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A WEATHER DECISION AID FOR UNMANNED AERIAL VEHICLE MISSIONS

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1. INTRODUCTION

The U.S. military and its civilian aviation counterparts have seen dramatic growth in the planning, development, and operational use of unmanned aircraft (UA) and unmanned aircraft systems (UAS) since the late 1990s. As UA have been introduced into the operational inventory, there has been a growing concern about the adverse impacts of aviation weather hazards on UA mission success rates. As the numbers of UA employed increase, so does the demand for timely real-time weather impact forecasts for mission planning, preflight, enroute, and recovery operations. Weather hazard avoidance is paramount for UA, as these aircraft are extremely sensitive to certain meteorological conditions to which manned aircraft are far less susceptible.

Forecasters and flight planners who support UA missions and their customers require pinpoint enroute UA weather sensitivity predictions to plan and execute the UA mission. The Tactical Decision Aid (TDA) technology currently under development at U.S. Army Research Laboratory responds to the requirements for manually derived, automated, fine-tuned, route-specific UA forecasts for all phases of the flying mission. Such a TDA will be suitable for use in civilian UA applications, as well as for manned aircraft mission, route planning, and execution tasks.

2. TODAY'S UA WEATHER SUPPORT SHORTFALLS

Current military and civilian weather support generally consists of standard alphanumeric weather briefing packages with accompanying graphics. Gridded meteorological databases have generally been presented to forecasters, pilots, and UA operators in the form of 2-D and 3-D weather maps with accompanying text to describe enroute meteorological conditions and any predicted hazards. Capabilities now exist to overlay flight routes onto the weather maps in order to depict enroute wind and hazardous conditions for pilots and UA operators. Plan-view and 2-D cross sections are often used for such depictions. However, there still exists a technology gap in presenting and using gridded weather databases for flight planning and mission execution processes, especially for UA operations, in an efficient and useful format. It is possible to bridge this technology gap by integrating the 3-D and 4-D forecast data grids directly into all phases of the UA mission, from planning and tasking to launch and enroute updates to landing and recovery. The presentation of data as a UA Weather TDA will be based on user requirements.

While fly-through animations for preflight mission rehearsal and the depiction of enroute weather data grid updates will be helpful, the ultimate goal of this TDA technology is to present mission planners and UA operators with automatically generated alternate route options to enable aircraft to fly around (horizontally and/or vertically) adverse weather conditions while still achieving the mission objectives. The current scientific state-of-the-art calls for such improvements to be implemented with human operators "in the loop." However, the future increase in UA operations in military and civilian airspaces demands automation and machine-to-machine (M2M) communications. Such exchanges will include aircraft routing changes occurring in real-time as new weather forecast grids are communicated to UA flight control computers and will allow the aircraft route to be adjusted according to current and predicted weather conditions ahead.

3. TECHNICAL CHALLENGE AND GENERAL SUPPORT CONCEPT

The primary objective of this work is twofold: first, to integrate spatial and temporal forecast databases with UA mission profiles to depict weather impacts along the planned flight path, and second, to determine the optimal flight path based on calculating alternative paths when the planned flight path is predicted to pass through unfavorable weather conditions. The optimal flight path will be based on user considerations, mission priorities, forecast conditions, and operational thresholds of the aircraft. The use of intelligent agents to automate the routine tasks involved in product generation and flight path optimization will usher in the era of M2M weather support capabilities for UA flights.

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3.1 *The Weather Database Concept*

Regional mesoscale model forecast grids will supply pertinent data to populate the 4-D weather data "cube" with required raw and post-processed parameters. Locally observed data from conventional and unconventional surface and upper-air meteorological sensing sources, including local pilot reports from manned and unmanned aircraft, will be assimilated to initialize a local 3-hour Nowcast nested data cube within the regional mesoscale model cube. UA mission planning forecasts can be derived from the regional data cube to include updates, mission execution forecasts, and enroute updates during the UA flights provided by updates to the Nowcast 3-hour forecast cube. This concept is depicted in Fig. 1.

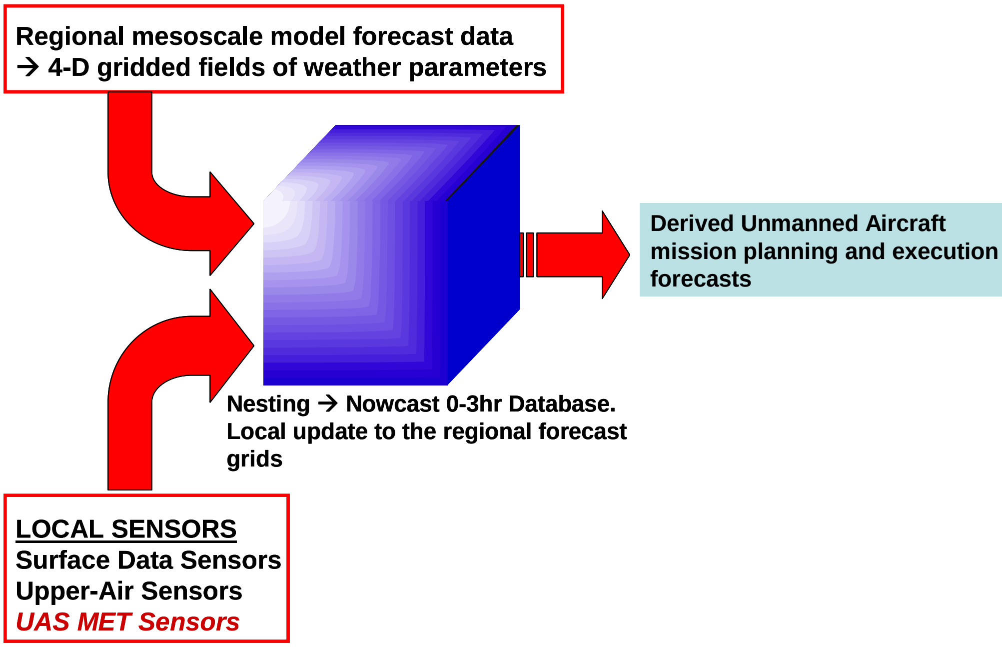

Fig. 1. Mesoscale modeling database and flowchart for the UA Weather TDA.

The gridded output provided by these data cubes will be applied to rule- and physics-based flight decision aids (Shirkey and Gouveia, 2002), focusing on critical UA thresholds for such parameters as icing, turbulence, convection, IFR conditions, winds, crosswinds, etc. When critical weather thresholds along the planned flight route are met, 4-D weather data cube grid points are identified and graphical route depictions can be appropriately color-coded to show the impact of the aviation hazard on the aircraft. For example, favorable conditions along the flight route can be depicted as the color green, marginal conditions as yellow, and unfavorable conditions as red. A sample of one possible depiction is shown in Fig. 2.

3.2 *Flight Route Optimization*

By combining the 4-D UA flight path with the 4-D weather forecast cube, adverse weather impacts on the projected flight path can be calculated as explained in section 3.1. Visualizing these impacts (see Fig. 2) will provide the forecaster, weather briefer, mission planner, and UA pilot/operator with an instantaneous picture of where to expect trouble spots along the route.

When marginal or unfavorable weather conditions are predicted enroute, the UA flight path will be optimized to avoid hazardous weather by determining the best alternate route from the launch point to the target point and return. By using automated technology that routes the aircraft along the most favorable flight path, unfavorable weather conditions will be avoided by steering the aircraft around, over, and/or under such conditions. Fig. 3 shows a flight path evolution, where an initial desired flight path from launch point to target area is shown passing through red (unfavorable) conditions. The route optimization algorithm will iteratively calculate the best and most favorable path, shown in incremental graphic mode in Fig. 3. The final acceptable flight path shown is one where weather conditions are depicted as green (favorable) for the entire route of flight. Such a solution provides as close to an "all weather" option as possible and serves to increase UA mission success rates without expensive aircraft redesign and re-engineering.

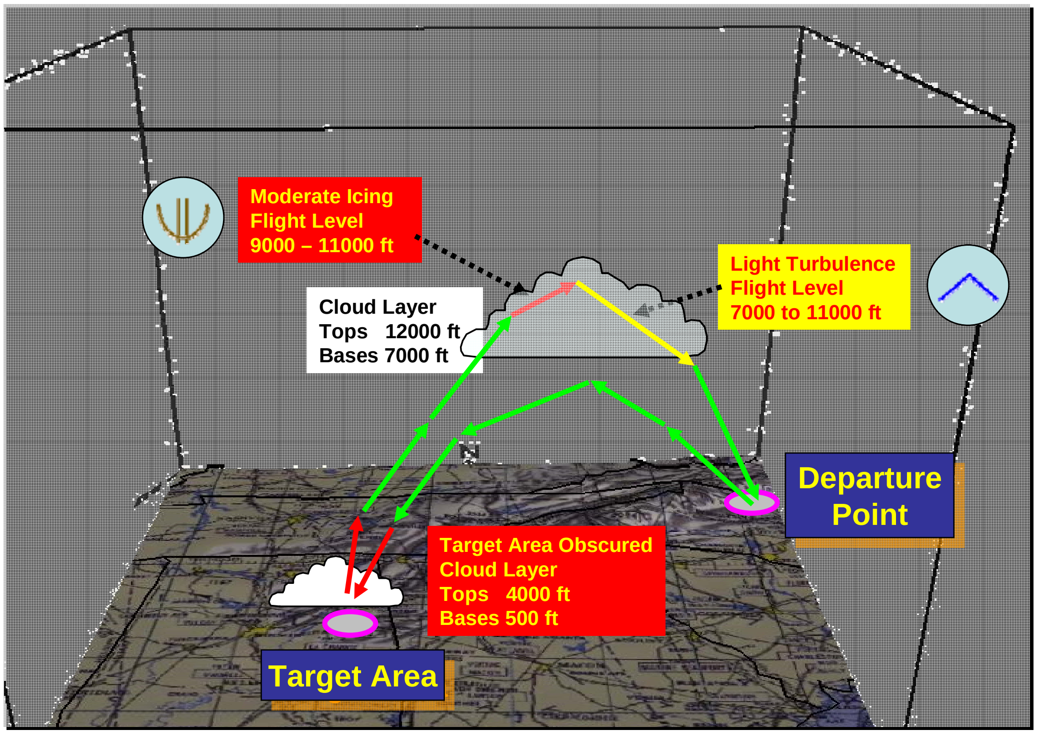

Fig. 2. Depiction of weather impacts on a planned UA mission profile. Green = Favorable conditions; no adverse impact on flight. Yellow = Marginal conditions; some impact on flight. Red = Unfavorable conditions; significant impact on flight.

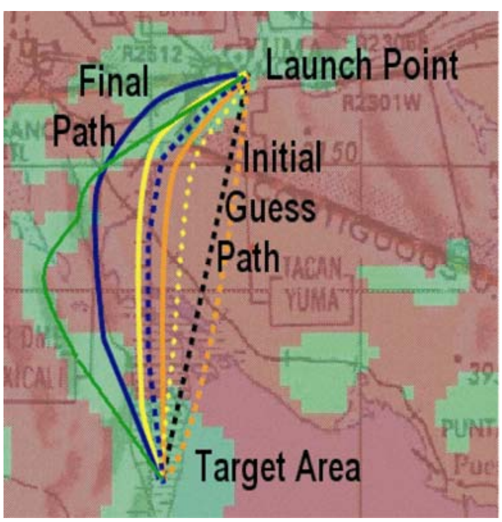

Fig. 3. Depiction of planned flight path evolution from original (passing through red, or unfavorable, conditions) to final (through green, or favorable, conditions).

4. APPLICATION TO AUTOMATED UNMANNED AIRCRAFT FLIGHTS

As the military evolves towards M2M automated technologies, complete automation of the UA Weather TDA is needed. With missions becoming more complex and with more UA flying in a given airspace at a given time, the human forecaster or weather analyst may not necessarily be a part of the preflight planning and enroute execution processes for each individual mission. Under conditions of computer-controlled automated flight using preprogrammed flight path waypoints, the flight computer will "receive" the latest data cube of weather impacts grids across the airspace volume of interest. The flight computer will match the current and planned route with corresponding grid point weather impacts, and automatically alter the route waypoints to avoid hazardous weather conditions ahead. This will be an ongoing and repetitive process for the duration of the flight as new 4-D weather forecast grid data are produced and disseminated to users. Fig. 4 depicts this iterative process for preflight and enroute capabilities. Manual override options will be programmed into the process, as needed, with the entire TDA package designed to reduce manpower tasking burdens on airspace controllers and support staff.

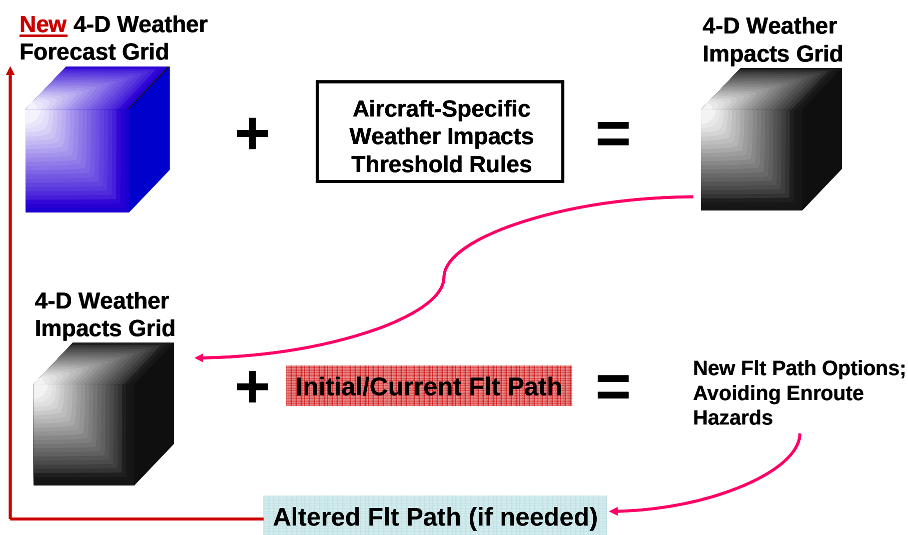

Fig. 4. Preflight and enroute recurring UA weather planning and flight path adjustment update process.

5. SUMMARY

A UA Weather TDA is being developed that will provide tailored UA weather support for all phases of the mission. The TDA will be able to be run in manual or automated mode, the latter addressing the complexity of increasing UA air traffic and mission requirements for a given airspace. Flight route optimization capabilities and 4-D visualizations will increase mission effectiveness in adverse weather conditions. M2M technology will allow for automated updates of new gridded weather databases to be communicated to the UA flight computer, resulting in dynamic rerouting of the UA enroute as predicted weather conditions change and enroute weather hazards are avoided. The UA Weather TDA technology under development will be suitable for use by military and civilian UA applications, as well as for manned aircraft mission planning and enroute weather support needs.

REFERENCE

Shirkey, R.C., and M. Gouveia, December 2002: Weather-Impact Decision Aids: Software to Help Plan Optimal Sensor and System Performance. *Crosstalk*, 17–21, http://www.stsc.hill.af.mil/crosstalk/2002/12/shirkey.html.