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Methodology report

Staffan Nählinder

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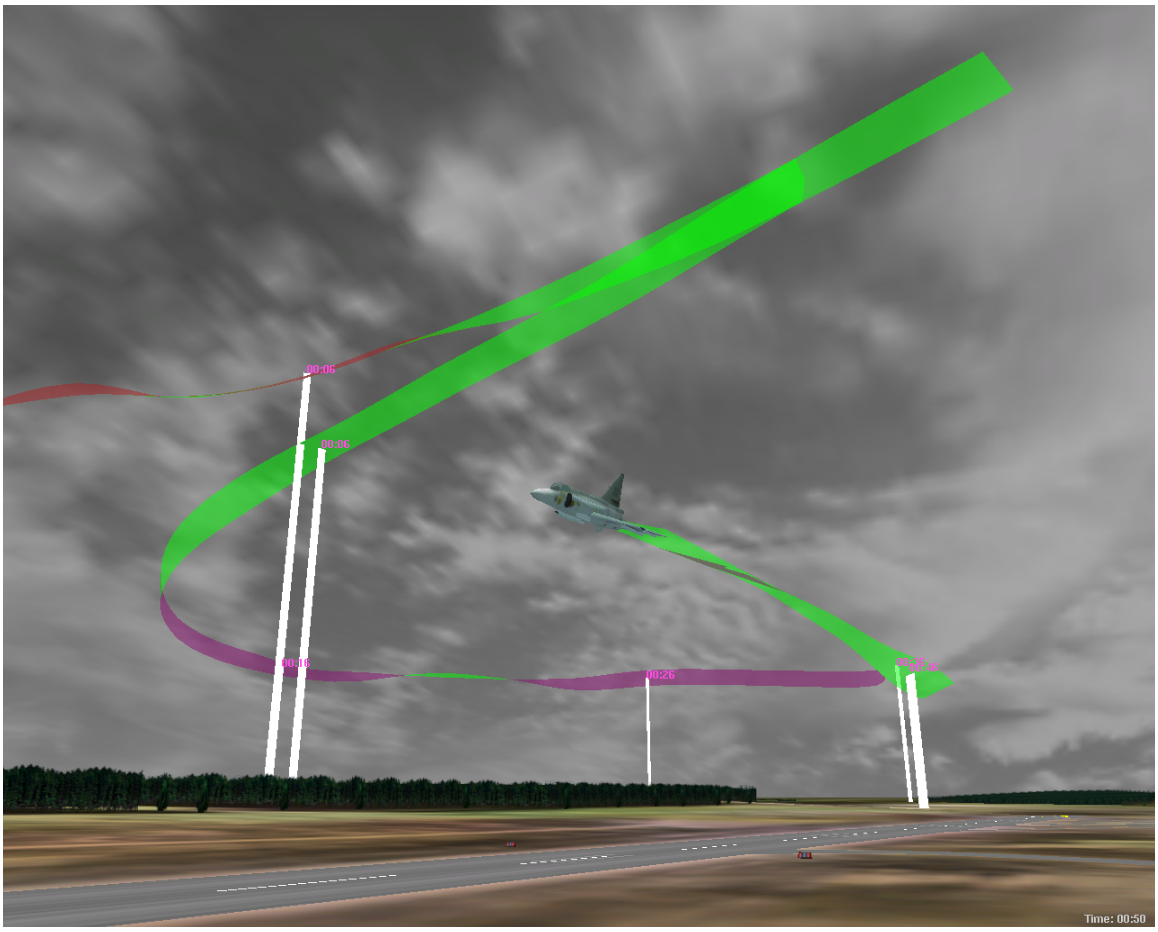

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Report title

ACES - Air Combat Evaluation System

Abstract (not more than 200 words)

ACES – "Air Combat Evaluation System" is a research flight simulator specialized in within visual range (WVR) air-to-air combat. The system consists of two simulator cabins (pilot stations) and one instructor station. ACES is built around several pedagogical tools intended to make WVR-combat much easier to learn. ACES is a research simulator used for evaluation of pedagogical concepts of learning dogfight and to serve as a development simulator to demonstrate and evaluate the strengths of embedded pedagogical tools and online (real-time) analyses of important air combat flight parameters.

Keywords

ACES; WVR; Dogfight, Flight Training

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Sammanfattning (högst 200 ord) ACES – "Air Combat Evaluation System" är en forskningssimulator som är specialiserad på luftstrid "Within Visual Range (WVR)". Systemet består av två flygkabiner (pilotstationer) och en instruktörsstation. ACES är byggd runt ett flertal pedagogiska verktyg som syftar till att underlätta träning och inlärning av luftstrid. ACES är en forskningssimulator som ska användas för att bland annat utvärdera nyttan av pedagogiska verktyg vid träning av luftstrid samt tjäna som en utvecklingsplattform för att demonstrera och utvärdera fördelar med inbyggda pedagogiska verktyg och realtidsanalyser av ett flertal inbyggda luftstridsparametrar.		
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Introduction

Purpose of this document

This document gives an overview of ACES (formerly known as the WVR "Within Visual Range"-Demonstrator), describing the technical components and briefly the possibilities and limitations of the system. It also briefly outlines the intended use of the system.

The intended readers of this document are the people working directly with the ACES system, but it can also serve as a reference for future reports concerning the system. Much of the information in this document is gathered from various SAAB Technical Reports as well as meeting minutes from the IPT-process ("Integrated Project Team") during the development of the system.

Background of ACES

The ACES (formerly known as the WVR-Demonstrator) has been procured of Swedish Armed Forces Headquarters (HKV) via the Swedish Defense Material Administration (FMV) from the "Industrigruppen JAS AB". Primarily it will be used by the Swedish Defense Research Agency (FOI). SAAB Aerosystems has together with SaabTech, Ericsson Microwave Systems and AerotechTelub delivered the system to FMV in June 2004. The system is now in place at FOI in Linköping. ACES is the second step of development after the so called "WVR-Illustrator", see Borgvall et al 2002.

ACES will be used in research concerning simulator fidelity, evaluation of embedded pedagogical tools, head-mounted-displays, dogfight, and analysis of forward air controlling. In the future, several other studies will take place. The simulator system will also be connected to The Swedish Air Force Air Combat Simulation Centre (FLSC) in Stockholm to explore the possibilities and benefits of distributed simulation. ACES belongs to the family of Swedish Air Force simulator facilities (such as the FLSC and the DFS) of central importance in systems development and evaluation.

ACES

ACES stands for "Air Combat Evaluation System" and is a flight simulator specialized for within visual range (WVR) combat. The system has two simulator cabins and one instructor station, see Figure 1. The main use is to train two pilots in dogfight. An instructor can control the scenario and follow up the combat as the two aircraft try to destroy each other. The flight models and the cockpit layouts resemble a SAAB JA37 "Viggen" aircraft. The simulator has both radar and a weapons system (gun and sidewinder robots "Robot 74"). ACES is a research simulator and is not intended to actually serve as a training platform for the Air Force. It is rather intended to be used for evaluation of dogfight and to serve as a development simulator to demonstrate the strengths of embedded pedagogical tools and online (real-time) analyses of important parameters. The ACES system has several embedded tools for demonstrating the progress of a dogfight combat scenario to the pilots in the cabins as they fly their mission. That is, the ACES system has been built around the concept of pedagogical training rather than high fidelity. A brief overview of the pedagogical tools is found below.

Figure 1. The ACES. The two cabins can be seen in back. In front the Instructor Station

ACES Hardware

The ACES system has two simulator cabins and one instructor station. Each cabin is run by four PC computers and the instructor station is run by three PC computers, see Figure 2. The cabins and the instructor station communicate with each other through

HLA. It is possible to connect ACES with other simulators in a distributed simulator environment (Löfgren, 2003).

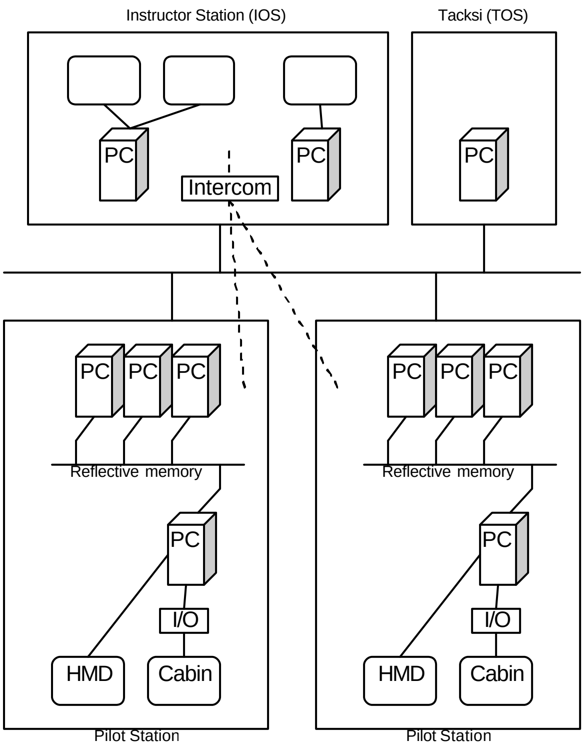

Figure 2. Schematic overview of ACES computers. Instructor station at top and two cabins below. Translated from Ladell & Rudström, 2004.

Cabins

The ACES system consists of two pilot stations, or cabins, that resemble the cockpit of a Viggen aircraft, see Figure 3. The cabins have a stick, throttle, pedals and a radar control from a real Viggen aircraft. The instruments are displayed on a 20 inch computer screen. The pilot can control the instruments with a mouse-control.

The head-up, out-of-the-window virtual world, is displayed in a Kaiser "Sim Eye XL100A" (Kaiser) head mounted display (HMD), see below.

Figure 3. Outside view of the two cabins.

Head-Mounted-Display ("HMD")

The Head-Mounted-Display displaying the head-up out-of-the-window view is a Kaiser "Sim Eye XL100A" (Kaiser), see Figure 4. The head mounted display has a head tracker, so the image in the HMD is updated as the pilot moves his/her head. The HMD is stereoscopic, that is it displays two different images – one for each eye – making the outside world appear even more realistic. Each image has a XGA resolution with 1024 x 768 pixels and is updated at 60 Hz. The HMD has a so-called see-through function which allows the user to see the instrumentation on a separate computer screen through the HMD in a specified area. It is possible to wear eyeglasses underneath the HMD. The Field of View (FoV) is 50° x 100° vertical and horizontal, respectively. There is a 30° overlap between the left and right image. The HMD weighs approximately 2.5 kilograms (5.5 lbs) including helmet, optics and displays.

Figure 4. The Head Mounted Display.

The electromagnetic radiation of the HMD is very low (Oskarsson & Nählinder, 2004), and is in fact of no concern. There is an integrated audio headset in the HMD so the pilots can talk to each other or to the instructor at the instructor station.

Time delays in the HMD

For obvious reasons, there are time lags in the system. Two of these lags or delays are especially important from a Man-System-Interaction point-of-view. First, there is a time delay from the time when the pilot moves his/her head until the image is updated in the displays. This time delay is important since it is known to correlate with simulator sickness. Second, there is a time delay from a change in Stick (or rudder or throttle) is made until the effect has effect in the visual system. If this delay is too long, it might have a negative effect on the feeling of realism of the simulator. Both of these time delays are calculated below.

The head-tracker – visual update time delay

The tracker has a documented internal time delay of 6.3 milliseconds. The Dirigent process takes an extra 11 ms to process the information and send it off to the Grape software which will draw the out-of-the-window 3D image in the HMD. The Grape software runs in 60 Hz but need three execution cycles to update the image meaning the delay is 50 ms. To calculate the total time delay between a head movement and an updated image in the HMD, the potential synchronization delay between the different computers running the different software must be included as well, see Table 1. The maximum synchronization time delay between two computers is 16.7 ms (computers are running at 60 Hz). There are two between-computer-synchronizations which must be included in the calculated total time delay. In the median time delay half of the maximum synchronization time is used.

Table 1. Time delays in milliseconds between the Head Tracker system and the Grape image (in the HMD). The Dirigent is a process controlling the communication between different software.

	Tracker	Sync	Dirigent	Sync	Grape	*Total (ms)*
Minimum	6.3	0	11	0	50	*67.3*
Median	6.3	8.3	11	8.3	50	*83.9*
Maximum	6.3	16.7	11	16.7	50	*100.7*

The change in stick – visual update time delay

The software detecting changes in stick position runs at 50 Hz, that is, the time here is 20 ms see Table 2. The Virtual Front Panel "VFP" (the instrumentation) will be updated 16.7 ms faster than the image in the HMD, because the VFP software is updated after two 16.7 ms cycles (the Grape process requires three).

Table 2. Time delays in milliseconds between the I/O system (for instance the Stick) and the Grape image (in the HMD)

	I/O-syst	Sync	Dirigent	Sync	Grape	*Total (ms)*
Minimum	20	0	11	0	50	*81.0*
Median	20	8.3	11	8.3	50	*97.6*
Maximum	20	16.7	11	16.7	50	*114.4*

The time delays above are important to be aware of when evaluating the system. Future evaluation will conclude if the time delays are too long or if they are not.

Instructor Station ("IOS")

The instructor station has three computer screens, one keyboard, one mouse, and one joystick (Åkerberg, 2004). The instructor can setup a scenario including positioning of the two cabins, a large number of target aircraft (controlled by software), and control the virtual environment such as weather and time of day, and visual appearance of the aircraft. The instructor can start and stop the scenario and also control the pedagogical tools for the pilots in the cabins, and manipulate the viewing options for the pilots, see "Visual enhancements" below. The instructor can control scene "cameras" and for instance let one pilot see the scene from that camera, while the other pilot sees the scene from his or her own aircraft.

At the instructor station, there is a display presenting the scene of the dogfight. This visual representation is controlled by the joystick and is always displayed on one screen. The other two computer screens can be customized to display different windows controlling different aspects of the simulation (simulated environment, aircraft loads, simulation speed, position of aircraft and target aircraft, etc).

There are two headsets and a microphone-loudspeaker that can be used individually or in parallel. That is, the communication can be set by software to allow one headset to speak to one cabin, the other headset to the other cabin, or both headsets can communicate with both cabins.

Software

The ACES is built around several GOTS (Government-Off-The-Shelf) software solutions. For instance "Grape" (for presenting the 3D-out-of-the-window world), the "SAAB F17 Database" (simulated world), "VAPS" (head-down instrumentation), "ARES37" for the aircraft model (JA37 "Viggen" aircraft), "TACSI" (for handling the scenarios), "RAMOS-EMW" for software model of the radar, and "Maple" for presenting 2D-maps of the scenario are all used in ACES. The instructor station has more customized software specifically designed for ACES.

Instructor Station ("IOS")

The instructor station runs on a Linux X-Windows environment and is easily controlled with a mouse and a keyboard. It is possible to customize the layout on the two computer screens regarding what controls to be shown when and where. These settings can be saved and re-loaded at another occasion.

Pedagogical Tools

The ACES system has several pedagogical possibilities and tools. It is difficult to simply describe all possibilities since the different tools may be used alone or combined with other tools. The tools are also discussed in Nählinder et al. 2004. Therefore the tools will be simply described and the reader should be able to understand how the tools can be used in combinations.

Time Tools (Frozen time, Cheat roll, Slow/Quick flight, Mistake correction)

It is possible to freeze (pause) the simulation at any time and subsequently restart the scenario from that time. It is also possible to move backwards in time (flight paths generated from log-files). The speed of the simulation can also be varied between 50% of normal to 150% ("slow flight" and "quick flight", respectively). During frozen simulation, the pilots can roll the aircraft at any angle, thus making it possible to see what's underneath the aircraft. This roll is called "cheat roll" and can only be done while the simulation is frozen.

When a simulation run is frozen and time is moved back (either directly or via playing the simulation backwards) using logged data, it is possible to re-fly a situation from that time. Both the first and the second flight will be saved in log files so it is possible to evaluate and compare the different flights. This process is sometimes called "Mistake correction" and can be done any number of times.

Space tools (Exchanged Positions)

The two pilots sitting in the two cabins can exchange aircraft (when simulation is frozen). For instance if a scenario is run, and the first pilot wins over the second, the time can be moved back - say one minute - and the pilots can exchange positions (aircraft) and retry the situation from that point in time, but with the geospatial advantage handed over to the second pilot.

Camera mode (Instructor view in HMD, God's Eye View of entire scene)

If a pilot is not flying an aircraft, either when the simulation is frozen or the aircraft is running from logged data, the pilot can take control of one of three cameras. He can move around in a three-dimensional space as he wishes to clearly see the situation from a chosen point of view. The instructor may also control a camera and can thus see the simulated scenario from any point of his choosing. A pilot (cabin) or the instructor may also choose to see the scenario from the "backseat" of either an aircraft or a camera. That is, the instructor can view the scenario from the cockpit of one of the aircraft. The instructor cannot control the aircraft, but rather he "rides along" with the pilot. The instructor can place one (or both) cabins in the "backseat" of one of the three cameras. The instructor then controls the camera and might place the camera allowing both pilots to see the scenario from where he thinks is the best viewing position. Other examples include the possibility to replay a scenario, but allowing only one pilot to control his aircraft (flying against a ghost aircraft re-flying the exact same path from logged data). The other pilot may be placed in the backseat of the controlled aircraft perhaps to learn how the one pilot handles that particular situation, see Figure 5.

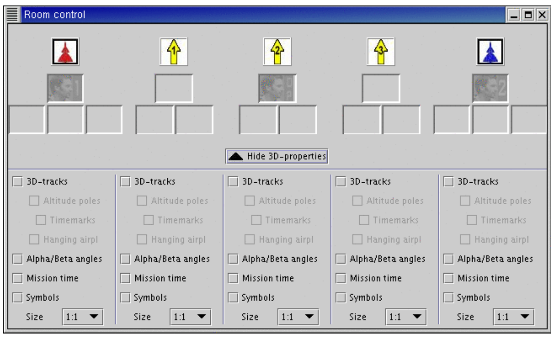

Figure 5. The pilot stations can be placed in either aircraft (Red and Blue) or any of the three scene cameras.

Communication

There are several possibilities for controlling the sound between the cabins and the instructor station. For instance, one pilot station can setup to communicate with one headset at the IOS, whereas the other pilot station can communicate with both headsets at the IOS. Or one pilot station can hear static mixed in with the communication but the other station does not hear that, for example, see Figure 6.

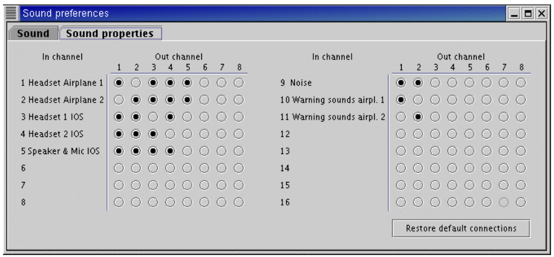

Figure 6. The communication setup. In - and out channels can be combined in many ways.

Visual enhancements

Besides environment features (such as time-of-day, wind and clouds) other visual enhancements may be displayed to the pilots. The visual size of aircraft can be manipulated (for instance one pilot station may see all aircraft enlarged by a factor of ten). Traces with or without altitude markers may be added to one or both pilot stations, see Figure 7.

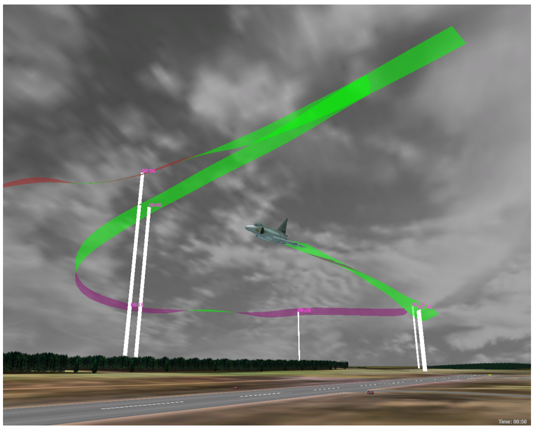

Figure 7. Traces and altitude markers show the aircrafts flight history.

Logged flights

All flights are always saved as log-files allowing pilots to re-fly any situation over and over again. It is also possible to let logged aircraft fly in the scenario as both pilots control "new" aircraft. That way, pilots can easily visually compare the outcome of several flights. "First time I flew I ended up over there, and the other aircraft beat me.

This time I ended up over here instead, and the other aircraft could not get me!" The communication is not logged.

Analyses of flight parameters

Several flight parameter analyses can be displayed at the instructor station, describing the progress of the dog fight. For instance it is possible to see a graph of the distance between the aircraft, the altitude and speed ratios etcetera. The purpose is to give the instructor information about how the dogfight evolves over time. The different analyses options are described elsewhere. The analyses can also be used at an after-action review situation.

Flight loggings

All flights are automatically saved and can be exported into computer files containing many flight parameters saved at several hertz. These parameters include, but are not limited to, aircraft position, speed, heading, altitude, alpha and beta angles, fuel remaining; pilots head movements, etcetera as well as information regarding use of weapons and other simulator information. The loggings can be used for off-line analyses of scenarios and flight paths. The log-files are saved as ASCII-text files and can thus easily be imported into parameter evaluating software.

Discussion

ACES is a flight simulator with the primary purpose of being a research simulator. It has many different possibilities regarding pedagogical aspects. These possibilities should (and will) be explored in order to be able to conclude if such pedagogical tools are of use when teaching and learning new skills. If they are found useful, pedagogical tools should probably be considered in a wide range of training simulators, not only in the aviation field and the air force but could most probably be useful in numerous training environments, even outside the military domain. ACES is also an excellent research platform for many other human-factors studies. It allows researchers to have control of many aspects of the simulation itself, as well as the cabins and the communication system. The flight loggings are extensive and many parameters are saved for off-line analyses, permitting performance and behavior analyses. The use of pedagogical tools to enhance the effect of synthetic training is believed to be a key issue in future simulator systems, and might prove useful in a wide variety of applications.

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