PUBLISHABLE EXECUTIVE SUMMARY

helico*P*ter and a*E*ronef navi*G*ation *A*irborne *S*ystem *E*xperimentations

Web site : www.pegase-project.eu

Background

Approaches, landings and take-offs, or more generally, manoeuvres or navigation in the terminal area, are among the most critical tasks in aircraft operation.

Today, the only certified navigation system available for landings, ground rolls and take-offs are the ILS and MLS which require heavy airport infrastructures; recently, one can notice a trend towards the GNSS systems (Global Navigation Satellite Systems) which have not the necessary integrity. This clearly highlights the unmet need for new systems which could either replace or complement existing systems.

PEGASE is a feasibility study of a new Navigation System which allows a three dimensional truly autonomous approach and guidance for airports and helipads and improves the integrity and accuracy of GNSS differential navigation systems. This new Navigation System relies on three key technologies:

- Specification of a reliable ground reference database

- Innovative correlation techniques between sensors outputs and onboard ground database

- A robust servoing algorithm for the management of the trajectories of both fixed wing and rotary wing aircraft.

The ambitions of the PEGASE project are twofold.

Firstly, it will pave the way for a new all weather autonomous standard Navigation System by validating the technologies necessary to achieve a cost effective navigation means that has higher accuracy and integrity than existing ones (typically ILS/MLS), yet is not susceptible to jamming.

Secondly, it will contribute to demonstrating that such a new Navigation System can help reduce noise levels and fuel consumption through new procedures in the terminal zone and address flow delays in adverse weather conditions. In this way, PEGASE contributes to the enhancement of the future 2012 Air Traffic Management.

Objectives

The main objectives of the study are:

- to assess the feasibility of the autonomous, all weather conditions, localization and guidance system;

- to determine the performance required for the vision sensors (Visual, Infra Red, Electromagnetic) and the ground reference database in order to provide an accurate guidance from the final approach leg to full stop on the taxiway/helipad and for the take-off run from alignment up to the final take-off segment[1].

The **expected results** of the study include:

- The System performances (accuracy, integrity …) based upon normal and limit cases (sensitivity and robustness with respect to environmental conditions will be assessed);

- Sensor performances specifications (these specifications could lead to some fusion process on the sensors outputs);

- The definition of the key elements (altimetry, ground element features …) of the database;

- The definition of a ground database generation process delivering the best available altitude reference data with a quantified error distribution;

- A generic functional system architecture;

- Operational concepts (minimum requirements on trajectories to perform the task …) and System limitations (decision height …);

- Elements for a certification road-map and indications for regulations update;

- Preliminary estimate of the cost of the NavAid System.

The study is carried out with existing simulation tools and Man Machine Interface (MMI) developed for fixed wing and rotary wing aircraft. It is not intended to study in this project dedicated MMI since no specific need has been identified. Coupling to systems such as Synthetic Vision System could be addressed in a further development stage.

---

[1] Even though PEGASE technologies could be extended to taxiing procedures, they will not be considered in this study.

Coordinator:

Organisation :	**DASSAULT AVIATION**
	78, Quai Marcel Dassault
	Cedex 300
	92552 Saint Cloud Cedex

Contact :	**Bruno PATIN**
Tel :	+33.147.11.58.54
Fax :	+33.147.11.53.65
Mobile	+33 672 78 72 07
E-mail :	pegase-coordinator@dassault3.ddo.net

Contractors involved

With respect to the first activity report, one member disappeared due to EADS reorganisation. This event led to an updated contract.

Company	1st name	Family name	e-mail	Phone number
Dassault Aviation	Bruno	Patin	bruno.patin@dassault-aviation.com	+33147115854
Alenia Aeronautica	Bruno	Tranchero	btranchero@aeronautica.alenia.it	+39 011 756 3891
Eurocopter france	Michel	Delorme	Michel.delorme@eurocopter.com	+33442852177
Eurocopter Deutschland	Wolfgang	Kreitmair-Steck	Wolfgang.kreitmair-steck@eurocopter.com	+49 89 6000 2289
European Aeronautic Defence and Space company	Bruno	Esmiller	bruno.esmiller@eads.net	+3314697 3588
Walphot S.A.	Didier	Mendel	Didier.mendel@waphot.com	+32 081 30 24 01
Elliniki Photogrammetriki	Velissarios	Printzios	Velissarios.printzios@elpho.gr	+302106146950
Consorzio Nazionale Interuniversitario per le Telecomunicazioni	Pietro	Cerri	cerri@ce.unipr.it	+390521 905711
Institut National de Recherche en Informatique et Automatique	François	Chaumette	Francois.chaumette@irisa.fr	+3329984 7255
Centre National de la Recherche Scientifique	Tarek	Hamel	thamel@i3s.unice.fr	+334 9294 2755
Eidgenössische Technische Hochschule Zürich	Manos	Baltsavias	manos@geod.baug.ethz.ch	+41 44 633 3042
Ecole Polytechnique Fédérale de Lausanne	Martin	Rajman	martin.rajman@epfl.ch	+41 21 693 52 77
Instituto Superior Técnico	Jose Raul	Azinheira	jraz@dem.ist.utl.pt	+351 21 8417478
Josef Stefan Institute	Stancko	Strcmnik	Stancko.strmncik@ijs.si	+386 1 4773 576

Second period work summarised description

As described above, the PEGASE project goal is to assess the feasibility of a global tracking and servoing ILS-like system using vision. Two different threads of activity have been defined:

- How to create an onboard database safe and secure enough to allow the tracking and servoing;

- Assuming we are able to build such a database, what would be the candidate algorithms that would allow the tracking and servoing to work.
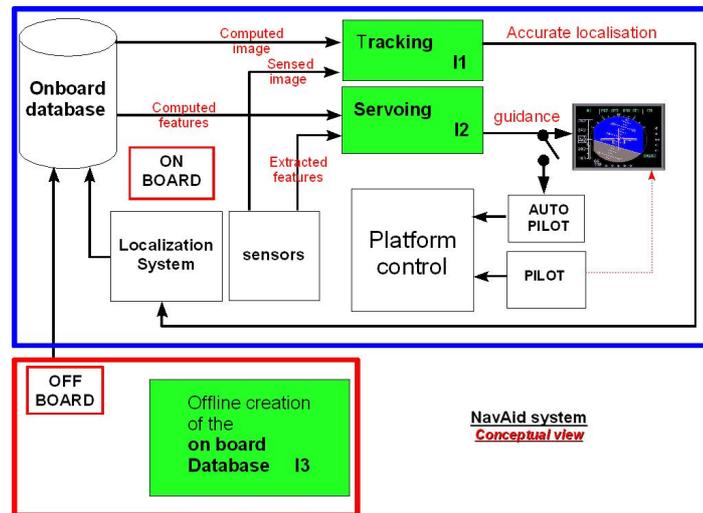
The first year allowed the partners to build a specification, put in place the basis of the work to be done through the shared simulation framework and began work on the sensors.

This second year of activity allowed the consortium to achieve some steps (all the following pictures, schematics and tables are provided as examples of the results):

- Sensors: this activity, led by EADS, was achieved allowing the partners to have:

  o A clear view of what are the requirements on the visual sensors when working for the landing / take-off functions;
  o A clear view of the needs to develop new sensors and mainly a front line radar imaging system;

Sensor	Advantages	Disadvantages
Millimetre wave radar	All weather Large search area Lower frequencies penetrates foliage Day/night operation Range and image data Velocity data with coherent system	Moderate resolution Simpler radar designs exhibit more susceptibility to corner reflector decoys and active jammers In development and test
Infrared imager	Fine spatial and spectral resolution imagery Day/night operation	Affected by rain, fog, smoke, .. Poor foliage and cloud penetration Requires cooled focal plane to maximize signal to noise ratio Large search area require scan mechanism or large detector array range data by performing a manoeuvre

Laser radar	Fine spatial and spectral resolution imagery Range and reflectance data Can be compact Day/night operation	Affected by rain, fog, smoke, .. Poor foliage and cloud penetration Most effective when cued by another sensor to search a relatively small area
Visible imager	Best resolution imager Technology well understood	Daylight or artificial illumination required Affected by cloud, rain, fog, haze and other atmospheric obscurant No foliage penetration No range data

    o   A software package able to integrate in the shared simulation framework in order to create "real" sensors using the image generator provided by Dassault Aviation;

Non degraded picture

Radiometric

Rain

picture distorsion

noise

artefact

- Database: this activity, led by ETHZ, provided many results:

    o   Work has been done, between ETHZ and Dassault Aviation, to reorganise the planning and the related activities in order to answer the alert raised

during the first year;

o WALPHOT SA, helped by Dassault Aviation, completed the work done upon the state of the art of the existing data sources to take into account the emerging satellite systems to come in the following years. The obtained data has been used but is an achievement on itself and could be provided for other purposes;

o ETHZ provided to ELPHO the fusion algorithm to be implemented in a commonly agreed geographical tool (ARCGIS). This algorithm has been thoroughly tested and developed on real data;
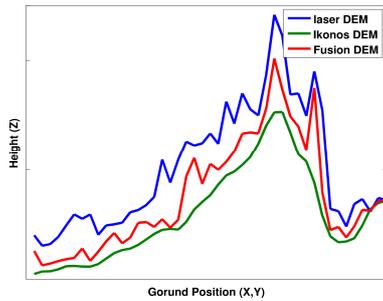
Fusion, with slope dependent weights
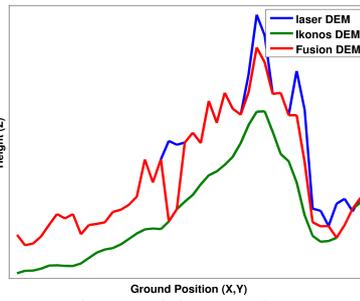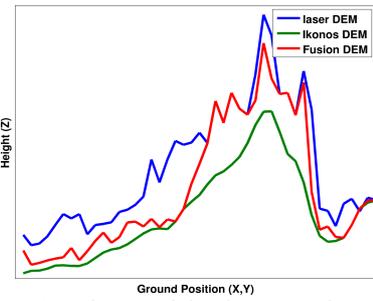
Fusion, with roughness dependent weights

Fusion, with slope and roughness dependent weights
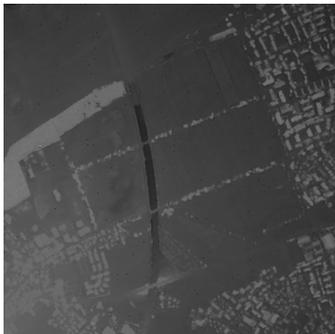

Fusion, with slope dependent weights
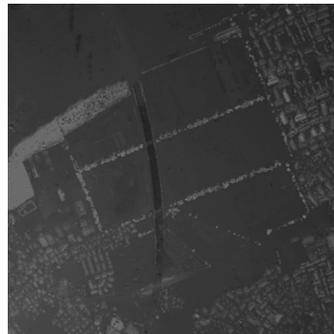
Fusion, with roughness dependent weights
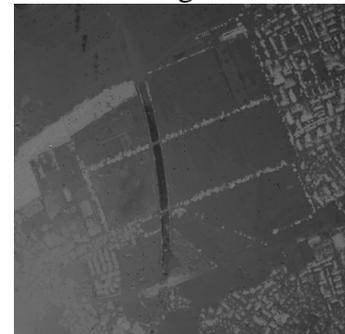
Fusion, with slope and roughness dependent weights

o ETHZ worked on the quality assessment of database introducing local measures such as roughness. First insights now exist that could lead to proposal towards certification world through EUROCAE working group;

o ETHZ elaborated a methodology to be further developed in order to automatically extract edges, leading to automatic buildings identification;

| Airport Buildings | |
Road	
Tree	
Shadow	
Grass	
Ground	

Correctness : 80%
Omission error : 11%
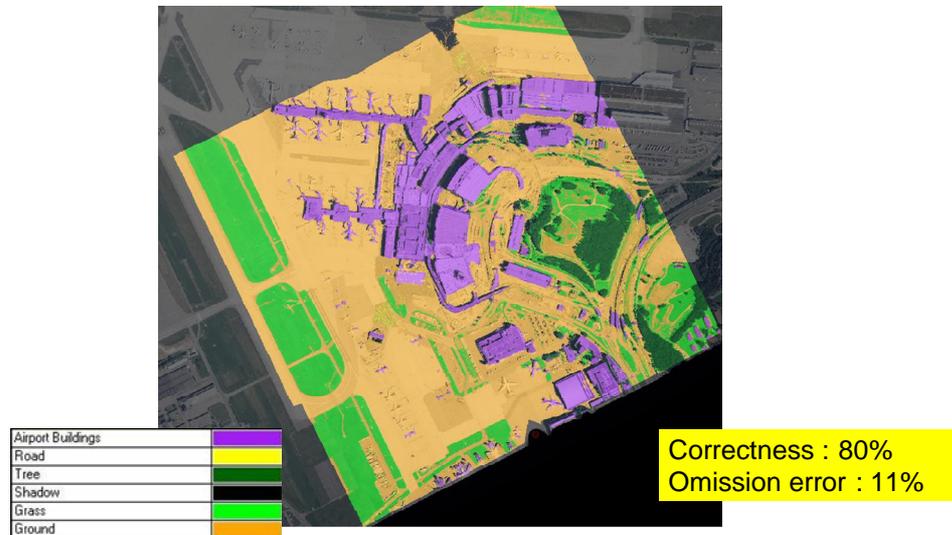
- o Dassault Aviation promoted a new way to approximate terrain data using Brownian motion. This approach, though at its research step, could lead to more accurate way to assess quality and manage accuracy of interpolated terrain data. This is an ongoing work;

- o The first assessment framework has been defined between the partners concerned during this period (ETHZ as leader, Dassault Aviation and WALPHOT). It should be used throughout the last period.

- Visual tracking and servoing: this activity, led by INRIA, provided many results as well[2]:

  - o Runway/helipad detection: Image processing algorithms have been developed by CNIT for the detection of a runway or a helipad in the images acquired by the on board camera.
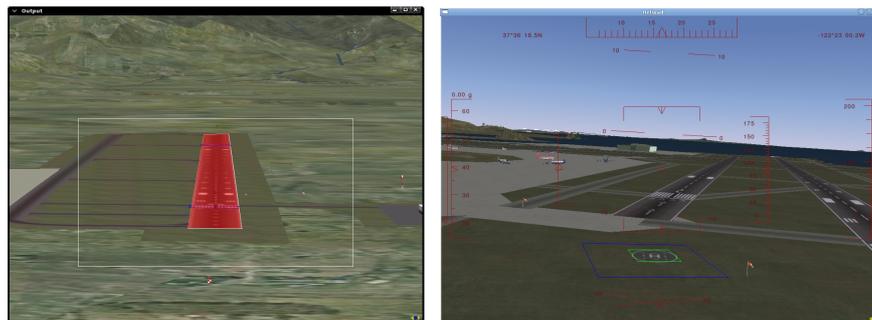

Runway and helipad detection on two example images.

  - o 2D tracking: An image processing algorithm has been developed by CNRS for the tracking of a runway in the image sequence.

---

[2] Note that almost all the methods mentioned below have been integrated and validated in the shared simulation framework thanks to the work of those in charge (see below).
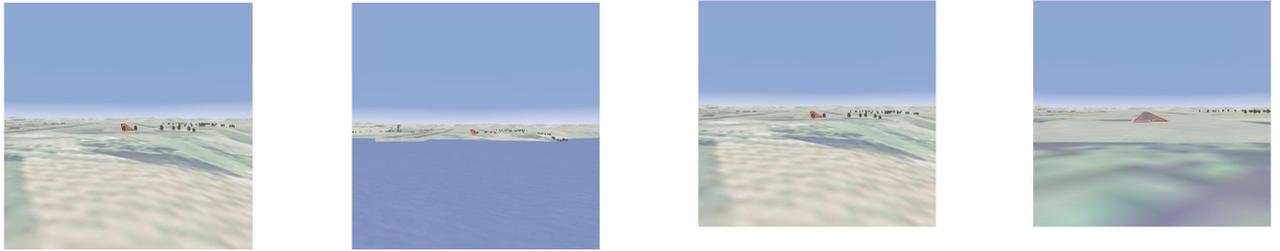
2D tracking results

- o 3D localization: An image processing algorithm has been developed by EPFL for the 3D localization of the on board camera using a visual memory composed of a set of points of interest.

- o 3D tracking: Complementary image processing algorithms have been developed by INRIA. EPFL and IST for the 3D tracking and trajectory estimation of the on board camera with respect to the environment observed during the landing phase. These algorithms are based on various image features and a geographical database provided by WP5.
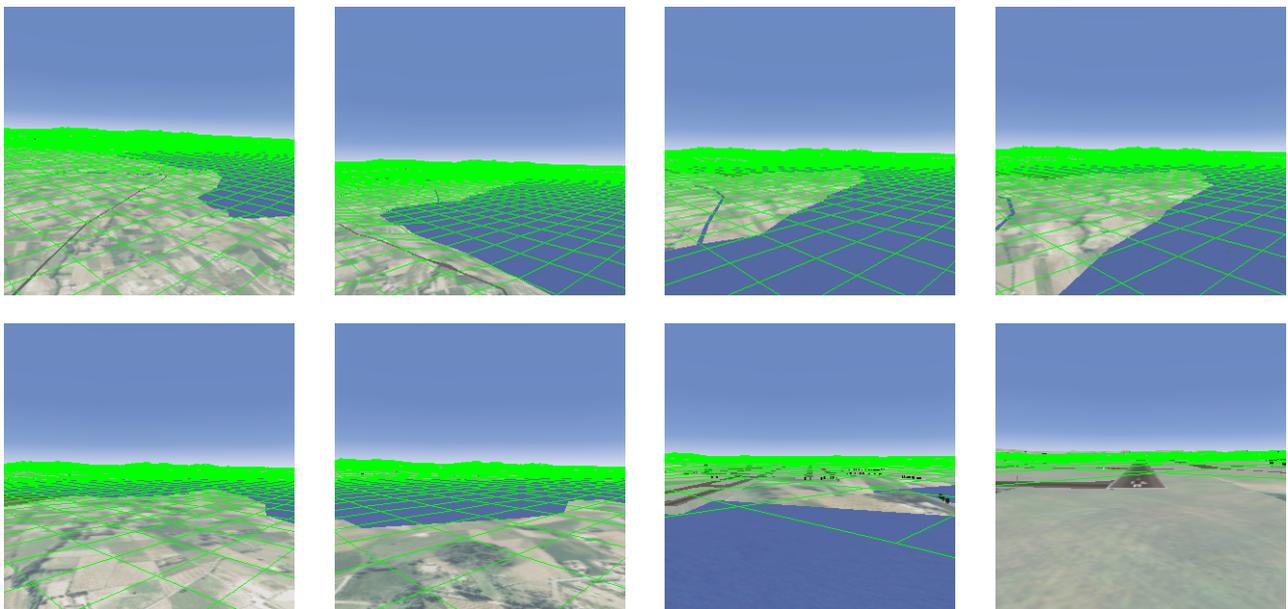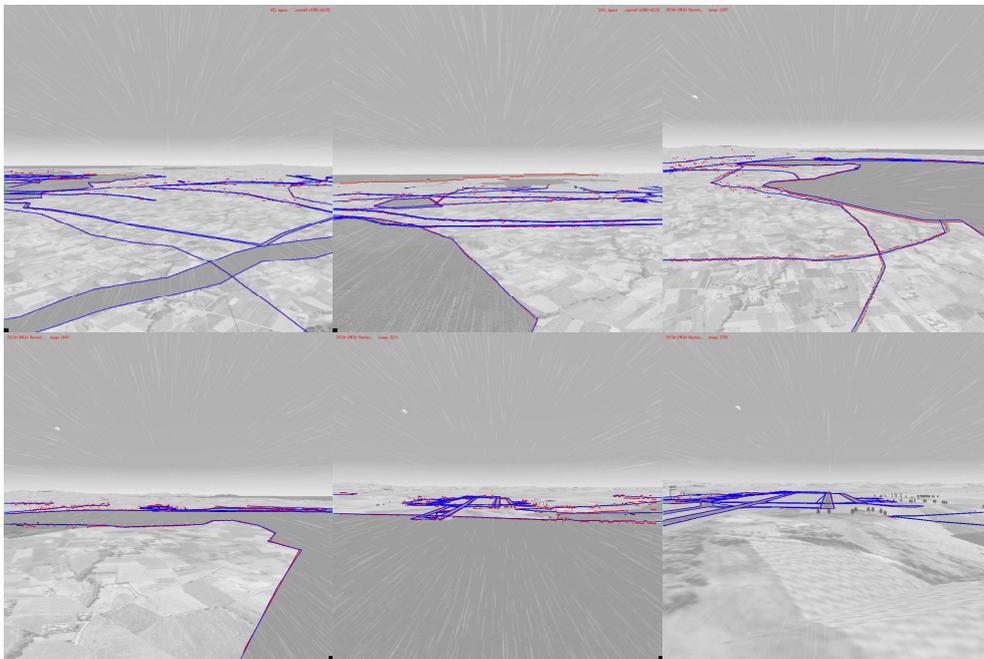

3D tracking combining detection and frame-to-frame tracking to provide a robust and stable estimation.
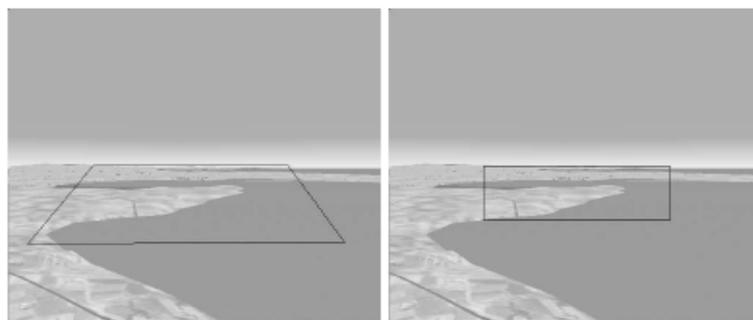
**3D tracking using a dynamic management of a region of interest between two consecutive images.**
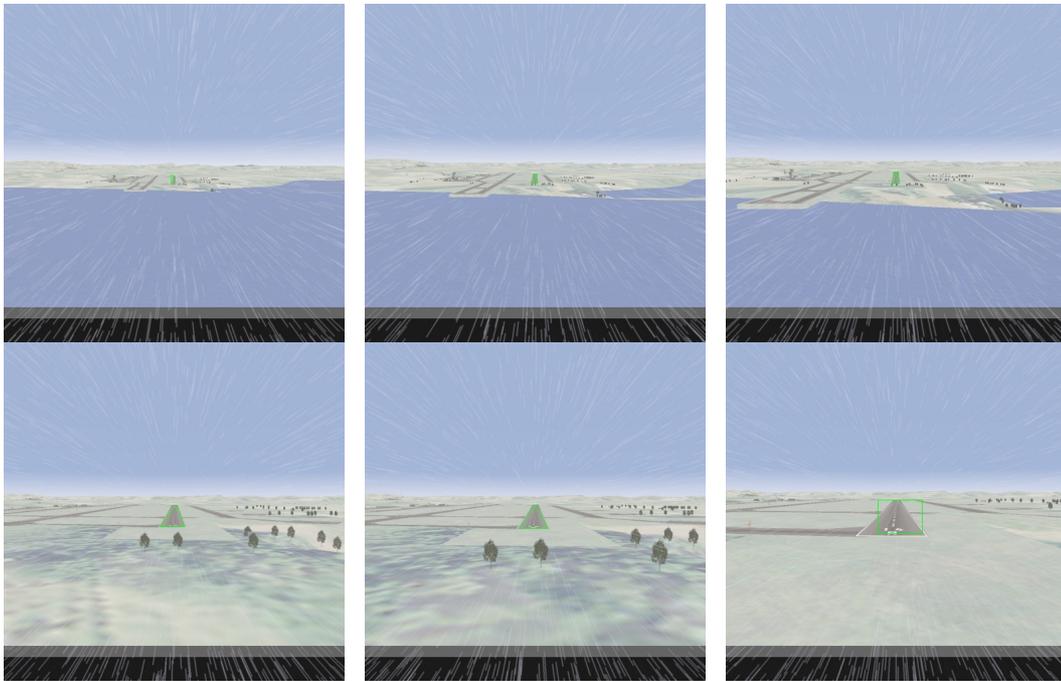
3D tracking using points of interest on the runway

3D tracking using a vectorial geographical database

o PBVS: JSI, IST and INRIA have developed position-based visual servoing methods for the automatic landing of fixed-wing aircraft.

o IBVS: Similarly, CNRS and INRIA have developed image-based visual servoing methods for the automatic landing of fixed-wing aircraft. These position-based and image-based control schemes address the different levels of the AFCS provided by ALENIA AERONAUTICA in the Pegase simulator.

o Obstacle detection: this activity has been defined last year following

questions from the commission. It is assumed entirely by CNIT that proposed a first version of algorithms for the detection of potential fixed or moving obstacles lying on the runway or the helipad.
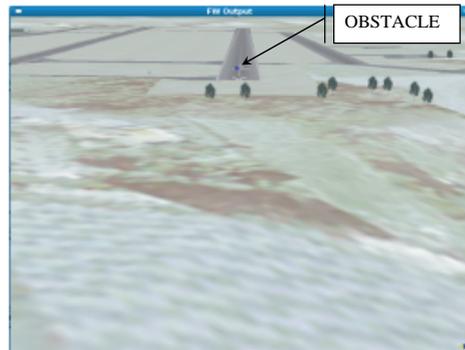

Furthermore, as for fixed-wing aircraft:

- o CNRS has developed an autonomous waypoint navigation method.

- o Finally, EUROCOPTER Deutschland has worked on the definition of the Human-Machine Interface to be used in the piloted simulation software.


HMI interface

In order to allow a smooth transition from the specifications to the assessments to be done at the end of the work, Dassault Aviation, with help from EPFL, promotes and provides the so-called "shared simulation framework" approach. This year saw the development of the version integrating the sensors function (EADS), a completed Fixed wing model (Alenia Aeronautica), parts of a rotary wing model (ECf and CNRS), the image processing parts (EPFL) and hard work is underway to completely integrate those developments made by the Tracking and servoing partners led by INRIA (EPFL, CNRS, IST, JSI). CNIT is also providing developments leading to the obstacle detection algorithm. Here follows a description of the architecture and some details on the interfaces as defined this year.
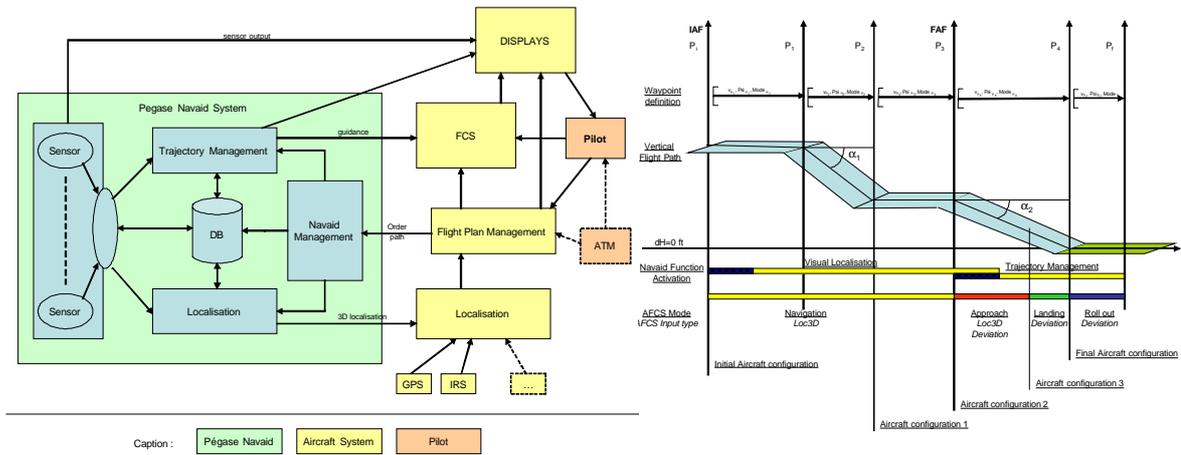
System and Scenario

Navaid algorithms
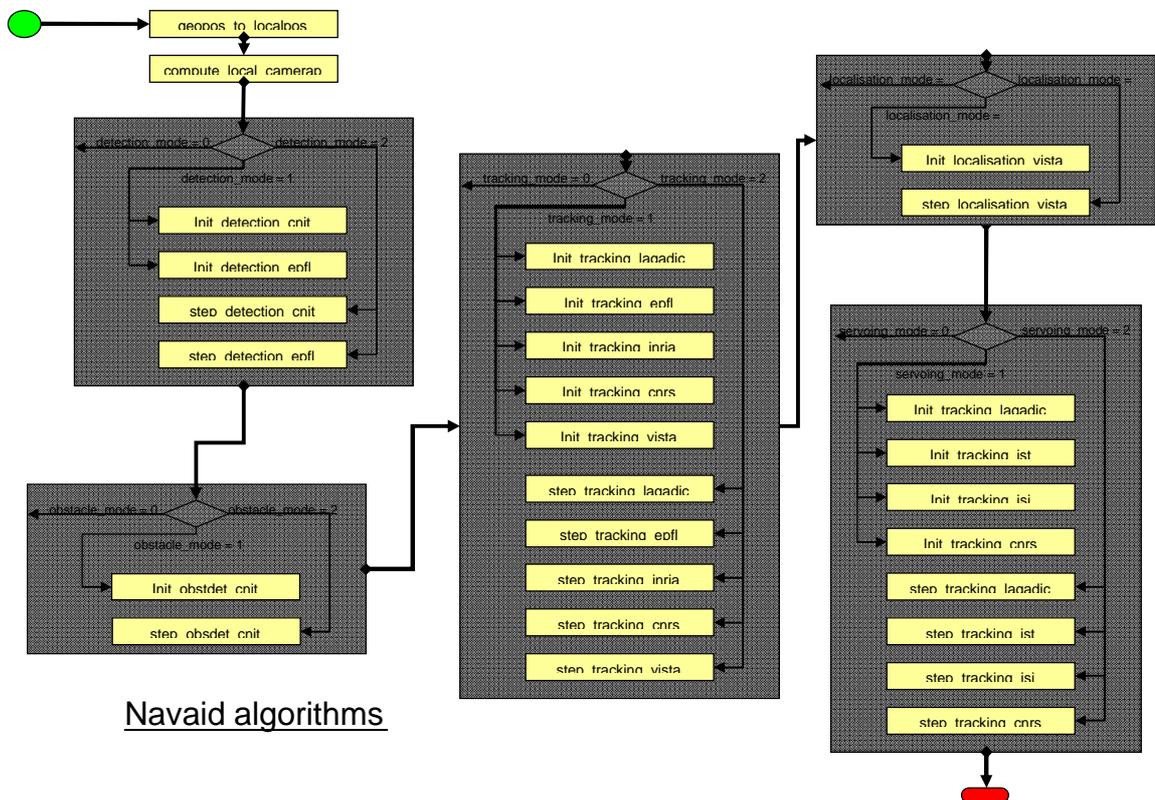
Finally, the work has begun, led by Alenia Aeronautica, in order to allow the consortium to assess all the parts developed above. The three assessment environments (Alenia Aeronautica for the detailed environment, Dassault Aviation for the global simulation and Eurocopter Deutschland for the piloted simulation) are under development extracting from the shared environment the parts needed. Moreover, sets of test cases have been agreed on which the consortium will build assessment scenarios.