MSC: Vehicle for Validation of Military Flight Simulation

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Rationale: Due to costs and penalties the ratio between ground based training and flying hours will soon drastically change. Evidence based arguments are needed to support proper decisions on what to train where.

INTRODUCTION

The AH-64 Apache helicopter trainer and the F-16 Unit Level Trainer of the Royal Netherlands Air Force (RNLAF) are single unit fixed base simulation facilities, primarily in use to meet procedural training needs. The Black Hawk helicopter trainer in Fort Rucker (US Army), on the other hand, is based on a moving ("hexapod") platform, and so is the Cougar helicopter training facility at Marseille, France. At Benson, Willingford (RAF) Chinook helicopter pilots train in a fixed base trainer. We can continue on this list, but the purpose was to name a few. At the end of the list we find the main ground base training facility for the F 35 "Joint Strike Fighter", which is specified to be a configuration of a set of linked fixed base cockpits. For each of these simulators a thorough procurement trajectory was followed, based on an extensive analysis of functional needs weighed against a careful consideration of technological and financial pro's and con's. The question however is whether the policy makers and procurement officers did get enough support from us, the scientific community, to make the proper evidence based decisions on military flight simulation. The answer, at least for the Dutch, is that they did not. For this a research vehicle is built by which we try to define what elements of flight hours can be flown on the ground, or in other words to determine the envelope for replacing flight hours with flight simulation.

For tactical combat simulation it is possible to do plenty of (group) training in a command and control structure in a set of linked cockpits. But how relevant exactly are elements as field of view, quality and resolution of the displays, the content of available visual information, and motion cueing? We know a little about each of them, but how far does their relevance goes in *interaction* for the immersive quality, the "presence" felt by the pilot in the simulation?

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In our research program we hope to establish:

- limits of fixed-base flight and combat simulation
- the added value of motion cueing
- the optimal training mix of fixed-base and motion-based flight simulation
- the determination of which training components can be most effectively accommodated in which simulation facilities
- specifications for training programmes; suggestions for the optimal training mix of flying hours and ground hours
- prototypes for spatial disorientation training and night vision training, with the man in the loop

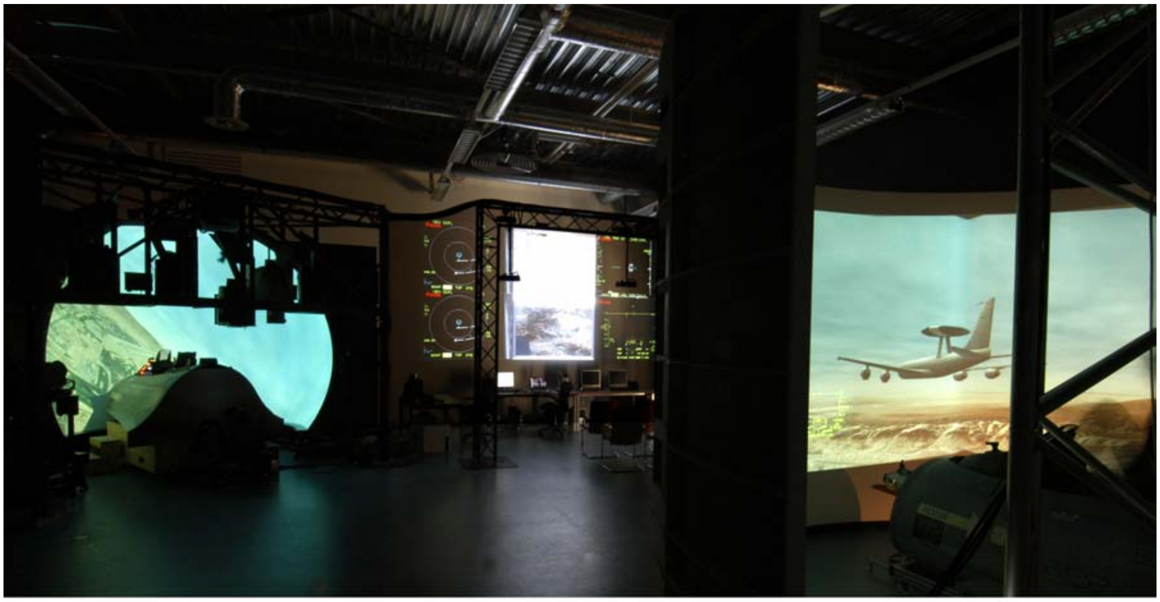
THE MISSION SIMULATION CENTRE (MSC)

In our strive to validate flight simulation[1] we built a facility which momentarily comprises four linked F-16 MLU M3 cockpits, one of which is placed on Desdemona, our advanced 6 DoF moving base, on which sustainable G's can be produced. The three other cockpits are in a fixed base configuration, each with a different quality of visual environment (see Figure 1). The environment of the first cockpit has a 180 x 45 degrees field of view (FoV), projected on a half cylindrical display by 3 projectors (1024 by 768 pixels) + one for the HUD-projection. The second environment consists of a dome of 270 x 120 degrees FOV (the BARCO SEER 8), irradiated by 8 projectors (1600 by 1200 pixels) + one for the HUD. Needless to say that this one is the reference standard at the moment. The third visual environment is created by a 'see through' helmet mounted display (HMD; nVisor ST), 47 x 38 degrees FoV (360 deg allowing head movements), 1280 x 1024 pixels. In Desdemona the FoV is 120 x 30 degrees, irradiated by 3 projectors (1280 x 1024 pixels) + one for the HUD. When needed, for reasons of comparison, the FoV and resolution of the BARCO dome can be made identical (by degradation) to that in Desdemona.

Instead of the HMD of cockpit no 3, also a simulated night vision device can be used (FoV: 40 degrees diagonally), in combination with 60 x 45 degrees outside view in the dark (1 projector).

Evans & Sutherland EXP50 Image Generators (IG) serve all displays. The scenario's are based on the same software modules (VTSG, Inc.) and are within the same Airbook framework (SimiGon) the RNLAF uses to train its pilots for the F-16 MLU 3 and 4 modifications. The cockpits match the MLU M3 and M4 configurations exactly and are, when desired, easily adaptable (Sim Industries). The F 16 Flight Model (Bihrle) is more than sufficient for the purpose. Together they form solid links in the hi-fi chain a scientist could dream of for his research platform and testbed.

[1] This paper focuses on flight simulation, but the same facility and research paradigm can also be used for military (on and off road) driving simulation and for simulation of fast small boat behavior.



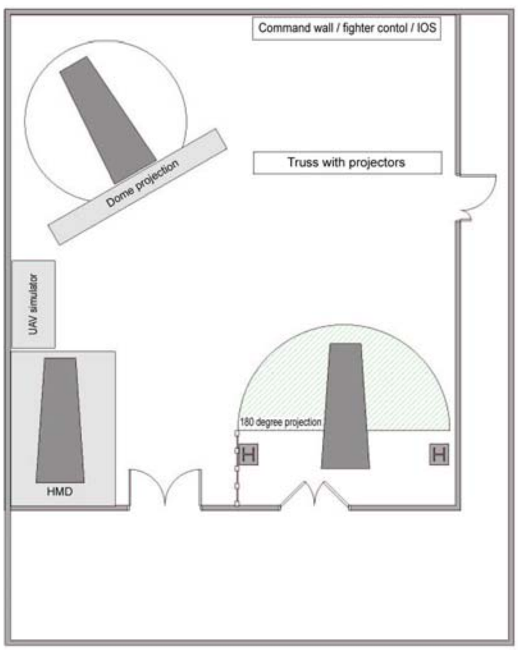


Figure 1: The Present Configuration of the MSC, with 3 Fixed Base Cockpits, an Instructor and Operator Station (IOS) and a Ground Station for Unmanned Areal Vehicle Simulation (UAV). The cockpit on Desdemona, the moving base, is situated in an adjacent hall.

Please note that the MSC is not a training facility (MTC). Although the fidelity is high, and in several aspects better than the present training facilities of the RNLAF, the demands for a research environment are different. For this the emphasis is more on flexibility than on robustness, multi-usability is preferred above specific strength, and the facility will be continuously upgraded according to new insights and technologies.

At present the main focus is on a fixed wing fighter environment, but other cockpits might as well join in.

DESDEMONA

The *piece the resistance* of the MSC is its moving base. Not only because of the benefit that a moving base is incorporated in the set up of 4 linked cockpits, but also that it is a unique device, with promising features, particularly specified for *military* flight simulation.

Desdemona (built by AMST) is based on a 6 DoF centrifuge design (see Figure 2). The simulator cabin is suspended in a freely rotating gimbaled system (3 DoFs, >360°) which, as a whole, can move vertically along a heave axis (1 DoF, ±1m) and horizontally along a linear arm (1 DoF, ±4m). To provide sustained centripetal acceleration (1 DoF, 0-3g), the linear arm can spin around a central yaw axis. As mentioned above the cabin has out-the-window visuals (120 x 30º FoV) and its interior can be re-configured for different aircraft types (available at the moment are F-16, Eurofighter and a generic cockpit for driving tanks, trucks and sportscars).

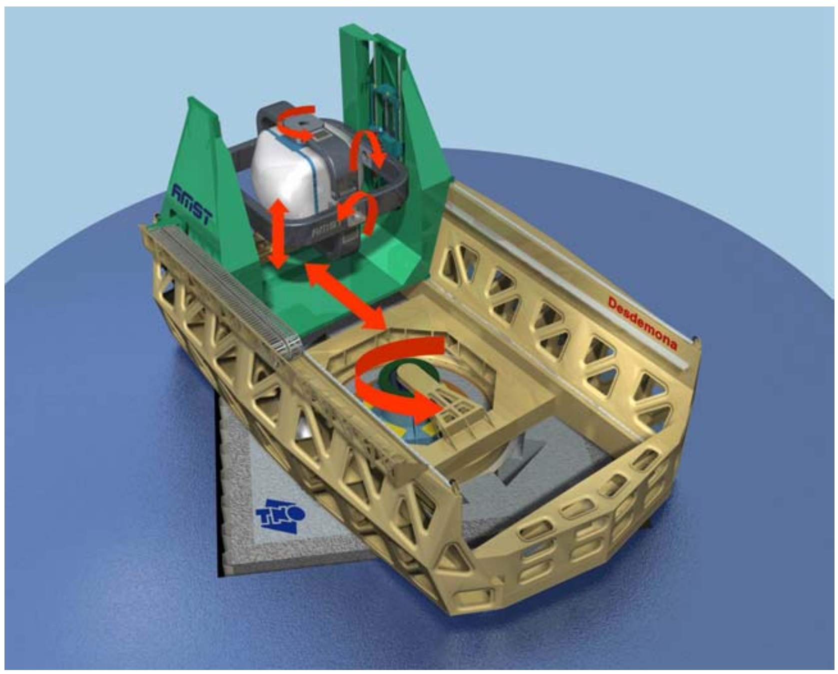


Figure 2: The 6 DoF of the Desdemona Moving Base Simulator. For further details see text.

Unique about Desdemona's six DoFs motion capabilities is that it can combine onset cueing along the x, y and z-axis (like a hexapod simulator) with sustained acceleration cueing up to 3g (like a Dynamic Flight Simulator, human centrifuge). But neither operation of Desdemona in the hexapod mode (tilt coordination), nor in the DFS mode (centrifugation) make use of the full motion envelope of Desdemona. Therefore an alternative motion cueing algorithm is being developed for Desdemona called 'spherical washout filter', especially to explore the possibilities for turning in flight (Wentink & Bles, 2005). Instead of directly high-pass filtering the x- and y-component of the specific forces, these components are first transformed to radial and tangential acceleration after which the radius, the cabin yaw angle and the central yaw rate are high-pass filtered (see Fig. 3). The spherical washout algorithm significantly enlarges the motion space, since the simulator moves back towards a certain base radius and *not* towards a fixed neutral point in space as is the case in conventional hexapod simulation. In addition, sustained specific forces can be simulated using a combination of tilt and centripetal acceleration. It is especially this feature which is promising for turning.

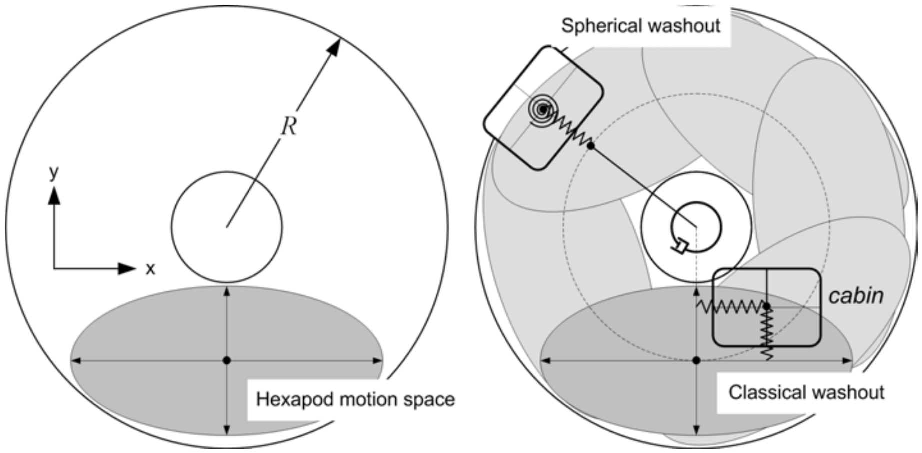


Figure 3: Left: Typical x-y Motion Space of a Hexapod Simulator Driven by a Classical Washout Filter. The potential motion space of Desdemona is a circular band from $R = 1m$ to $R = 4m$ ($R = 0m$ represents a singular point). Right: The motion space of the Spherical Washout Filter occupies the complete circular band since the ellipsoid motion space moves with the cabin in a circular direction. The classical and spherical washout principles are compared by visualizing the direction of washout in the x-y plane by springs and dampers (two springs for classical washout and two springs and a damper for spherical washout).

It depends on the parameter settings in the spherical washout algorithm to what extend tilt coordination or centrifugation is applied. In Figs 4, 5 and 6 two examples are displayed about simulation of the onset of a linear acceleration step function with different degrees of motion. In Fig. 4 the virtual simulation is realized by linear acceleration using the almost the full length of the track and by tilt coordination. The left graph shows the top view illustrating the trajectory of the cabin in Desdemona's circular work space, the black cabin being the initial position. The right graph shows the resulting linear accelerations along the different axes (note that f_y remains zero).

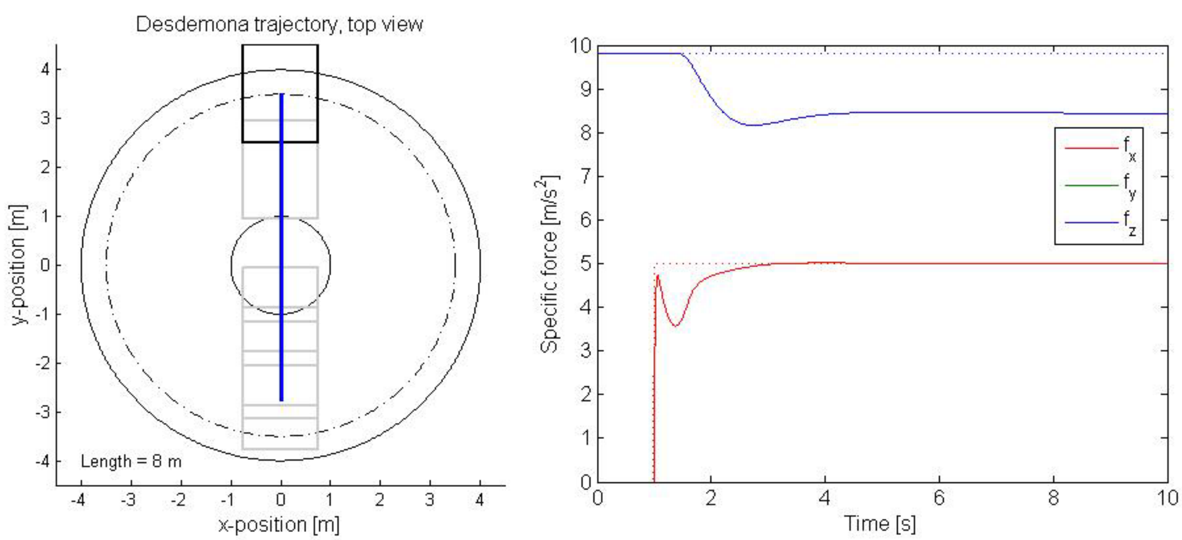


Figure 4: Left: Top View Showing the Displacement of the Cabin over the Track. Right: the resulting linear accelerations in the cabin.

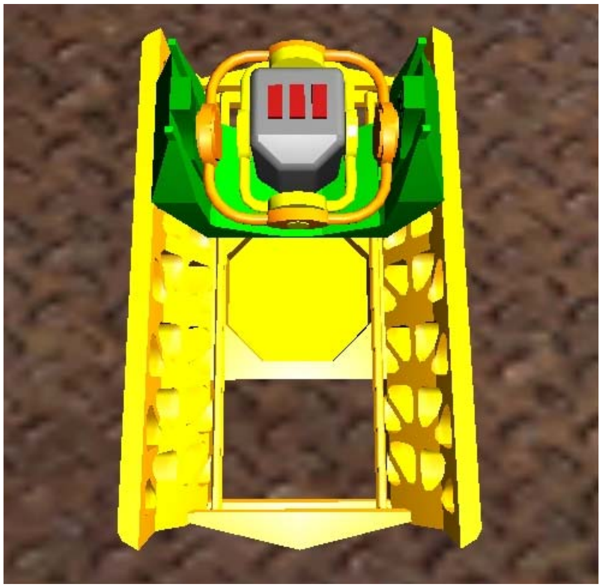


Figure 5: Top View of Desdemona for both Simulations as Displayed in figs. 4 and 6. The pilot is looking inward.

In Fig 5 this initial position of the cabin with respect to the track is illustrated more clearly.

Applying also centrifugation, realized by different parameter settings in the spherical washout algorithm, results in a completely different motion trajectory, as is shown in Fig 6 The parameter choice will vary in accordance with the mission to be accomplished.

We have to stress here that these "spherical washout filter" characteristics are purely theoretical at the moment. Desdemona is in the process of finalization. The acceptance tests will be performed in Summer 2006, and when lucky the first steps in testing the washout filters can be taken in the fall.

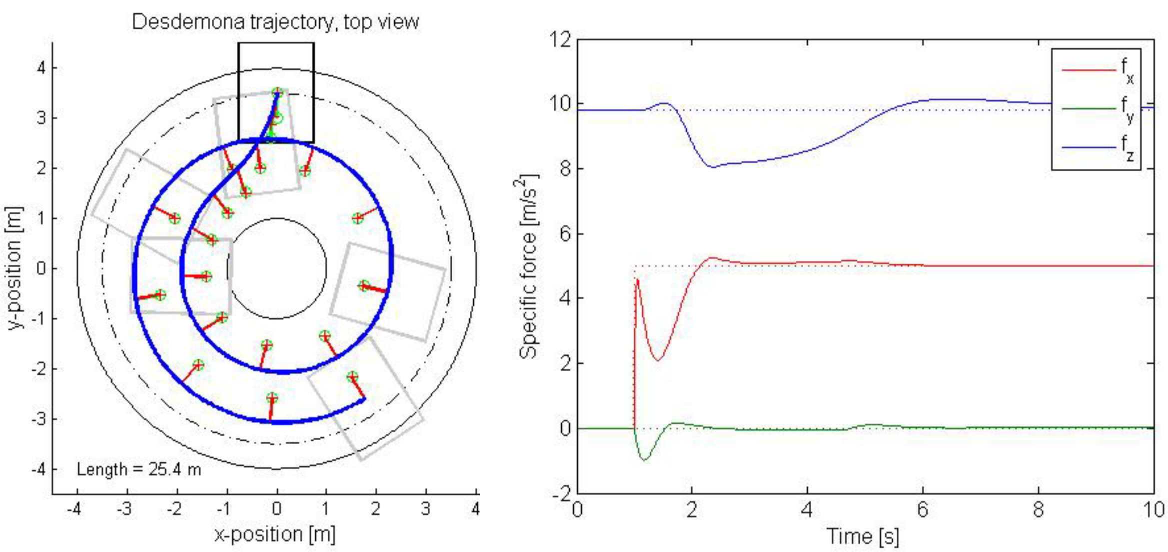


Figure 6: Left: Trajectory of the Cabin when Simulating a Sustained Acceleration by Centrifugation and by Tilt Coordination. The red vectors indicate the real vectors, the green ones the vectors as generated during the simulation. Right: Linear accelerations as exposed to the subject in the cabin.

PROLOGUE

This paper has an open end. Although pretty satisfied about the recent finalization of the fixed base part of the MSC and in good faith that Desdemona will be operational in the late summer, it basically only means that we can start with the actual research. Of course, the research aims are exactly defined (mentioned in the introduction), the paradigm has been set and the manipulation of the variables is prepared, so that one might expect a head start. Another good element is that our subjects are the actual operators (pilots of the RNLAF) and that scenario's are used which are identical to those the Air Force is using, so that the ecological validity of our results is high and, consequently, directly relevant to the decisions the policy and procurement officers have to make with respect to the specification of the Mission Training Center the RNLAF wants to procure.