The Emerging DoD Requirement for More Realistic Weather in Flight Simulation

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ABSTRACT

High fidelity DoD simulators (especially virtual flight simulators) frequently include the capability of simulating variable weather conditions, so that a greater range of training tasks can be effectively conducted in a safe and forgiving virtual environment.

While other aspects of simulator performance have kept improving, weather simulation fidelity has ostensibly stagnated. The required fidelity of weather simulation in DoD virtual flight simulators has not appreciably increased for several decades. The reason for this is not technical limits or even cost, but rather that the requirement for more realistic weather has not evolved along with other types of simulation fidelity. Commercial database standards, such as OpenFlight, remain predominantly silent on how to express or model weather features, such as clouds, contrails, and snow/rain/ice.

This paper explores the history of the requirements and technical approaches of implementing weather simulation into DoD virtual flight simulators, beginning in the late '70s and extending to today's devices. It also assesses the new, emerging requirements for mission rehearsal and networked simulation and their potential for deriving the requirement for more realistic weather simulation fidelity. Commercial (FAA) flight simulator weather modeling requirements will be presented. Authoritative, real-world weather data sources, models, and data types are described. A conceptual design for implementing them in modern flight simulators is presented including visual and sensor displays, as well as its potential impact on improved training. This paper also describes the rules of engagement to incrementally prototype the addition of common, high fidelity weather modeling into high fidelity flight simulators. The prototyping goal is to provide Air Force Distributed Mission Operations (DMO) with a blueprint for achieving improved fidelity and expanded training capability during DMO networked operations.

The focus of this paper is on virtual flight simulation applications, but ideas and methods discussed here could be applicable to virtual ground based simulations as well, especially those that may be networked to virtual flight simulations.

INTRODUCTION

The weather in combat can be your greatest friend or your harshest foe. It can be your ally or your enemy.

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In military operations, weather is the first step in planning and the final determining factor in the execution of any mission.[1]
-General Carl "Tooey" Spaatz
First Chief of Staff of the Air Force

Weather is an important factor during most DoD real-world operations. Weather conditions can cause military operations to fail or succeed and are a key factor during operations planning and execution. Weather becomes even more important during DoD flight operations, since weather can affect the ability to take off, fly the planned route, evade detection, rendezvous, identify ground targets, execute the mission plan, and recover. There's also the always present danger that weather can kill you.

High fidelity DoD virtual flight simulation should likewise be affected by simulated weather conditions, as in the real world, yet the requirement for higher fidelity weather simulation in DoD flight simulators hasn't appreciably changed for the last thirty years, even though better ways of simulating a more realistic weather environment are available and affordable.

Weather in the real-world changes with time at each location; sometimes just a little, sometimes a lot, but it always changes. Weather in the real-world is also different at different locations; sometimes a little, sometimes a lot. Neither of these characteristics of real-world weather are supported well in DoD flight simulators.

HISTORY OF WEATHER SIMULATION IN VIRTUAL FLIGHT SIMULATORS

DoD

During training in the actual aircraft, weather can be a complicating factor that can cancel missions or cause ineffective training requiring re-fly. Flight student training schedules or planned graduation dates can be delayed because of weather. Required flight currency events may not be met resulting in aircrew non-currency because of weather. Weather can be a challenge for flight training schedulers and managers. Even more importantly, weather related factors can result in aircraft accidents and loss of life.

A flight simulator doesn't have those limits, and can be flown in simulated weather conditions that are appropriate to the training task. It can be raining and dark outside the sim building, but inside the sim it can be clear and bright. Aircrew training managers and courseware developers have long understood this advantage and have developed lesson plans, syllabi, and simulator mission profiles accordingly, most often with Ceiling And Visibility Unlimited (CAVU) "Severe Clear" weather conditions in the flight simulator, and sometimes weather conditions just at the edge of landing minima. Simulators have been built to support this.

Both the aircraft and a properly modeled simulator fly differently in different weather conditions. Air density affects engine thrust, wing lift, aircraft drag, and (over time) aircraft weight caused by changes to fuel consumption. Icing and hail can be especially dangerous. In air-to-air and ground-to-air operations, potential targets may often be first spotted because of contrails, long before the aircraft itself can be seen.

From their inception, early DoD digital flight simulators have included the ability to vary density altitude (a combination of barometric pressure and temperature), wind direction and velocity, gusts, and (after the advent of out-the-window visual systems) flight visibility. Other weather

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effects have been added with time, to include the effects of turbulence on motion bases, aircraft instrumentation readouts, and control loading, as well as visual special effects, such as thunderstorms, lightning, scud, and runway obscurants such as ice, snow, and rain. Many of these effects were developed to satisfy FAA requirements, not those of DoD, but are already available in commercial visual systems procured by both commercial aviation and DoD. Ordinarily these special effects are invoked by the simulator instructor to satisfy specific training requirements, without regard to their meteorological basis. This is well and fine, since the object is to train crew members, not meteorologists.

DoD flight simulators often make use of Standard Atmospheres, which are based on hundreds of thousands of real-world weather samples which are then reduced to average, usually global values for atmospheric temperature, pressure, and other properties over a wide range of altitudes. The most current U.S. Standard Atmosphere was founded on an existing international standard, and was last updated in 1976(2).

An interesting observation is that Standard Atmosphere weather conditions are statistically correct, but do not exist in the real-world. In the real-world, no column of air from the surface to (let's say) 35,000 feet ever conforms exactly to a Standard Atmosphere. Real-world weather conditions are not uniform and are not exactly predictable. The real-world NEVER performs as a Standard Atmosphere indicates, but if you sample the real-world often enough, the average will perform as a Standard Atmosphere indicates.

Most DoD flight simulators set up their weather conditions through pre-loaded automated mission profiles or through manual insertion of weather parameters through the Instructor Operator Station (IOS) that are best suited to train specific skills in the flight simulator. Weather conditions in DoD flight simulators are often homogeneous and do not differ with location or time. If a training task requires a different weather condition, the IOS operator can select another mission profile or manually change weather parameters. Temperature will change with altitude as a function of a Standard Atmosphere. Wind direction and velocity may often be set at several elevation levels and the experienced winds may be the result of interpolation between set elevation levels.

There also appear to be different interpretations of how weather data is computed using Standard Atmospheres. Mr. David Lerman is a senior engineer working for L-3 Communications/Link Simulation & Training at AFRL, Mesa with over thirty years of math modeling experience with flight simulators. He has noted over the years that of the many flight simulators he's reviewed, all compute pressure altitude incorrectly during non-standard temperature conditions (not 15ºC at Zero Feet Mean Sea Level). These simulators all used a homogeneous Standard Atmosphere solution, but they used it wrong during non-standard weather conditions. He assumes that some flight simulators must do it correctly, but he's not familiar with them. He plans to submit a paper on this subject at the upcoming Fall SISO Simulation Interoperability Workshop meeting in Orlando, Florida.(3)

A significant exception to reliance on Standard Atmospheres in DoD virtual flight simulators occurred in the late 1970s with the advent of Pressure, Wind, and Temperature (PWT) simulation in B-52, C-130, and KC-135 flight simulators, with B-2 flight simulators following suit a few years later. PWT was developed specifically to train Pressure Pattern Navigation, an arcane navigational technique no longer practiced or taught. In the real world pressure, wind, and temperature are all related to each other, and that relationship is (or at least was) taught to all military and commercial pilots in ground school. As an example of that relationship, with PWT, as the simulator flies toward a high pressure system in the Northern Hemisphere, drift is to the left and outside air temperature increases, and vice versa when flying toward a low pressure system. The greater the pressure change during flight, the greater the drift and temperature change.

PWT is fed by a global grid of real-world, historical, pressure, wind, and temperature data with eleven elevation levels at each grid point. Digital weather grid maps were produced by Government meteorologists over the northern hemisphere for all four seasons. PWT transforms the gridded data as a mirror reflection to support training in the southern hemisphere. As the simulator flies across the earth, the PWT software interrogates the selected stored grid and triple interpolates pressure, wind, and temperature values three dimensionally between grid posts and between elevation values. PWT can also be overridden through the IOS to use a Standard Atmosphere solution to support more conventional training. PWT is still being used, at least in C-130 simulator training.

The significant point to be made regarding PWT design is NOT that Pressure Pattern Navigation needs to be taught nowadays, but rather that thirty year old simulation technology could easily support the storage and computation of real-world, 3D gridded weather data. PWT math models and design data(4) are government owned and available.

FAA

The FAA National Simulator Program (NSP) has long established full flight simulator fidelity standards through the FAA Advisory Circular 120-40B(5) and now the new Appendix A to 14 Code of Federal Regulations Part 60(6). These documents contain the FAA rules regarding the fidelity required to perform discrete training tasks or phases of flight in a flight simulator. The FAA requires an extensive list of weather effects and conditions, both in terms of how the simulator flies and what the crew sees through the windscreens.

FAA-certifiable full flight simulators must take into account temperature, altitude, crosswinds, wind shear, wet and icy runways, and turbulence. Visual systems must include a full range of flight visibility conditions, clouds, icing, light/medium/heavy precipitation, storm cells, wet and snow covered runways, wet runway lighting reflections, and runway lights partially obscured by snow.

As in the case of DoD flight simulators, most FAA NSP approved simulators set up their weather conditions through pre-loaded automated mission profiles or through manual insertion of weather parameters through the IOS, and weather conditions are often homogeneous and do not differ with location or time.

Some DoD flight simulator programs have found it useful to reference FAA fidelity requirements, especially since both DoD and FAA are supported by essentially the same industry base that is accustomed to the FAA requirements and has developed technologies to satisfy FAA requirements. DoD flight simulator programs that reference FAA NSP requirements must add their own unique requirements to those of the FAA, since DoD flight simulators are often used differently (low level, formation flight, threat avoidance, weapons delivery, networked operations, etc.) and have different sensors and equipment (NVGs, FLIR, ground mapping radar, offensive/defensive equipment, etc.).

The significant point to be made is that DoD flight simulator training requirements are not the same as FAA flight simulator training requirements in all respects. Simply because the FAA does not require some aspect of simulation fidelity does not mean that DoD flight simulators do not require it or can receive considerable training value from it.

Commercial Development/Flight Games

Microsoft's Flight Simulator® flight immersion "game" for personal computers has enjoyed considerable success for over twenty five years, with millions of copies sold in the $20-$40 price range per copy. Microsoft ceased Flight Simulator product development in early 2009. Laminar Research's X-Plane® flight immersion "game" has sold over 750,000 copies starting at about $20, and is continuing development. Both products allow flight hobbyists to see and interact with many of the same stimuli present when flying real aircraft, but from home in front of their PC.

Besides the weather characteristics required by most DoD or FAA flight simulators, Flight Simulator and X-Plane also include the ability to tap into hourly METAR meteorological data published on the web. This means that when setting up for a takeoff from one of tens of thousands of different airports, Flight Simulator and X-Plane will show last-reported visibility, temperature, winds, and cloud conditions at that airport, then takeoff, climb, cruise, and descend to land at one of tens of thousands of airports while experiencing the weather conditions that existed in the real-world METAR report for the arrival airport. Both Flight Simulator and X-Plane can fly in reported weather conditions that actually exist, not in Standard Atmospheres that do not exist…anywhere…ever.

The image generator vendor community supporting both DoD and FAA flight simulators makes extensive use of PC-based commercial rendering engines that offer remarkable and inexpensive (compared to twenty or even ten years ago) fidelity, to include highly realistic cloud and sky rendering that was unachievable at any cost twenty or even ten years ago. The polygon-based clouds in yesterday's image generators often resembled a Klingon Battle Cruiser or a sperm whale more than they resembled a cumulonimbus. In some cases, courseware developers were hesitant to use that capability because of its lack of fidelity.

Today's image generators can render particle-based and shaded clouds that appear highly realistic, even to the experienced aviator. Also, several third-party vendors, such as Sundog Software's SilverLining™ and Simul Software's CloudWright™, offer extensive libraries of very realistic cloud and sky models. Some of our PC-based image generator vendors purchase ready-made libraries, while others develop their own.

The significant point to be made is that inexpensive, commercial flight games include weather simulation capabilities not supported by very expensive DoD flight simulators. DoD flight simulators exist for training, not entertainment; however, the once clear line demarcating training from entertainment is becoming blurred as both applications are converging in their common pursuit of increased immersion during simulation events. Several DoD simulation organizations are now pursuing gaming technologies for training applications.

FORCES AFFECTING MORE REALISTIC WEATHER

Conventional Training

There is strong and logical training value from continuing to apply "statistical" or Standard Atmosphere weather parameters during conventional training in virtual flight simulators. That will not and should not go away.

This is especially true during initial skill acquisition where (for example) landing training at weather minima or range work under unlimited visibility conditions can expedite and simplify completion of discrete training tasks without the complexities and complications of changing and non-uniform real-world weather conditions.

Weather in the real world can make training task accomplishment very difficult in the aircraft. A virtual flight simulator can provide a stable and consistent weather environment specifically tailored for the training task at hand.

Courseware Inertia

There is some risk that courseware inertia may prevent best use of newly available technology and its ability to simulate more realistic weather.

As an example, during discussions with an Air Force pilot who flies a single seat aircraft, he mentioned that he received very good simulator training prior to the aircraft training phase, with the exception of weather complications. During his first aircraft range flight with wingmen he encountered unexpected marginal weather conditions while enroute to the range. Although taught and briefed regarding unanticipated weather penetration procedures, he and his formation "floundered around" quite a bit and really could have used a simulator event or two beforehand. His comment regarding "floundering around" was probably understatement on his part.

His comment is indicative of the potential effects of courseware inertia. His simulator had been upgraded several years before with a new visual system that could generate very realistic clouds and weather conditions. The old visual system could not generate realistic clouds, and the new capability did not yet make it into training courseware, curriculum, or simulator mission scenarios. All of his simulator events for range training were CAVU "Severe Clear."

Simply because a new and useful capability is added to an existing simulator does not automatically mean that it will be used properly.

The availability of more realistic weather simulation should not focus on training scenarios that have only one possible outcome-failure with a smoking hole in the simulated ground. Scenarios should be kept realistic and challenging, but survivable at the skill level of the typical trainee.

Emerging Training Applications

The relatively new requirements of training higher order skills (meta-skills such as situation awareness and decision making), accomplishment of mission rehearsal, and participation in networked simulation exercises can derive a requirement for more realistic weather.

Metaskills and Mission Rehearsal. Part-task, procedural training of many flight skills does not require a sophisticated or complex weather environment. If the training task is (for example) learning to takeoff and land in Visual Flight Rules (VFR), the weather conditions can be set to the conditions best suited to initial skill acquisition, such as day or night CAVU and no winds. More complicated flight conditions (restricted visibility and ceilings, crosswinds, gusts, scud, rain/snow, wet/icy runway conditions, etc.) can be added as the student progresses. The weather conditions need not change with time or with simulated aircraft movement through the environment and are easily controllable through automated mission profiles or manual changes of weather parameters from the IOS.

Higher order metaskills such as Situation Awareness (SA) are composed of many skills, all integrated and demonstrated at one time to resolve complex tasks. Having complete, accurate and up-to-the-minute SA is essential where successful decision making is required during complex technological and situational events. SA has been recognized as a critical, yet often elusive foundation for successful decision-making across a broad range of complex and dynamic systems, including aviation and air traffic control.

Although SA is somewhat of a DoD term, the FAA has been training their version of it for years. The FAA has been using a training concept called Line Oriented Flight Training (LOFT) where students toward the end of their training are required to use a wide variety of their acquired knowledge of normal, abnormal, and emergency procedures across aircraft subsystems during operationally relevant problem scenarios.

Flight simulators can be well suited to train metaskills, but typically require very high order realism to do so, since the students integrate a wide variety of sometimes ill-defined stimuli when arriving at the best decision or action for the task at hand.

Mission rehearsal in flight simulators includes the requirement to practice a mission scenario in a simulator shortly before executing the same mission in the aircraft. This demands a very realistic simulator environment that is as identical as possible to that of the real world in the near future, perhaps one or two days after the mission rehearsal event. The simulated spatial environment would have to closely resemble what the real world will soon look like and the meteorological environment would need to be forecast. Again, very high order realism would be required.

Simulator Network Correlation. The correlation required for networked simulation demands a common and consistent weather environment.

Networking of different virtual simulators requires strong attention to achieving sufficient environmental correlation. What one player sees should be consistent with what others in the network see, otherwise the concept of “fair fight” cannot be supported and any training results or operational conclusions can become questionable.

The theme of networked correlation can be broken down into three domains; those of Behavior, Appearance, and Time. The domain of Behavior includes the characteristics of movement, velocity, acceleration, emissivity, reflectivity, absorption, and skill level. The domain of Appearance includes the characteristics of size, color, material, intensity, location, elevation, contrast, and attenuation. The domain of Time includes characteristics of latency, recency, duration, sequence, periodicity, and stop/start. Behavior can change Appearance over Time. It’s a very complicated issue, and weather plays in all three domains.

The correlation issue becomes even more complicated with the addition of live simulations to the networked event. The combination of live and virtual entities in a networked exercise can place highly demanding fidelity requirements on the virtual simulation environment. The weather must be real world or it will not match that of the live entities. The use of Standard Atmospheres and static weather conditions will not match real world weather experienced by the live simulation.

Large investments of time, attention, and funding have gone into satisfying demanding requirements for improved modeling of environmental features in simulator databases. Common tools and common formats have been adopted by Industry that allow feature geometry and appearance to be shared across vendors to decrease database generation cost and assist correlation during networked operations. Correlated cloud modeling and weather effects are not included or supported by those tools and formats.

Even if all entities in a networked event share the same environmental weather data, differences in how the data is computed internal to the simulations could still cause objectionable correlation errors.

There does not appear to be any available method of sharing weather modeling characteristics or constraining weather correlation in a network environment. Sufficient attention has not been placed on the importance of correlated weather modeling or on rules and standards for weather modeling.

Improved Weather Scene Rendering

Improvements in commercially available visual/sensor image generation and rendering techniques, especially of clouds, can make more realistic weather effects affordable.

Clouds can be modeled in several ways. They can be modeled as two dimensional billboards for long distance viewing near the horizon. The billboards contain a texture map of a cloud, and can either rotate to face the observer as the observer moves through the scene, or move along with the observer. For shorter distance viewing very realistic, three dimensional, volumetric clouds can be modeled and rendered by modern image generators. These clouds can also be realistically shaded by the current sun location. Overcast clouds or cloud decks can be modeled through the use of horizontal texture maps of both their bases and tops. Although the polygons that the texture maps are attached to do not move relative to the simulated aircraft, the texture maps can be assigned a velocity vector opposite to that of the simulated aircraft, providing realistic velocity cues when entering or exiting the cloud decks.

As previously noted, the FAA has been at the forefront of requiring new weather effects. Much of the competitive image generator vendor base that serves the FAA also serves DoD. DoD programs can take advantage of these effects if they wish, with some consideration made to processing overheads attached to them. Those overheads are becoming less restrictive with time.

An Authoritative Source of Real World Weather Data

The Air and Space Natural Environment, Modeling and Simulation Executive Agent (ASNE MSEA) Team is the DoD-level organization that is chartered to provide the DoD Modeling and Simulation (M&S) community with (among other things) meteorological data, products, analyses, and support. The ASNE Team does not set requirements for environmental data, the Warfighter and Modeling and Simulation users ultimately do that. Their job is to respond to Warfighter requirements in all matters meteorological and space.

The ASNE MSEA Team, through partnerships with the Air Force Weather Agency (AFWA), the Naval Meteorology and Oceanography Command, and the National Geophysical Data Center, provide authoritative meteorological data to a wide variety of DoD modeling and simulation programs and exercises.

Through the use of the Environmental Data Cube Support System, numerical model data is utilized to create tailored products and data to fit the specific needs of individual M&S applications. DoD modeling and simulation programs can request meteorological data in one of several commonly used formats, with specific data types, units, precisions, grid spacings, and other parameters. The data can be historic, current, or forecast and can also be a single snap shot in time or time-phased across several hours, weeks or days.

If a DoD M&S program wants authoritative environmental data to support their model or simulation or merely expert meteorological advice, the ASNE MSEA Team should be contacted. As a DoD organization they stand-by to support the M&S community.

An interesting note is that a predecessor organization to AFWA produced the real-world, 3D gridded weather dataset that drives PWT.

REAL WORLD WEATHER DATA EFFORTS

SEDRIS

The DoD-sponsored Synthetic Environment Data Representation Interchange Specification (SEDRIS) program has developed an Environmental Data Coding Specification (EDCS) that includes explicit descriptors for ten different types of clouds, cloud base, cloud layer/thickness, cloud top, cloud top temperature, and cloud water mixing ratio. SEDRIS weather descriptors tend to focus on portions of the weather environment that can be seen, such as clouds. It must also be noted that SEDRIS EDCS provides a data structure or holding place for cloud models, but does not provide the models themselves.

ASNE MSEA has supported at least one DoD M&S program with authoritative weather data using SEDRIS conventions.

ARMY ASTARS

The Army Special Operations Forces Aviation Training and Rehearsal Systems (ASTARS) program provides flight simulation resources to the 160th SOAR(A) Night Stalkers at Ft Campbell, Kentucky. The ASTARS program is administered through Army PEOSTRI in Orlando, Florida and includes design, development, and implementation of the SOCOM Common Data Base (CDB). CDB includes a real-world, 3D gridded, time-phased weather environment capability.

ASNE MSEA has supported ASTARS with authoritative, real-world, historical weather data using elevation levels, data types, grid resolution, and units for the selected time period to specifically support ASTARS training and rehearsal requirements.

AFRL REST

Several years ago, the Air Force Research Laboratory's Rehearsal Enabling Simulation Technology (REST) program created a 22 geocell environmental dataset in Air Force Common Dataset/Navy Portable Source Initiative (AFCD/NPSI) formats covering many Air Force, Navy, and Army training ranges in the US desert southwest. It has been made available to any DoD program as a starting point for additional value-adding and conversion into run-time databases.

In addition to the normal GeoTIFF, Shape, and OpenFlight files that are often used to create spatial environments, the dataset includes a weather dataset layer using the data types, resolution, and units developed for ASTARS, but covering the southwest ranges area. It includes historical weather data covering 64 geocells at 20 different elevation levels, with a 20nm grid spacing, for each hour over a seven day period. The REST weather data layer is also available for any DoD program to inspect, use, and conduct experiments/analyses.

ASNE MSEA generated the AFRL REST weather dataset layer.

DMO O&I

> **The requirement for the Air Force's emerging distributed mission operations program to provide immersive mission rehearsal environments is better satisfied with realistically modeled weather.**
> **-Air Force Doctrine Document 2-9.1, Weather Operations, 3 May 2006**

The Air Force DMO Operations and Integration (O&I) program has the charter to identify deficiencies and develop standards to minimize correlation differences and enhance fidelity during DMO networked operations.

Because of the significant impact of weather conditions on realistic DMO operations, DMO O&I recently published and approved a revision to their Synthetic Natural Environment (SNE) Standard[6] to include weather data types, units, and precisions. The Standard does not define data format, only content. Either manual weather data entry through an IOS prior to or during simulator missions, or off-line during mission profile generation is considered sufficient for Standard compliance.

The DMO SNE Standard supports static weather conditions that do not change with time. The Standard allows for one set of weather conditions to be homogeneously applied throughout the entire DMO gaming area, with no differences in weather in any location, although the Standard does suggest that some systems may interpolate between weather conditions at different locations in the gaming area.

The DMO SNE Standard was developed to meet and not exceed the weather simulation capabilities of existing DMO programs, some of which are supported by 10-15 year old simulation technology with limited weather modeling capabilities. The Standard is not intended to require new weather simulation capabilities, but rather to ensure that the existing weather simulation capabilities generate a weather environment that is as consistent and correlated across DMO participants as possible within existing design and budget limits.

If real world, 3D gridded, time-phased weather data would be used by current DMO flight simulators, some automated method of inputting weather data would be required. An IOS operator would be overwhelmed with inputting weather data changes as the simulator moved through time and space. The task of manual entry would be error prone and would be simply too hard to do. Most of the costs would be associated with automating weather data entry.

Perhaps the least expensive and most pragmatic way of integrating more realistic weather into DMO may be during future DMO programs' competitive acquisition phase. The requirement for more realistic weather can be clearly stated and proposals can be generated and competitively priced to meet that requirement. This demands a long term view, since changes to weather modeling requirements and system design in existing programs do not appear to be cost effective in the short term via engineering change proposals.

DMO Standards are living documents that are intended to be changed and modified as the DMO community matures and supportive technology evolves. The DMO O&I SNE Standard is a good start.

ASNE MSEA worked closely with the DMO O&I Standards Development Working Group during drafting, coordination, and approval of the Standard.

A CONCEPTUAL PROTOTYPE DESIGN

An Exemplar Prototype to Reduce Risk

The DMO O&I SNE Standard is bounded by the capabilities and limits of existing DMO programs. It does not reflect the capabilities of existing technologies nor the derived requirements of networked simulation.

Methods should be found to prototype the integration of improved weather realism into flight simulators. Prototype design methods and actual cost should be made available to the DMO community to lower their perception of cost, schedule, and performance risk.

Some work had already been done. Math models and algorithms developed many years ago for PWT could be used as the design basis for the integration of realistic weather in a runtime aero model. Some early integration of real world weather data has been demonstrated in the USAF AFRL XCITE threat modeling system, but much more work remains.

Prototyping results can also be used to assess potential benefits of improved weather realism, to make changes to the DMO O&I SNE Standard as it continues to evolve, and to help future DMO-compatible simulator programs to more confidently define their requirements.

Prototyping Rules Of Engagement

Prototyping should focus on methods to reduce the cost, schedule, and performance risks associated with the integration of real-world weather into DMO.

Prototyping should at least initially focus on data types, units, and precisions enumerated in the existing DMO O&I SNE Standard.

Prototyping should focus on existing software designs and math models that incorporate real-world, 3D gridded weather data into flight simulators.

Prototyping should focus on real-world weather performance parameters frequently missing from DoD flight simulators; namely, variability with time and location.

Prototyping should focus on methods to automatically incorporate authoritative weather data into flight simulator scenarios that impose the least amount of additional work on flight sim operators.

Prototyping should include capture of potential DMO training benefits and recommended changes to existing DMO Standards.

Prototyping should focus on an incremental approach to real-world weather integration into different flight simulator functions and subsystems.

Prototyping results must not impede or restrict the creative and competitive flight simulator and image generator vendor community.

Anticipated Benefits of Prototyping Realistic Weather

The prototyping effort alluded to here is conceptual. The described effort would prototype the integration of real world weather data into targeted simulations existent at AFRL/RHA, Mesa, Arizona. The intent of the prototyping effort would be to reduce the cost, schedule, and performance risk associated with the integration of real world weather data into DMO simulation systems.

Prototyping would require close coordination with ASNE MSEA offices, the DMO O&I program, and the Industry base, and the results would be shared with the DMO and DoD flight simulation community.

CONCLUSIONS

The DoD flight simulation community has paid scarce attention to improving weather modeling fidelity as compared to many other aspects of environmental realism which have immensely improved.

The results of a prototyping effort to improve weather modeling can help prepare the path toward supporting the emerging DoD requirement for more realistic weather in flight simulation.

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