
# DCS History Excursion and Techniques

## Volumetric clouds and lighting

An integral part of all flight simulators is the recreation of the sky. As developers, we treat all possible atmospheric phenomena with special reverence and attention to detail. Our goal is to develop and implement solutions as realistically and efficiently as possible based on existing and near term hardware.

### Eagle Dynamics SA

Over the past 30+ year history of DCS, the implementation of clouds has radically evolved. The first iterations were implemented based on a particle system where each cloud was represented as a separate object. This made it quite easy to scatter them around the maps and use this data to calculate line of sight blocking. However, this was a rather inefficient rendering technique with many issues and shortcomings. These included sorting problems and rotating/intersecting particles when moving the point of view. Additionally, with particles, it is almost impossible to effectively describe and render huge multi-layered cloud formations that cast shadows on the terrain, objects, and themselves, while adequately taking into account the scattering and attenuation of light.

Our new approach involved a complete abandonment of the particle systems in favor of the raymarching technique. In this approach, clouds no longer exist as separate objects, but are rather represented as continuous volumes in which the cloud density is known at each point in space. To draw such a volume, you must calculate each pixel along the line of sight and calculate the fair integral of the illumination and opacity of the clouds.


This approach:

- Allows you to effectively solve the issue of self-shadowing;
- Allows you to implement a physical model of light scattering, similar to the one used in our sky model;
- Allows you to conveniently describe large volumes of clouds and create a large number of types.

In 2014, the first version of raymarch clouds was created. These were single-layer clouds designed for flat earth which suffered from noticeable limitations in quality and rendering distance as well as self-shadowing issues. A global coverage map was supported, and weather fronts could be created. Taking into account the limited power of video cards at that time, it was not possible to fit them into the rendering frame budget in a way that would satisfy the majority of our customers. Those of you who have been with us for a while may remember how an earlier update included clouds being rendered at the edge of the render field and how they would slide by, simulating movement. From your feedback, it became clear that this new cloud technology was not ready based on available hardware.

As hardware evolved, new challenges emerged. It became clear that single-layer clouds were no longer sufficient  as they do not allow creation of multi-layer configurations, and they do not allow multi cloud type support, such as cumulonimbus, in one volume. Furthermore, support for a spherical earth map was also put on the agenda.

In 2021, a new volumetric cloud system was released, written almost from scratch. This system:

- Was designed for a spherical earth;
- Allowed up to 16 independent layers;
- Had a drawing radius of 400 km; the radius can be increased even more without much loss of quality;
- Had extremely advanced and efficient mechanisms for integrating lighting and cloud composition;
- Self-shadowing was no longer limited to a small radius; clouds on the horizon could now cast a shadow across the entire map;
- All transparent objects and effects blended with the clouds;


- There was no longer the problem of sorting effects and glass with clouds based on the particle system;
- Rain and snow were now part of the system;
- Most of the optical effects that appear on clouds had been implemented like rainbows, moonbow, halo, glory, fog bow, and more.
  https://en.wikipedia.org/wiki/Halo_(optical_phenomenon)
  https://en.wikipedia.org/wiki/Glory_(optical_phenomenon)
  https://en.wikipedia.org/wiki/Fog_bow
  https://en.wikipedia.org/wiki/Moonbow

However, there is more work to do as not all cloud features have been realized. Some of the remaining tasks include:

- Development of a dynamic cloud generator;
- Support new cloud types;
- Support additional lightning effects;
- Improve rendering and lighting quality and optimization;
- Add the ability to describe weather fronts and local cloud formations;
- Dynamic cloud simulation;
- Ability to import real weather data;
- Provide a cloud editor interface;
- AI and visual and sensor line of sight blocking;

# The Fog Problem

The current fog technology has existed since the creation of DCS and had the following limitations:

- Only calculated for a flat Earth;
- Did not adequately take into account the light from the atmosphere, and this resulted in the fog not “fitting” well into scene lighting;


- Did not take into account shadows from the new cloud system and did not blend with them;
- Was always continuous and uniform;
- No self-shadowing;
- Did not blend with rain volume.

The dust effect is done in a similar way to fog, but is implemented as a separate effect. Furthermore, it doesn't correctly blend with new clouds, take cloud shadows into account, nor affect the visibility of sensors. In addition, due the fact that the new cloud system is calculated for a spherical Earth, and the current fog is for a flat Earth, they cannot blend with each other. So it became apparent that the need to implement a totally new fog that would support both the new cloud system and a spherical Earth was urgently required.

In order for the new fog to be fully compatible with the new clouds, it is logical to make it part of the new cloud system. A seemingly simple task, it was in fact an extremely non-trivial one requiring many man years of dedicated work. Drawing the fog in one pass along with the clouds while storing information about the density of the fog in the same volume as the cloud data was highly complex and challenging. This is due to the high data-density required to describe clouds and fog that are not comparable. To describe low and dense fog, a very small voxel size is required, but a larger voxel is sufficient to describe a small cloud. Moreover, even today, the technique of raymarching clouds is quite computation-heavy, and the entire frame of clouds is not drawn completely in one pass. Instead, the technique of temporal reprojection is used that allows cloud samples drawn in previous frames to be reused. This technique isn't perfect either as it introduces a whole class of problems and artifacts that only get worse when trying to paint thin, dense fog against the ground. All this poses a serious engineering challenge.

Today, we do not know of a single successful implementation of a single volumetric cloud system that can draw fog in one pass without a significant performance hit.

# Our New Fog

Despite all these challenges, we succeeded in developing a truly state-of-the-art and unique solution that resolves all the issues listed above. Features of this new fog system include:

- A novel approach to fog reconstruction has been implemented;
- Fully compatible and integral with cloud shading;
- Accounts for a spherical Earth;
- High quality fog appearance without the look of lower-resolution rear projection;
- It can be extremely dense and down to ground level;
- Shadows from clouds and ground are taken into account;
- Supports self-shadowing;
- Blends with clouds;
- Can be any color and color-blends with the clouds;
- Compatible with rain volume;
- Allows for patchy fog areas;
- Supports animations of moving fog;
- Maximum thickness of 5 km that can be used to simulate suspended matter in the air.

The dust effect is also now implemented, and is based on the new fog with full shading compatibility. Just like fog, the dust effect can affect the AI and sensor visibility, which was not the case in previous versions of DCS.

From the Weather Tool in the Mission Editor, you can manually set fog or select the automatic mode. Today, in automatic mode, fog appears at sunset and dissipates after dawn. This mode will be further developed to take into account weather, precipitation, cloud density, temperature, humidity, etc.

A scripting fog API has also been added that allows you to animate the fog in any way you like and bind it to an event. All this is synchronized over a network, allowing you to create fog animations as part of online missions. See:

https://www.digitalcombatsimulator.com/en/support/faq/1257/#3342022

# Volumetric Lights

Light scattering is one of the key features of clouds and fog as it creates a glowing effect around light sources. This is in tandem with addition of volumetric light sources. Fog and clouds are now illuminated by different light sources depending on their density.

Moreover, clouds and fog now receive and scatter light from the Earth. In the included inmates, you can see how the clouds and fog are highlighted by city lights, and the night lighting now looks even more realistic.

# New fog demonstration


# Volumetric Lights demonstration