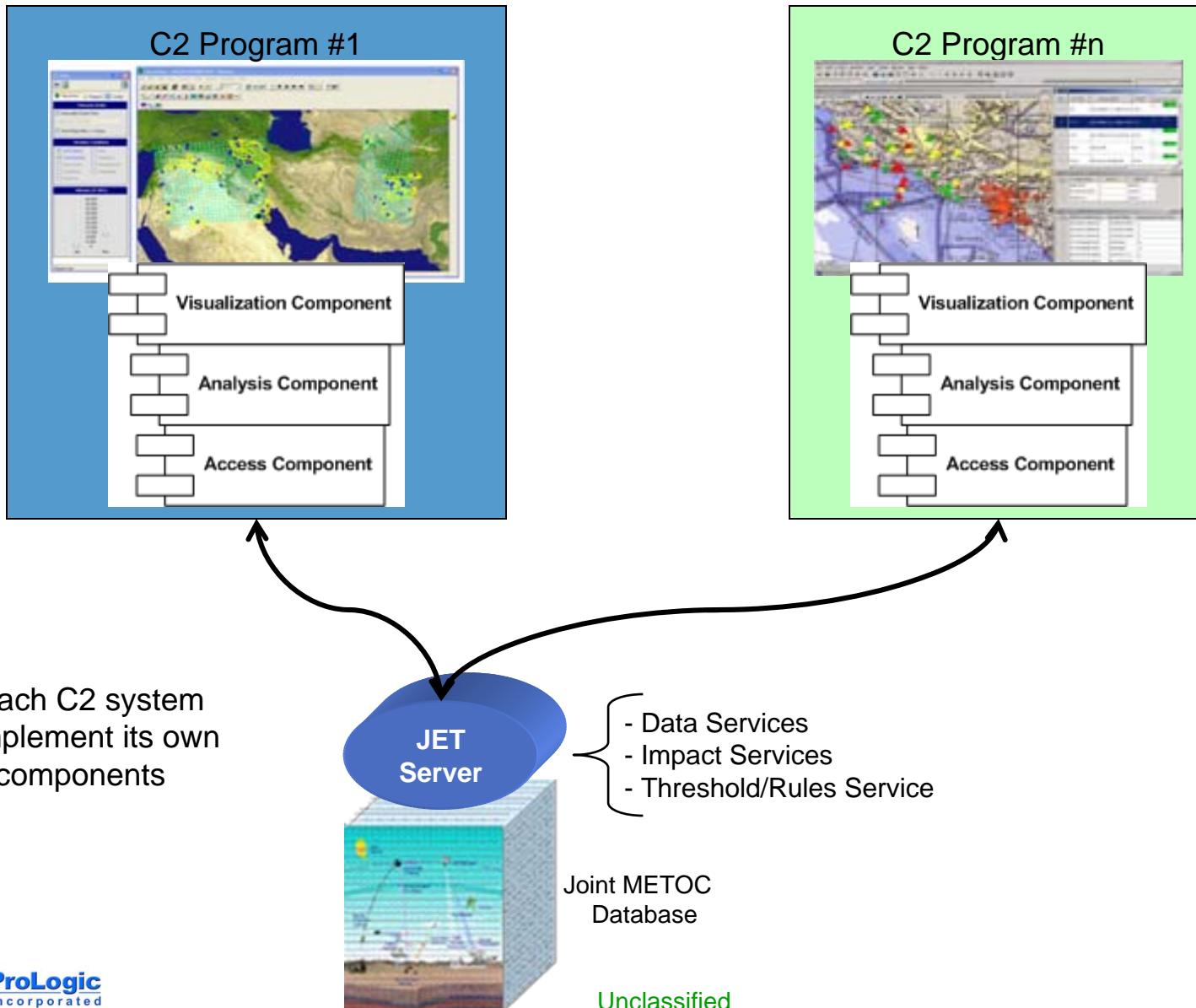What will happen within 6-120 hours

Why Hard: Impact Determinations

- **Impact determination is extremely complicated.**
  - MANY unrestrained degrees of freedom
  - Very sensitive to context
  - Much of it is physics-based and very non-linear
- **Information clutter and overload**
- **Warfighters are so use to doing without weather that they don't know "what weather where."**
  - Expertise extraction has heretofore been difficult at best.
- **Forecast accuracy**
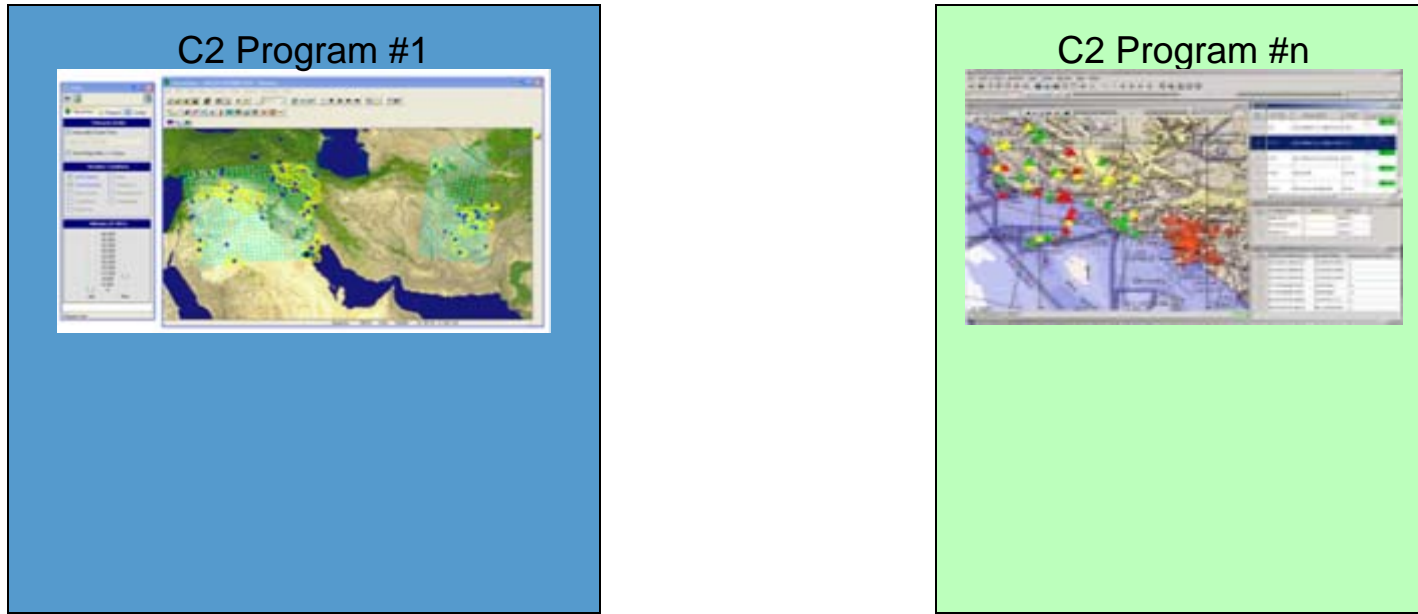 - What decisions can we support?
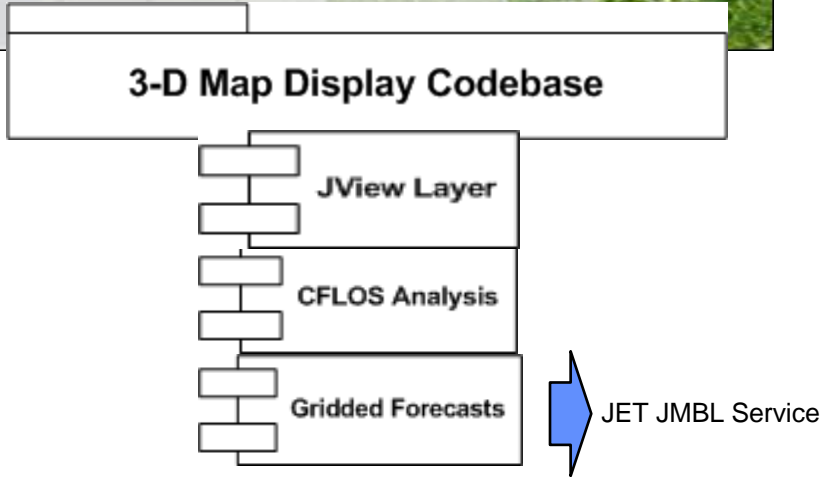 - Reasoning with uncertainty
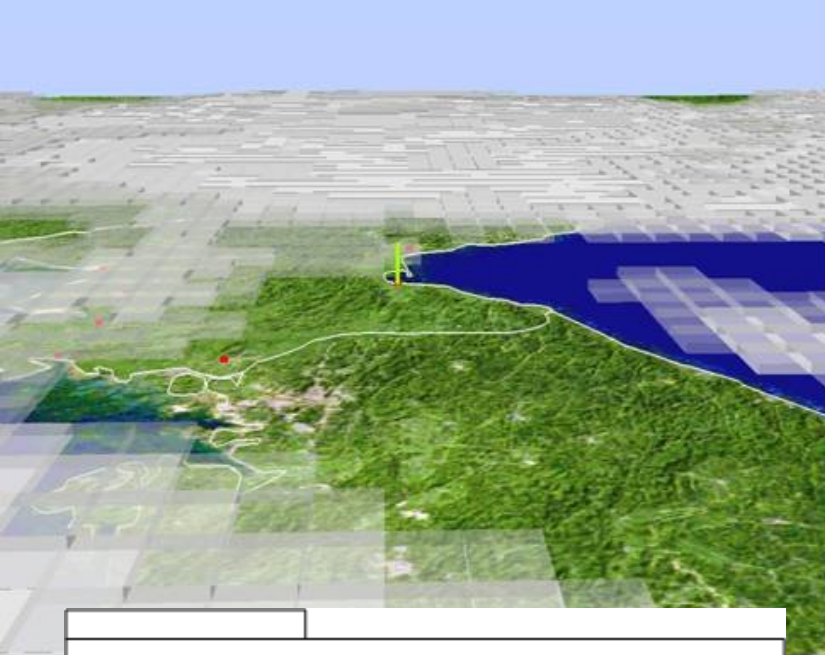
Independent Struggles

C2 Program #1

Visualization Component

Analysis Component

Access Component

C2 Program #n

Visualization Component

Analysis Component

Access Component

Today, each C2 system has to implement its own weather components

JET Server

- Data Services
- Impact Services
- Threshold/Rules Service

Joint METOC Database

Ultra ELECTRONICS

ProLogic Incorporated

Independent Struggles

C2 Program #1

C2 Program #n

WxSTORM is a collection
of verified, validated, and tested
common components
In SDK form made available to
all C2 system developers

JET Server

- Data Services
- Impact Services
- Threshold/Rules Service

Joint METOC Database

WxSTORM SDK

FIGURE IT OUT ONE TIME FOR EVERYONE

3-D Map Display Codebase

- JView Layer
- CFLOS Analysis
- Gridded Forecasts

JET JMBL Service

Paragraph: 6.4.1.1
Name: *Integrated Prioritized ISR Plan*
Description: The AOC WS requires ability to produce an ISR Plan overlaid with environmental conditions.

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IM Plan, Airspace Control Plan (ACP), Air Defense Plan (ADP), ISR Collection Plan, Personnel Recovery Plan, ATO, Space Tasking Order (STO), Combat Support Plan, Assessment, Component IO Support Plan, and Air Mobility Guidance.

6.4.1. Synchronized JAEP and JAOP Development Linked with Execution Results (Assessment). To increase the efficiency of the JAOP development process and the operational effectiveness of the plan, the AOC WS requires the machine-assisted capability to link operations assessment results to the development of the JAEP, JAOP, Joint Air Operations Targeting Cycle and Joint Air Operations Tasking Cycle. This includes all AOC WS divisions, processes, and products (e.g., link actions to effects; trace effects throughout the process; include an integrated prioritized ISR plan incorporating National, theater, Service, and multinational/coalition sensors and platforms; integrate IO, Mobility, and Space).

Threshold	(1) Joint ATO Cycle Timeline (Joint Publication [JP] 3-30, Figure III-12); notional 36-hour timeline (target nomination to ATO message release) – Reduction to <24 hours; requires that system(s) generate DoD standard compliant tasking messages; e.g., USMTF ATO/Airspace Control Order (ACO), operational tasking data links (OPTASKLINK); requires system(s) to correlate from assessment data/information the effects-on-target for past, current, & and planned missions, to identify to user both current & and planned mission against same target, & and to incorporate capability to coordinate target nominations & and objectives across intra-AOC processes & and functional positions; this shall include capability to import/export products to/from MS Office applications/tools
Objective	(1) Joint ATO Cycle Timeline (JP 3-30, Figure III-12); notional 36-hour timeline (target nomination to ATO message release) - Reduction to <18 hours

6.4.1.1. Integrated Prioritized ISR Plan. The AOC WS requires the capability to produce an integrated prioritized ISR plan incorporating National, theater, Service, and multinational/coalition sensors and platforms, overlaid with environmental conditions, airspace restrictions, and IPB products (threats, Named Areas of Interest [NAI], Target Areas of Interest [TAI], Enemy COA [ECOA]) to guide ISR timing and direction

Threshold	(1) ISR plan optimizes available assets for 100% of the stated collection requirements (does not mean satisfaction of all requests); a. Requires receipt of/access to component collection nominations including assessment requests for ABP planned missions & and to resource availability data; b. Requires generation, approval processing, & and publishing of the Joint Integrated Prioritized Collection List (JIPCL); c. Requires receipt, factoring, & and feedback of proposed adjustment to ACMs. d. Requires plan data accessibility for integration within MAAP process for JFACC-controlled assets (¶6.4.1.2) (2) System(s) shall incorporate & and archive data using a standard data/message originator identification for traceability; e.g., identify specific source identification for each target on Component Target/Collections Lists
Objective	(1) ISR plan optimizes available assets to support the JIPCL & Air Battle Plan (ABP) dynamic collection requirements for assessment (NTISR) (2) System(s) automated feedback on status of collection requests

6.4.1.2. MAAP Production, Analysis and Evaluation. The AOC WS requires the capability to accomplish machine-assisted development, analysis, comparison, modification, and selection of MAAP alternatives (JP 3-30) to include visualization of effects and options to produce decision quality information to decision makers. The MAAP visualization shall provide the capability to simulate and graphically represent (visualize) the execution of the MAAP and the resulting (pro-
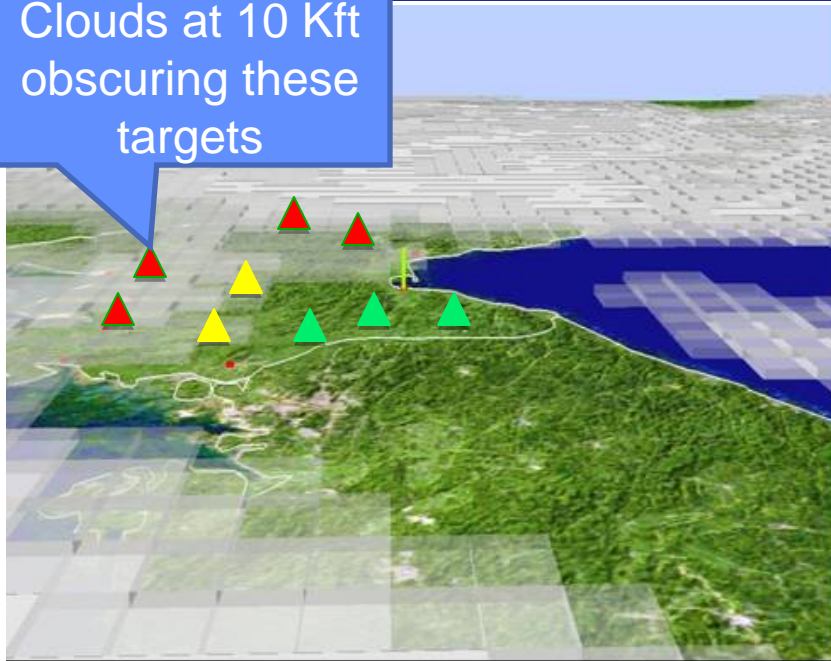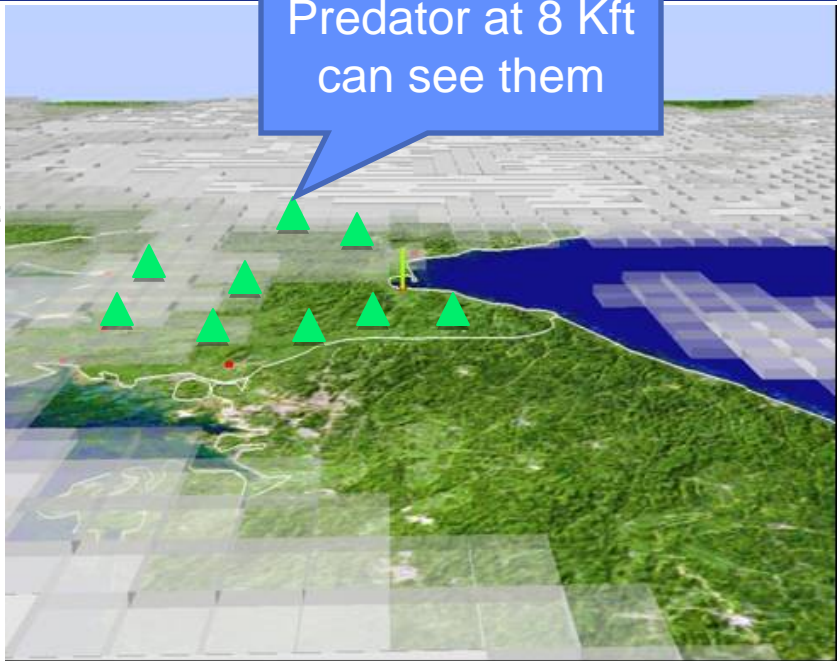
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6-4

WxSTORM-Enabled ISR Planning

Clouds at 10 Kft obscuring these targets

Predator at 8 Kft can see them

10 Kft

8 Kft

WxSTORM has the code to enable C2 applications to render clouds and other weather parameters on several different map displays and supplies the means to analyze CFLOS windows of opportunity, by altitude and time for any set of targets.

Summary

- **Weather impacts military operations.**

- **We need to figure out how to INCORPORATE advice in C2 applications.**

- **Collecting C2 requirements and translating into specific solution modules.**

- **Doing the hard work and sharing capabilities via a Software Developers Toolkit.**

- **Continually inject better into SDK => All C2 apps.**

- **Funding was cut so we are spinning down until next time.**
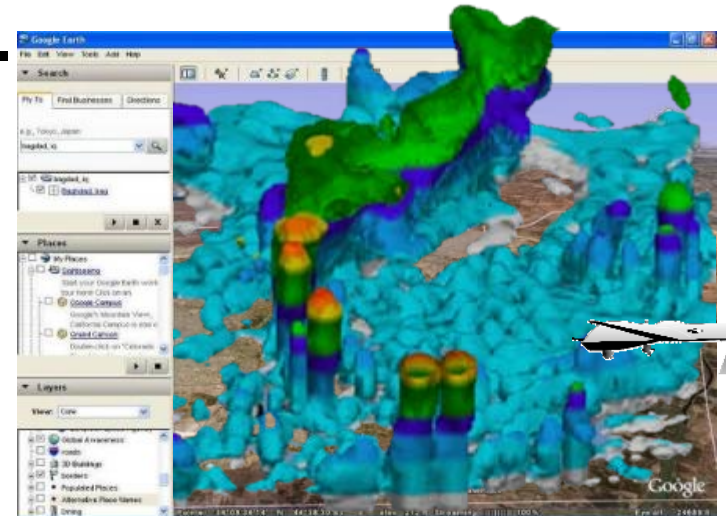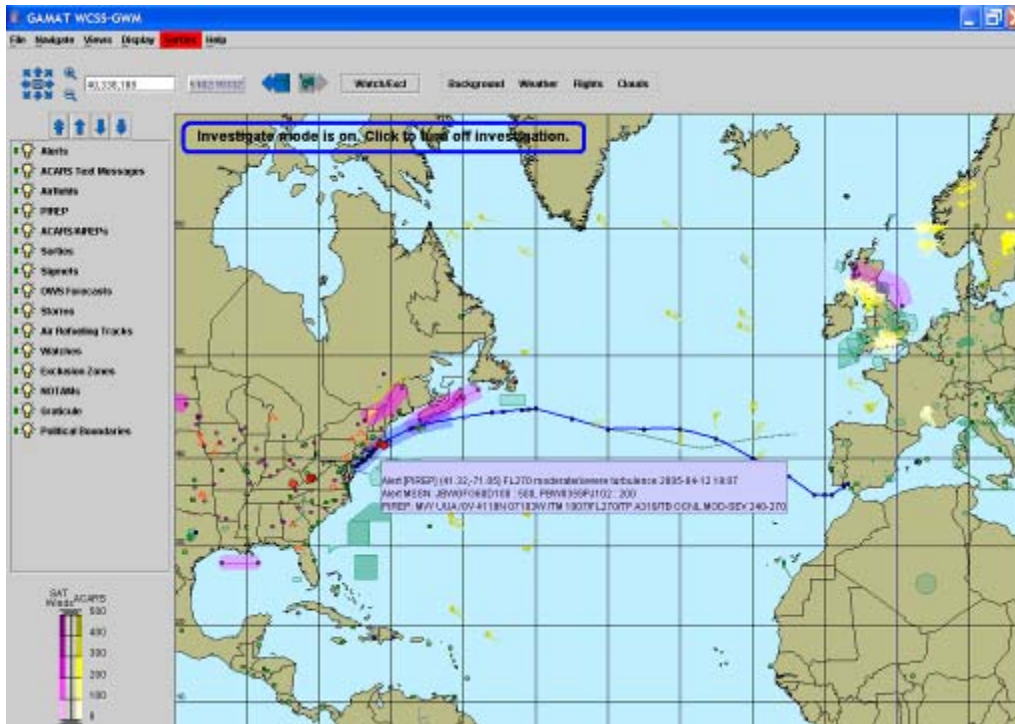
BACKUPS

Examples of Incorporation

HOW MIGHT WE INCORPORATE ADVICE?

Tanker Support for Fighter Aircraft

Tanker Airlift Control Center (TACC)

Global Air Mobility Advanced Technology (GAMAT)

Work-Centered Support System For Global Weather Management (WCSS-GWM)
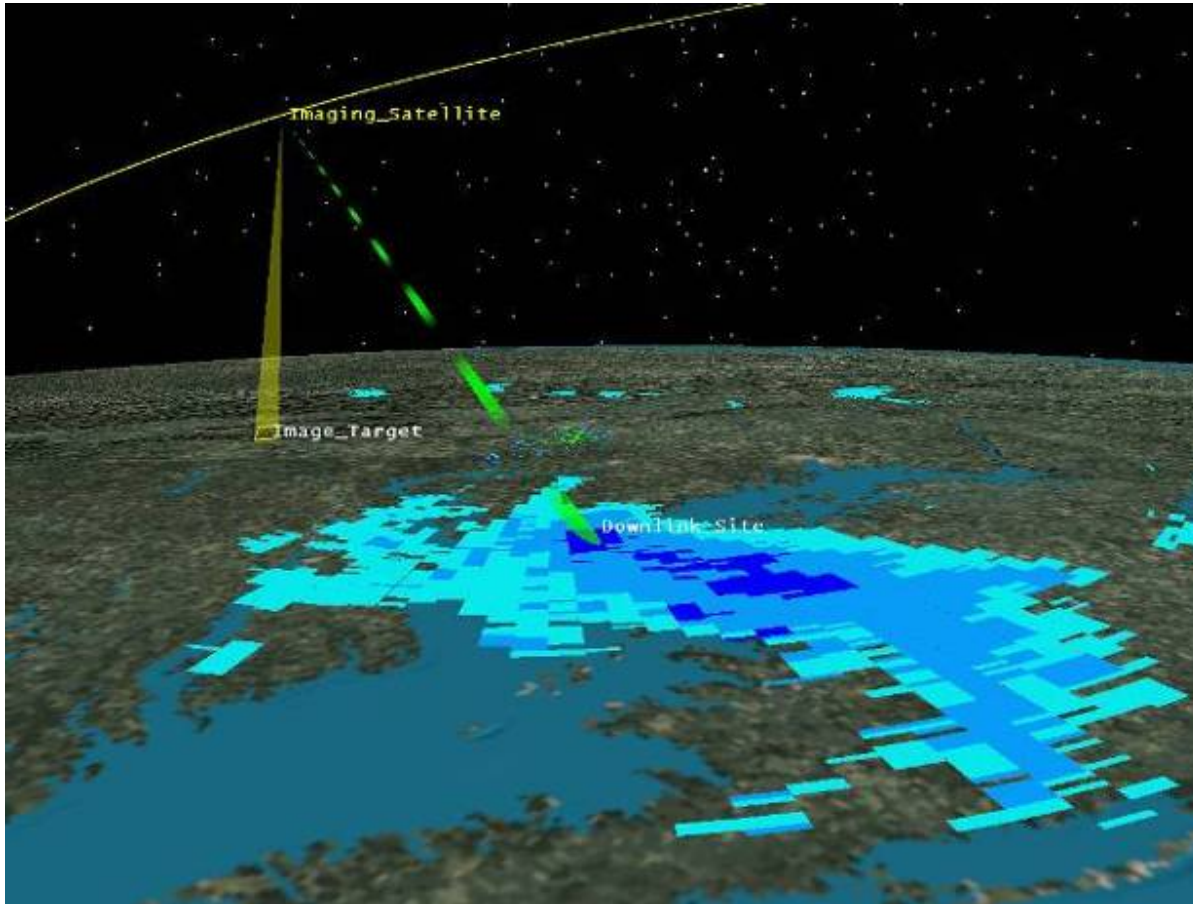

- Learn from and include this success

- HOW do we represent weather that would impact the success of ferrying fighters across the ocean for example?

CORONETS

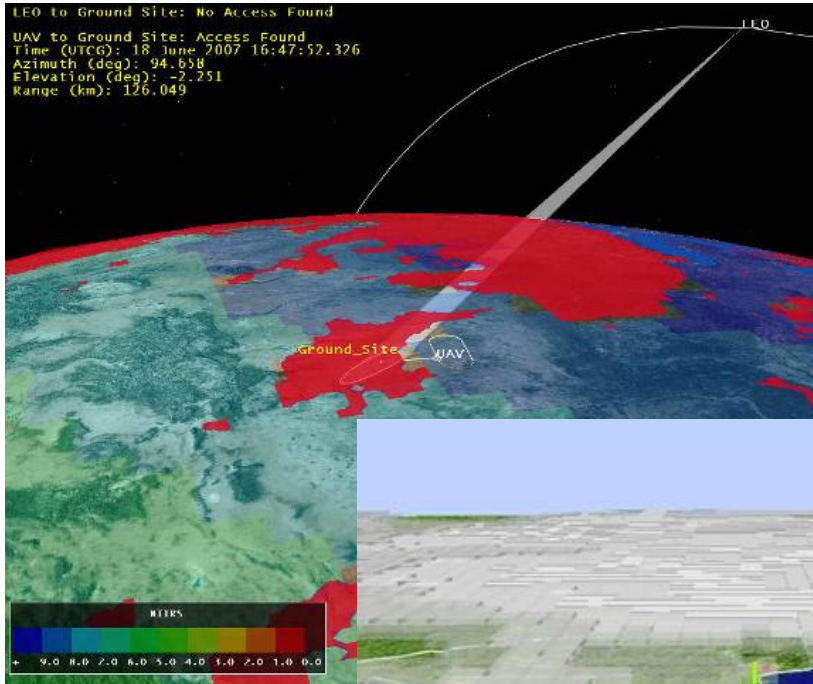Example courtesy of Sam Kuper, AFRL 711 HPW/RHC

Communications Impact

- Rain attenuation affecting communication.
- Limiting the downlink to ground station receiver and thus affecting the movement of collection to decision-maker.
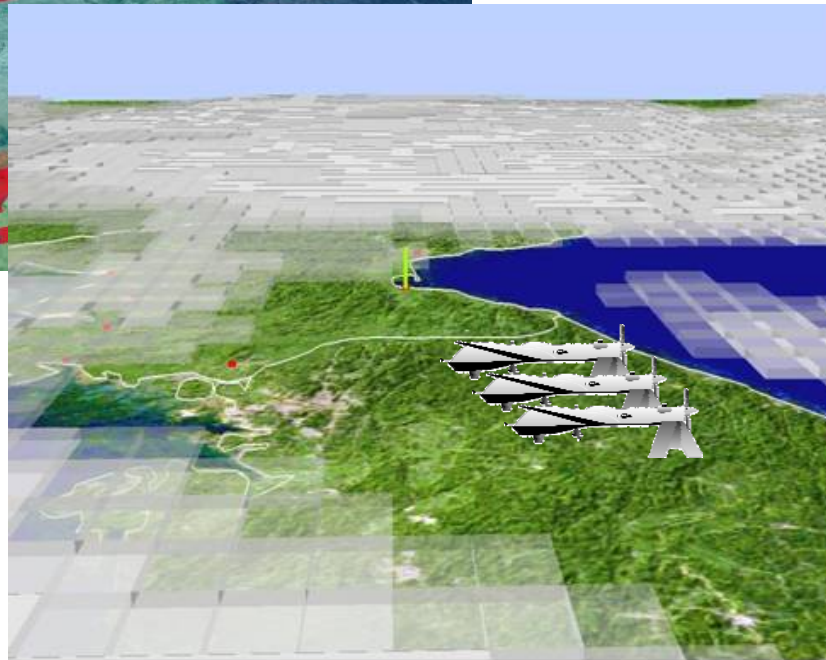
ISR Support


```
LEO to Ground Site: No Access Found
UAV to Ground Site: Access Found
Time (UTCG): 18 June 2007 16:47:52.326
Azimuth (deg): 94.658
Elevation (deg): -2.251
Range (km): 126.049
```

Asset Allocation
- Satellite does not have Line-of-sight to the target for capturing the image.

- The UAV being lower and having more control of where it flies can capture an image of the target location.

Predictive Cloud-Free Line Of Sight (PCFLOS)

- Evaluate multiple ISR asset locations and "time-windows" based on cloud cover forecast effect on planned mission.

Got Comm?

Representing Wx Impact

AOC WS 10.2 CDD

Airspace Management Display Codebase

- CJMTK Layer
- Impact Analysis
- Flight Hazards
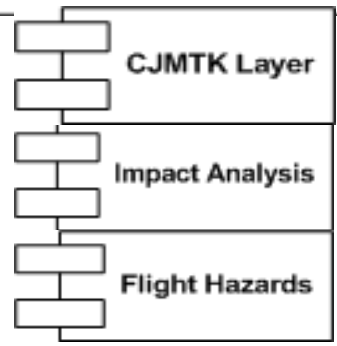
Paragraph: 6.5.1
Name: Airspace Management
Description: AOC requires ability to plan and manage airspaces using a graphic display with ability to resolve conflicts in space and time.

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Objective	(1) Inter-Theater; Global (2) Accuracy – 99.9% of original content conveyed to other divisions & process stations (3) Time to Access – <5 seconds throughout the AOC Network; <1 second to data received at the node (4) Accessibility-Authorized mission partners can access & use environmental & and geo-spatial assessments

6.4.1.3. Automated Tools to Support Strategy and Plan Development. The AOC requires the capability to conduct probabilistic and deterministic analysis to evaluate all planning products and processes vis-à-vis specified effects-based measures of performance and measures of effectiveness. This capability shall also produce suggested corrections to processes and effects-based COAs, with rationale for corrections.

Threshold	(1) Machine-assisted probabilistic analysis capability; provides COA alternatives to include identification of conflicts & potential mitigation among such items as own force platforms/weapons/effects deconfliction, force risk against enemy threats, projected effects-on-target (6.4.1.3.1 below), ROE risk against managed target lists (2) Completeness--The sophistication of the method (e.g., rock drill, M&S, wargame) fits the complexity of the plan.
Objective	(1) Automated probabilistic & deterministic analysis capability; Provides COA alternatives with rationale (2) Threshold = Objective

6.4.1.3.1. Targeting Effects Assessment. The AOC requires the capability to accurately assess targeting effects and aggregates against COAs in RT/NRT to continuously validate and adjust strategy.

Threshold	(1) Accuracy--display enables the trained operator to correctly interpret actions & results > 95% of the time; requires capability to aggregate available ATO process, targeting, & assessment information with pedigree on a single screen/presentation/user-interface (link to all phases of ATO process, database & feedback/alert/notices publication/subscription updates); must include precision location information, CID, engagement options/assets employed, estimated effect-on-target, CDE, ROE, weather/environmental data (actual [analysis] prediction & historical [climatological]), opportunity cost if other target/mission affected, accommodate multiple weapons per target (2) System(s) shall provide automated collaborative capability to accomplish analysis in-theater, across components & against COCOM/JFC COA(s) (3) Timeliness--Analyze & characterize 90% of the events within 60 seconds & remaining 10% within 3 minutes (4) Assessments available across the AOC network in <5 seconds of completion
Objective	(1) Accuracy - correctly interpret actions & results 100% of the time (2) Timeliness - Threshold = Objective (3) Assessments automatically linked to strategy, planning, & execution applications for potential adjustment of future operations

6.5. Airspace Management Planning. The AOC WS requires a distributed collaborative machine-assisted capability to continuously plan, monitor, and adjust Air and Space deconfliction of platforms, weapons, and other effects producers (e.g., IO, ISR, Mobility) transiting and operating within defined battle spheres.

6.5.1. Airspace Management. The AOC WS requires the capability to accomplish airspace planning and management using a graphic display (e.g., import and overlay graphic representation of routes, ACMs, civil airspace, or airspace requests) and automatically display time and

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6-7

AOC WS 10.2 CDD

Cursor on Target Codebase

- FalconView Layer
- Impact Analysis
- Flight Hazards

Paragraph: 6.6.2
Name: Replanning/Retasking Capability
Description: AOC requires ability to replan and retask with consideration of weather as a key planning factor.

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space conflicts information in three dimensions correlated to time and prioritized options to re-solve.

Threshold	(1) All imported graphic information displayed & alphanumeric information automatically presented to operator in <5 seconds of availability on intra-AOC network; requires capability to aggregate available information on single screen/presentation/user-interface; requires receipt, factoring, & feedback of proposed adjustment to ACMs from ISR Plan (6.4.1.1) & MAAP (6.4.1.2) process data for ATO production; requires also RT/NRT asset & SA data from such sources as COP, datalink, IP network exchange for dynamic/ TST events (2) System identifies horizontal, vertical, & time conflicts & notifies the user for resolution
Objective	(1) Threshold = Objective (2) System identifies horizontal, vertical, & time conflicts & provides prioritized resolution options to the user; plan updated automatically (in publication, subscription, discovery across network; as necessary by prepared DoD standard message) on user-selected option

6.6. Execution. The AOC requires the capability to monitor, control, and direct execution of the ABP including the capability to adjust (replan and retask missions) ongoing operations to address dynamic situations (e.g., personnel recovery, time-sensitive targeting, or mission aborts).

6.6.1. Machine-Assisted Capability to Integrate Multi-INT Data. The AOC requires the machine-assisted capability to horizontally integrate multi-level (National, Theater, tactical), multi-INT, multi-source (Open-Source Intelligence [OSINT], Non-traditional intelligence, surveillance, and reconnaissance (NTISR), space-, air-, and ground-based sensors, other advanced programs, and non-US ISR information) to enable the F2T2EA kill chain against fixed, mobile, and emerging targets.

|	
Threshold	(1) Capability includes machine-assisted Multi-INT correlation of information derived from National & theater Imagery intelligence (IMINT), signals intelligence (SIGINT), Moving Target Indicator (MTI), Human Intelligence (HUMINT), & ground-based sensors; requires capability to aggregate available information on a single screen/presentation/user-interface & collaboratively associate to JIPTL, managed target lists within AOC targeting process (2) Intra-AOC; Intra-Theater (3) Accuracy - 99% of original content conveyed to other divisions & process stations (4) Time to Access - <5 seconds throughout the AOC Network (5) Accessibility—Tactical through operational level forces can access processed information (6) Fixed & mobile targets
Objective	(1) Machine-assisted Multi-INT fusion of information derived from National & theater IMINT, SIGINT, MTI, HUMINT, & ground-based sensors, OSINT, NTISR, & Space & Information Operation (SIO) (2) Inter-Theater; Global (3) Accuracy – 99.9% (4) Time to Access – Threshold = Objective (5) Accessibility— Authorized mission partners can access fused information (6) Fixed, mobile, & moving targets

6.6.2. Replanning/Retasking Capability. The AOC requires the machine-assisted capability to replan and re-task Air, Space, Information, and ISR operations and create and disseminate ATO and ACO changes. The replanning capability shall address the full range of planning factors. Planning factors include, but are not limited to, weapon/platform/target pairing, kinetic/non-kinetic weapons, ISR assets and planned collections, collateral damage, ROE, restricted and protected targets, proximity to friendlies/neutrals/non-combatants, Special Operations Forces (SOF) ground teams, Non Government Organizations (NGOs), air refueling, airlift and airdrop. Air-

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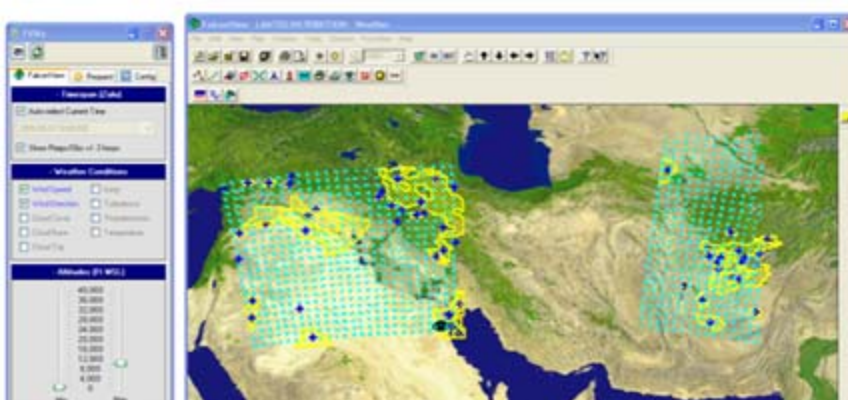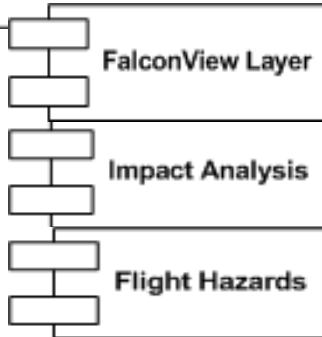
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21

**Examples of Incorporation**

SUCCESSES

WxSTORM-Enabled Situational Awareness

- **Global Awareness Presentation Services (GAPS)**

- **User-Defined Operational Picture (UDOP)**
  - Decision-focused view of the operational environment that organizes disparate data sources to support accurate situational awareness (SA) and timely decision-making in a distributed net-centric environment

- **Web-enabled Data Sources**
  - Satellites, Tracks, ISR, Intel, Events, Routes, ATO, Imagery, **Weather**, etc.

  USSTRATCOM and STRIKE AOC

WxSTORM provides visualization components for C/JMTK, STK, GoogleEarth and others.
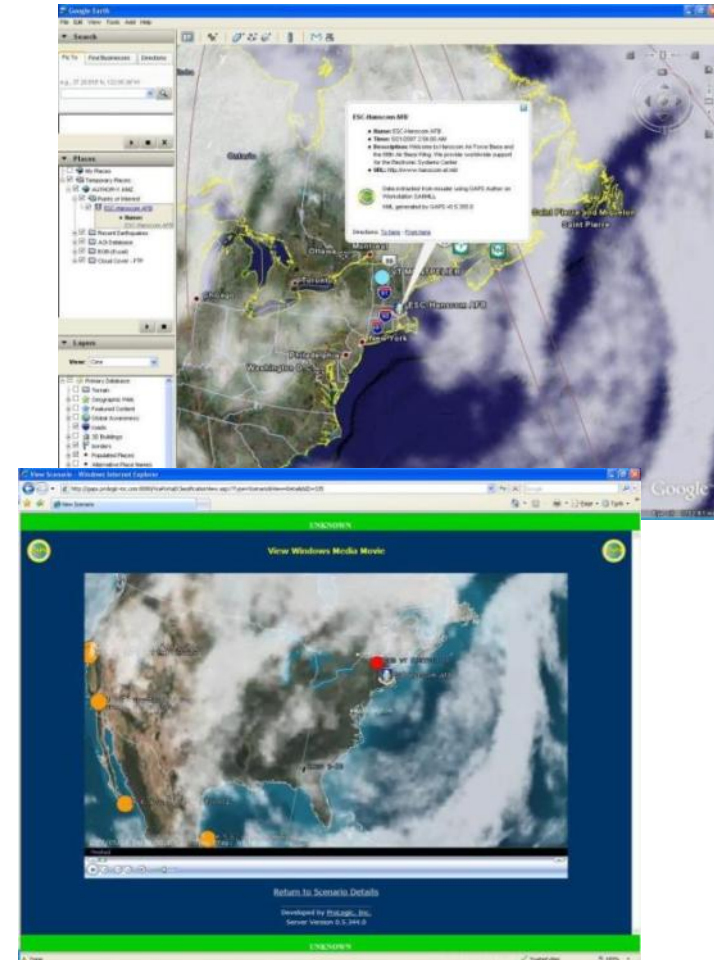
WxSTORM-Enabled Airspace Deconfliction

- **JASMAD Background:**

  – CJMTK-based airspace management

  – Being developed as an AOC weapons system net centric information capability

  – Manages battlespace with single joint airspace management and dynamic deconfliction capability

  – Coordinates real time ATO planning and execution

    ■ Minimizes conflicts and maximizes airspace usage

  – Enhance user's situational awareness

  – Automates and visualizes the Joint Air Tasking Cycle

  – Creates and processes ACMs, ACOs and the Airspace Control Plan (ACP)

  – Provides near real-time deconfliction during mission execution down to kill box level
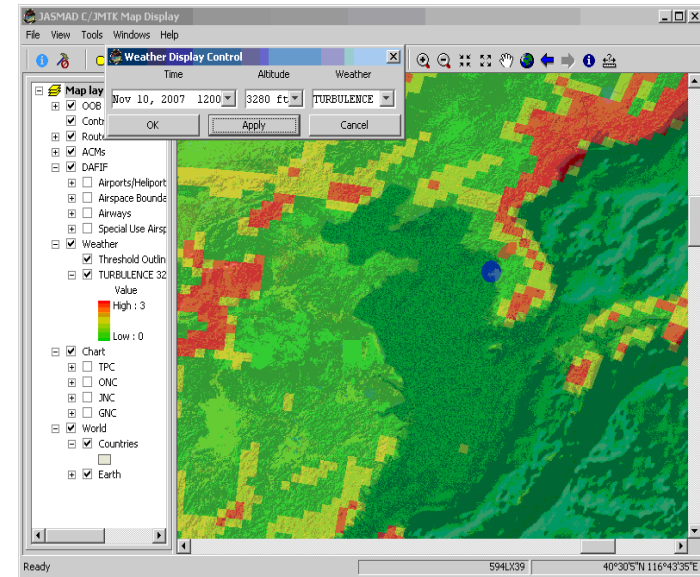

WxSTORM provided analysis components which helped JASMAD create an airspace layout that avoids hazardous weather areas.
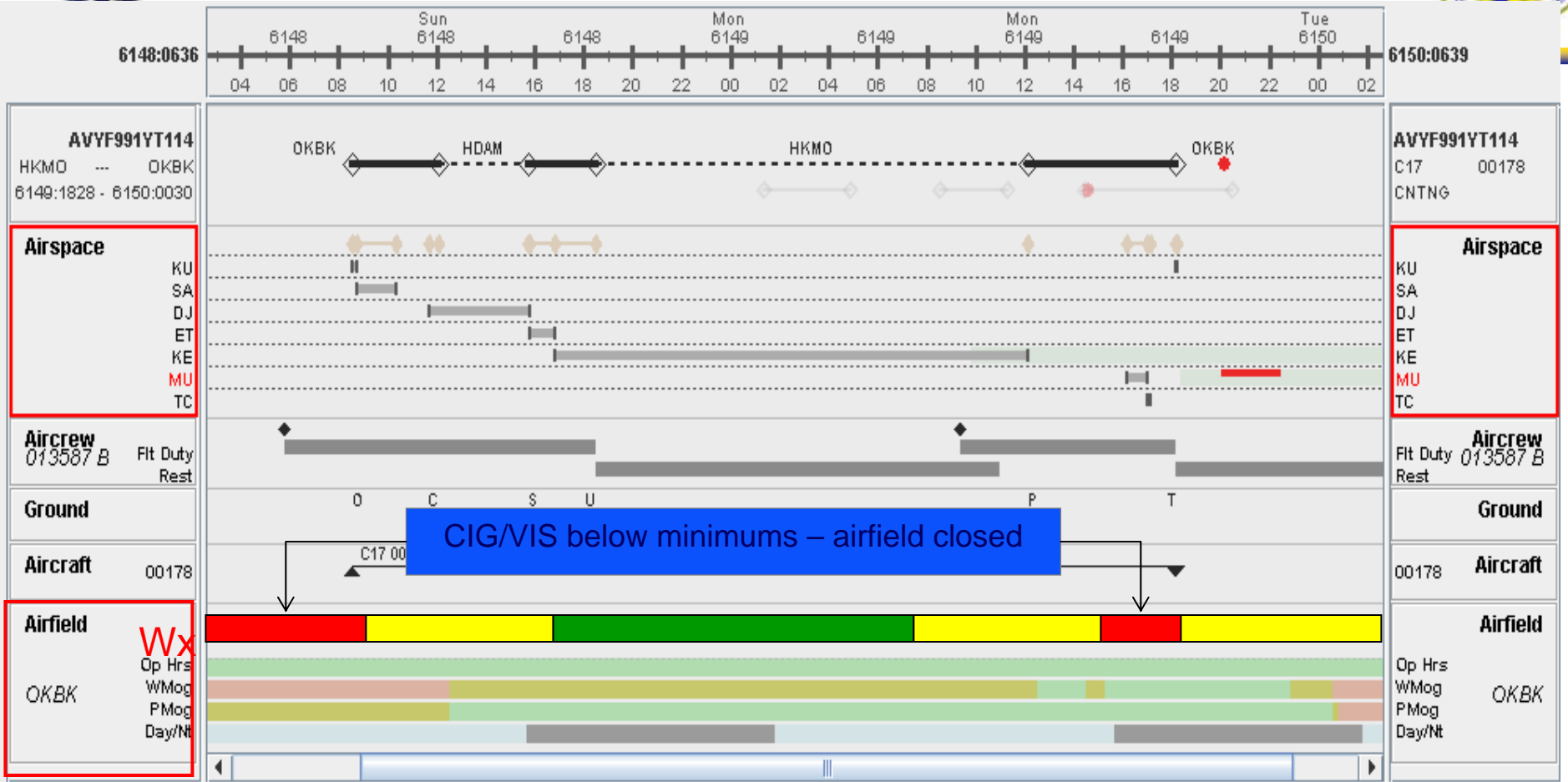
WxSTORM-Enabled Route Planning

- **Optimal routes**
  - Avoid hazards
  - Conserve fuel
  - Meet diplomatic clearance constraints

- **Requires spatial analysis to avoid conflicts between routes and hazards**

- **Requires spatial analysis of multiple possible routes against the 3D wind profiles**
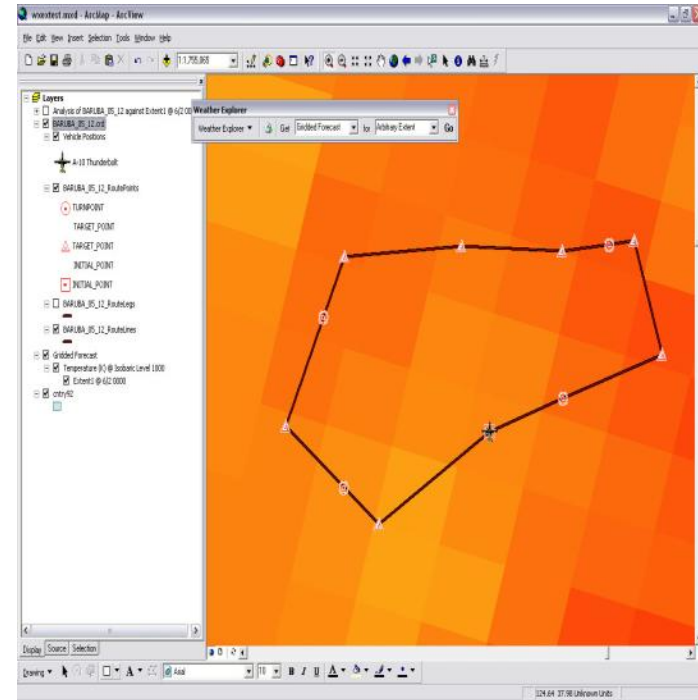
WxSTORM enables analysis capabilities to find optimal air routes for mission success

WxSTORM-Enabled Trafficability

- **Battlespace Terrain Reasoning & Awareness (BTRA)**

- **CJMTK-based trafficability**

- **Fast All Season Soil Strength Model (FASST) – WxSTORM enabled feed**

- **Requires spatial analysis to avoid conflicts between routes and impassable terrain**

WxSTORM enables analytical capabilities to include weather effects when computing terrain conditions

# WxSTORM-Enabled Timelines

CIG/VIS below minimums – airfield closed

In addition to providing situational awareness of airfield impacts, WxSTORM modules enable GRS/WIDE to dynamically build adverse weather constraint spaces used by their optimization algorithms for AMC mission planning based on weather, fuel efficiency, and diplomatic constraints

FalconView Weather Prototype

- **Special Operations Mission Planning Environment (SOMPE)**

  – METOC Graphics Overlay

  – Partnered with GTRI

- **Goals:**

  – Integrate Weather Impacts Analysis and Visualization into FalconView

  – Weather Forecasts and Observations

    ▪ GRIB parsing and visualization

  – Provides access to JMBL data

  – DoD Weather Data Sources:

    ▪ JWIS

    ▪ JET

    ▪ WDAC

- **Leverages** *Weather Toolkit* **for development of Overlay**
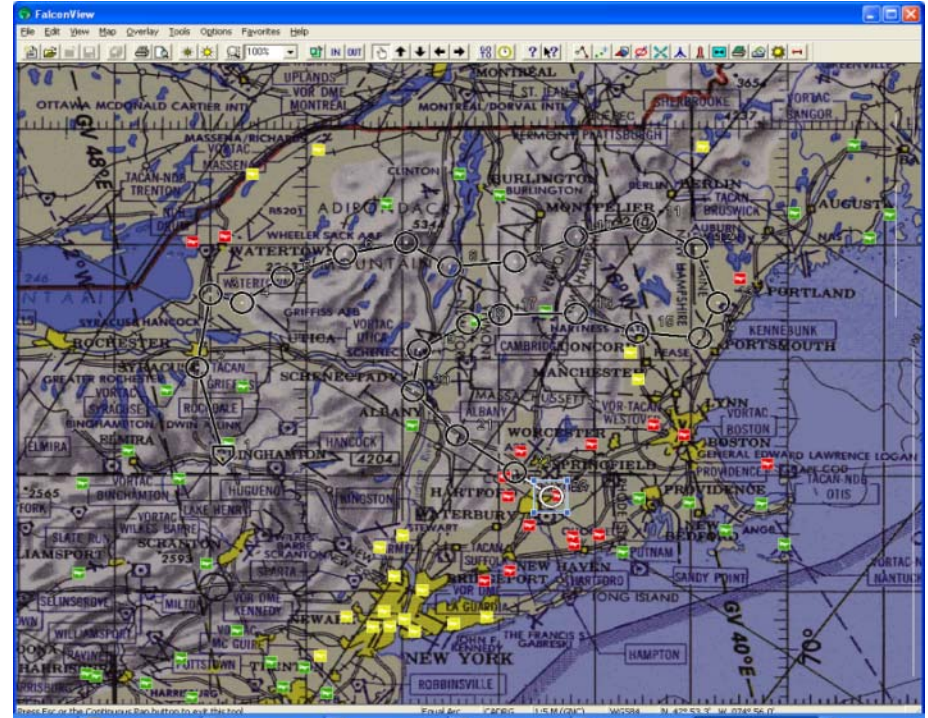
Airborne Web Services (AWS)

- **Many web-enabled data sources:**
  - Air Tracks
  - ATO/ACO
  - Blue Forces
  - Munitions
  - GMTI
  - **Weather**

- **AWS server uses JMBL**

- **Currently integrating** *Weather Toolkit*