AERO-MS

Developed by NLR, TAKS, MVA

The AERO-MS provides a quantitative description of the present and future air transport system aimed at the assessment of aircraft engine emissions. The main capability of the AERO-MS is to assess the effects of a range of possible policy options to reduce aircraft engine emissions taking into account the responses of and effects on all relevant actors (airlines, consumers, governments and manufacturers). The effects of policies are computed relative to a future scenario, whereby a scenario reflects an expectation of autonomous developments with respect to air transport and flight activities. The economic and technical modelling of air transport within the AERO-MS consists of five interacting models, which are involved with:

Apart from the models, the AERO-MS contains a User Interface which is involved with the interaction between the five AERO models and the interaction between the user and the system. A user of the AERO-MS is thus interfacing with the integrated system rather than with the individual models. The five models are briefly described below. Figure 1 provides an overview of the core models in the AERO-MS.

Aircraft technology model (ATEC)
The model ATEC is involved with the computation of technical characteristics by aircraft type and technology level based on a modelling of fleet development over time. Aircraft technology particularly applies to the fuel use and emission characteristics of different aircraft types. The technology characteristics are expressed as a function of aircraft ‘technology age’ which is defined by the year in which the aircraft (type) is certified. The technology age distribution is determined by the fleet build-up which depends on the development in time of aircraft sales (following air transport demand) and aircraft retirement.

Air transport demand model (ADEM)
The model ADEM matches the demand and supply side of air transport, i.e. air transport demand in terms of passengers and freight and the frequency and capacity of air transport services offered. Volumes of passengers and cargo transported, passenger fares and freight rates are determined in the process of balancing supply and demand. Aircraft flights are determined by origin-destination (flight stages) and expressed in terms of aircraft types and technology levels, in accordance with available fleets.

The starting point for the modelling of air transport demand and aircraft flights is provided by the Unified Database of the AERO-MS, which is a computerised description of the volume and pattern of global air transport activity in the base year (the Base year of the original AERO-MS was 1992; recently the base year was updated to 2006). The Unified Database is based on the WISDOM database from EUROCONTROL.
Aviation cost model (ACOS)
The model ACOS computes all relevant variable aircraft operating cost components and total operating costs. Variable operating costs are associated with flights by aircraft type and technology level and include: fuel costs; route and landing (airport) charges; flight and cabin crew costs; maintenance costs; capital costs (depreciation) and finance costs. In addition, total operating costs include a number of other, volume-related, costs such as the costs of ground-handling, sales, ground facilities (buildings) and overhead. Based on the total operating costs, ACOS determines the unit costs (per passenger and kg of cargo transported) of air transport by aircraft type, technology level and IATA region-pair. In particular, the model ACOS converts the costs of possible measures in the air transport sector to changes in unit operating costs.

Flights and emissions model (FLEM)
The model FLEM provides a detailed description of the actual flight profiles of individual aircraft flights. Fuel-burn and emissions for each flight are computed in three-dimensional space, taking into account the geographical flight specification and the technical characteristics by aircraft type and technology level. The emissions considered include CO₂, NOₓ, SO₂, CₓHₙ, CO and H₂O. In addition to the computation of fuel-burn and emissions there are a number of other important functions of FLEM. The detailed description of flight paths in FLEM allows for
the simulation of a number of specific policy options related to flight operation. Also there is a
direct connection between ATEC and FLEM allowing FLEM to take into account
developments in aircraft technical and environmental performance as forecasted from
scenarios and policies. And finally FLEM provides the information on fuel-burn as a basis for
the cost computations in the AERO-MS.

**Direct economic impacts model (DECI)**
The model DECI is essentially a post-processing model. One of its main functions is to
provide a comprehensive overview of the results of the other models in the AERO-MS, in
particular the information related to air transport volumes; operating costs, revenues and
results; fleet size and flight operation. Another main function of DECI is to compute a number
of direct impacts to the relevant actors involved in air transport such as: the contribution of
airlines to gross value added; changes in government income and expenses; changes in
consumer surplus and expenses; and changes in the required fleet.

**Model interactions**
Based on the core models described above, the AERO-MS represents an integrated system
of *interacting* models. The model ATEC provides inputs on aircraft technology characteristics
by aircraft type and technology level to each of the models ADEM, ACOS and FLEM. The
models ADEM and ACOS closely interact, whereby ADEM provides information on flight
volumes by aircraft type and technology level to ACOS as a basis for computing operating
costs, while ACOS provides information on changes in unit costs (following from measures)
to assess the impacts of measures on flight volumes in ADEM. The resulting information on
flight volumes by aircraft type and technology level from ADEM is used by the model FLEM
for the computations of fuel-burn and emissions. In turn, information on fuel-burn resulting
from FLEM computations is used in ACOS to allow for the computation of fuel cost. Finally,
the information on fleet size and flight operation as compiled in DECI can be fed back into
ATEC to ensure consistency with the fleet build-up used in ATEC to determine fleet
technology characteristics. In order to facilitate the above interactions between and among
different models, the design of the AERO-MS includes a number of iteration procedures and
specific provisions.

**Scenario developments and policies**
The AERO-MS is capable of handling a wide variety of scenario developments and policy
options. Scenarios reflect different expectations of autonomous developments affecting air
transport activities and related impacts. The AERO-MS contains a large number of scenario
variables that can be specified by the user, within the following three main categories:
- Technology development (providing inputs to ATEC, ACOS and FLEM).
- Transport market developments (providing inputs to ADEM and ACOS).
- Macro-economic and demographic developments (providing inputs to ADEM).

Policy options to be considered also fall in three different main categories, as follows:
- Aircraft fleet technology measures and policies (providing inputs to ATEC).
- Financial measures and policies (providing inputs to ADEM and ACOS).
- Operational measures (providing inputs to FLEM).
Outputs of the AERO-MS
The various models in the AERO-MS provide a wealth of different outputs. Provisions made in the User Interface of the AERO-MS allow for a detailed inspection of all individual model results. In addition, facilities have been provided to generate output reports according to the user's own specifications. A standard 'scorecard' facility is available for the comparison of model runs reflecting different scenario and/or policy situations. Main categories of model outputs in the scorecard representation are:

- **Air transport and aircraft operations**: passenger and cargo demand by type; revenue ton-km; number of flights; aircraft-km.
- **Effects on airlines**: operating costs, revenues and results; contribution to gross value added; airlines related employment.
- **Economic effects on other actors**: (change in) government income/expenses; consumer surplus and expenses; required fleet.
- **Fuel consumption and emissions**.
- **Operating efficiency indicators** (such as: operating cost/RTK; fuel/ATK; load factors).

Analysis principle
Policy options are evaluated in the context of alternative future “business-as-usual” economic and technological scenarios for the aviation sector. The AERO-MS comprehensively integrates the relevant economic, commercial and technological responses of alternative policy options within the scenario contexts considered. In this respect, the AERO-MS distinguishes between three different modelling situations:

- The **Base situation** representing the best possible knowledge of the air transport system in today’s world.
- Projections of future scenario’s containing alternative, autonomous economic and technological developments without policy options (referred to as the Datum situation).
- Projections of alternative (sets of) policy options within a specified scenario context (referred to as the Forecast situation).

This basic analysis principle is illustrated in Figure 2.

![Figure 2 Basic analysis principles of the AERO-MS](image-url)
Recently the AERO Base year was updated to the year 2006. Driven by different sets of assumptions on autonomous developments, the effects of alternative futures (Datum situations) can be analyzed by comparing the modelling results with the Base situation. Within a selected future (Datum situation) reflecting a specific scenario context, the effects of alternative sets of measures (Forecast situations) can be analyzed by comparing the modelling results with the selected Datum situation.

Following the above analysis principle, the effects of alternative policy options are quantified in relation to a common benchmark represented by the selected Datum situation. This produces a “snapshot” of each policy option against the same scenario in the same year, allowing a comparative evaluation of policy options on a consistent basis. In order for this ‘snapshot’ evaluation procedure to be valid, it must be ensured that the measures were introduced sufficiently long before the selected forecast year so that, by that year, a more or less complete adaptation to the measure(s) will have been achieved.

The AERO-MS is global in coverage, but functions at a highly disaggregate level in several “dimensions”, including:

- Spatial dimensions ranging from individual flight stages (based on airport pairs) to a country and (IATA) region level.
- Air service demand for different classes of passenger traffic and air cargo.
- Air service supply represented by ten generic aircraft types differentiated by combinations of seating (or cargo) capacity and range capability.
- Aircraft technology related to fuel efficiency and emissions based on different technology age classes within generic aircraft types.

Each explicit flight stage is described in the Unified Database in terms of its passenger and cargo demand, and the number of flights performed by each generic aircraft type, split according to technology age class and region of carrier registration. Other relevant input data include fares, freight rates and costs for different carriers, routes and aircraft types, as well as data on aircraft engine characteristics for the modelling of fuel-burn and emissions. The economic modelling in the AERO-MS is applied to commercial aviation. Non-commercial general aviation and military aviation have been included only in the fuel-burn and emission calculations (as part of FLEM).