# PROOSIS

## Propulsion Object Oriented Simulation Software

PROOSIS is a stand-alone, flexible and extendible object-oriented simulation environment for modelling gas turbine engines and other systems (control, electrical, thermal, hydraulic, mechanical, etc.). It was originally developed by Empresarios Agrupados Internacional S.A. and an aeronautics consortium of European universities, research institutes and corporate companies. It is based on EcosimPro, the European Space Agency's preferred tool for rocket propulsion, environmental control and life support systems, among others.

PROOSIS has an advanced Graphical User Interface and uses a high-level, "engineer-friendly" object-oriented language (EL) for modelling engine systems and state-of-the-art technologies in areas such as numerical solvers, non-causal modelling of reusable libraries, XML file formats, map handling etc.

Any gas turbine engine configuration or system can be constructed graphically by 'dragging-and-dropping' the required component symbols from the included libraries to a schematic window. Using EL, users can also create new components and libraries, or extend the existing ones.

PROOSIS is capable of steady state and transient simulations as well as customer deck generation (dll, exe, ARP4868, AS4191). Different types of calculations can be performed (single or multi-point design, off-design, test analysis, sensitivity, parametric and optimisation studies, mission analysis, diagnostics, control system design and test, etc).

PROOSIS can also perform multi-fidelity, multi-disciplinary and distributed simulations. These are greatly facilitated by its open architecture, which allows it to connect to external commercial (Excel, Matlab, COM) or in-house tools and link with codes written in C, C++ and FORTRAN.

These features make PROOSIS a useful tool for all phases of the engine life cycle, from preliminary and detailed design to post-certification and in-service support, and allow it to serve as a common framework in multi-partner collaborative engine projects providing common standards and methodologies.

Lastly, PROOSIS also provides a multi-domain simulation platform for the simulation of gas turbines, engine/aircraft systems and power plants.


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EMPRESARIOS AGRUPADOS

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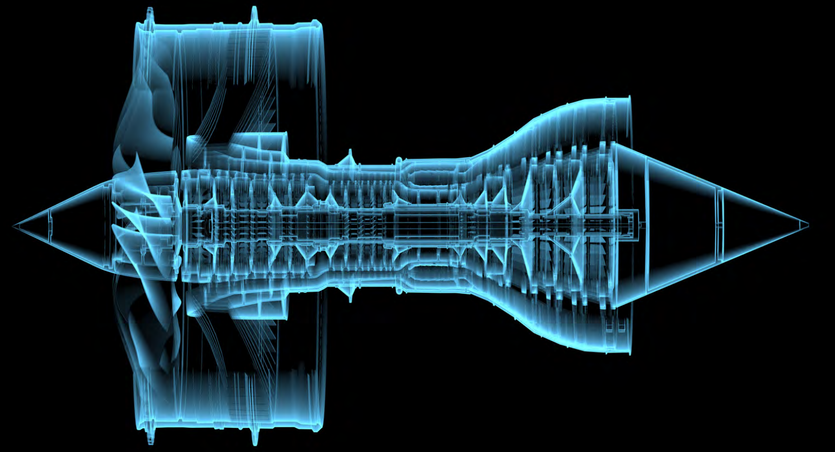

# PROOSIS

## TURBO Library

TURBO: A flexible components library for gas turbine modelling with PROOSIS

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## THE TURBO LIBRARY

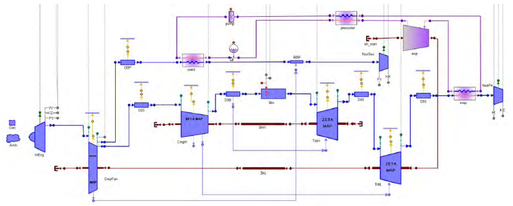
PROOSIS's ability to model engines relies on its TURBO library. It contains a wide range of components for building performance models for any gas turbine configuration by simply dragging and dropping the required components.

The library, for which the source code is also provided, takes advantage of the object oriented approach so that it can be easily extended by including new components or customizing the existing ones. Different modelling methods are available for each component, so that the model can fit specific user needs. By means of extendible switch variables, the user can use different correlations for pressure drop, efficiencies, etc.

With the PROOSIS modeling capabilities you can connect the 0D TURBO components to higher fidelity external models for a particular part of the engine (zooming), for example a 1D or 3D compressor model. Thanks to its compatibility with FORTRAN and C/C++ you can reuse in-house existing codes.

Components are modeled based on open literature and respect international standards with reagards to nomenclature and performance methodology. Some of the features of the components are:

- Turbomachinery
  - Design and off-design models with MFT and BETA maps (using either pressure ratio or specific enthalpy change)
  - User chosen number of bleeds. Extracted flow as input, scheduled (vs corrected speed relative to design), imposed by downstream conditions or by the control system
  - Variable Inlet Guide Vane (VIGV) scheduled through a table or imposed by the control system
- Ducts and burners:
  - Pressure drop and efficiencies by input data, performance maps or user customized correlation.
  - Convergent and convergent-divergent nozzles with discharge and thrust coefficients as input, tables (Nozzle Pressure Ratio / Nozzle Angle) or customized user-given functions.
- A variety of fluid model/fuels
- Different secondary air system configurations can be modeled with the included mixer and splitter components
- The included heat exchangers can be used to model complex industrial or aeronautical cycles with intercooling, recuperators, precooler, etc.



Unmixed Flow Turbofan (UF-TF) coupled with an Organic Rankine Cycle

## ENGINE PERFORMANCE

TURBO/PROOSIS is being successfully used as an engine performance tool for a variety of contemporary as well as future concept engine configurations (e.g. open rotor, geared and contra-rotating turbofans).

PROOSIS/TURBO offers advantages for engine performance calculations not only on the modeling flexibility, but also on the variety of calculations that can be performed. By means of the graphical PROOSIS wizards or the EL language, any typical engine performance calculation can quickly be set up for a single engine model: a single or multipoint design can be quickly configured, as can the parametric, sensitivity or transient calculations.

Design point calculations and performance trends can be easily calculated and plotted, as well as the effect of the design parameters on engine performance through the sensitivity calculations.

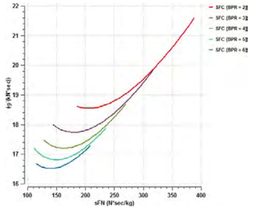
When trying to reproduce a given cycle, the library and PROOSIS provide the flexibility to adjust any cycle input parameter (geometry data, design parameter, flight/operation conditions, adaptation factors to match given performance values.

Cycles meeting different design conditions at different flight or operating conditions can be directly calculated with the Multipoint calculation wizard and the TURBO library. Several limiters to the performance values can be imposed at each point by means of groups of inequalities.

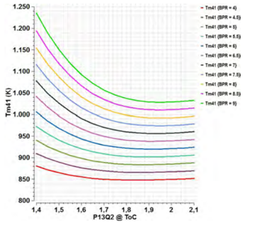
Optimization calculations can also be easily configured into just a few steps with the PROOSIS Optimization Toolbox, as well as model identification (adaptation) calculations.

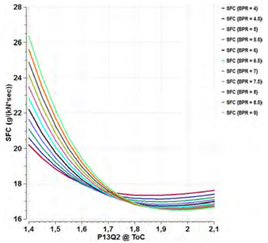
During off-design calculations, the engine can be governed with any controlling parameter (Fuel flow rate, turbine inlet temperature, thrust, etc.) in steady (flight envelope, operating lines, flight modes) and transient calculations. User defined performance limiters can also be imposed in both calculations.

More complex or atypical calculations can be configured with the EL language, for example, fixed or rotary wing mission analysis, operation with alternative fuels, estimation of noise and gas emissions, etc.

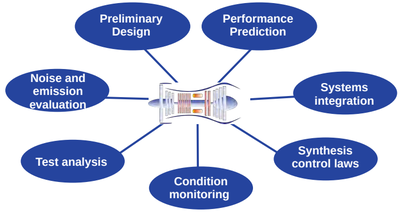



UF-TF Performance trends fullfilling analytical optimal fan pressure ratio (P13Q2) constraint



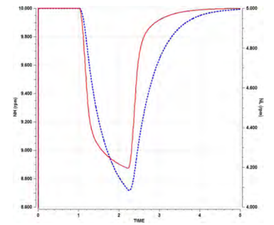

UF-TF: Turbine blade metal temperature and SFC at Cruise conditions variation with P123Q2 and BPR at top-of-climb (design point)

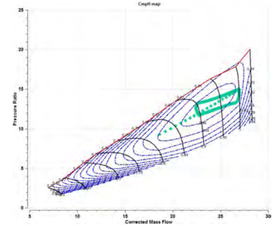



Whole life cycle calculations with TURBO/PROOSIS models

Thanks to the open connectivity features of PROOSIS, engine models can be reused from other tools, like Ms Excel, or MATLAB. The engine model can be easily exported as a Simulink block, being possible for example to simulate a control system developed in Simulink together with the PROOSIS engine model. The PROOSIS model can thus be integrated in external tools for noise and emission estimation, test analysis, condition monitoring, etc.

For a quick configuration of typical models and calculations, a library (GTE_EXAMPLES) exists with a wide range of aircraft engine models (turbojet, different turbofan configurations, turbopropellers, turboshafts, etc.) and calculations (design point and off-design, optimization, parameter estimation, mission simulation, component zooming, dynamic simulation with control system integration, etc). They can be used as templates or starting points for specific user calculations or, together with the book "Introduction to Gas Turbine Modeling with PROOSIS" as educational supporting material.

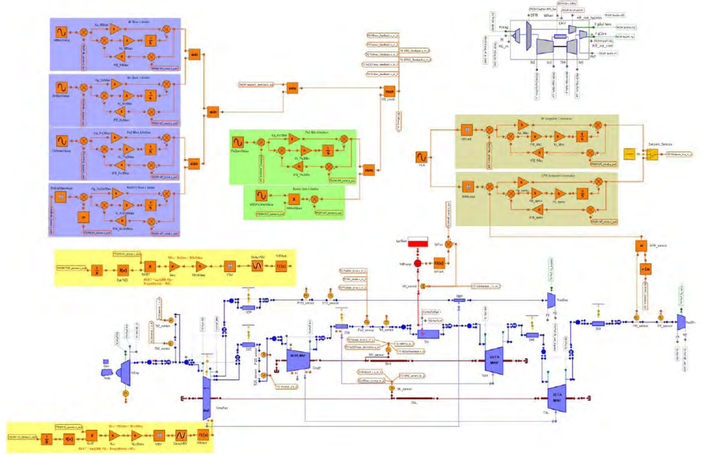



Operating line and transient simulation for an UF-Turbofan

## DYNAMIC SIMULATION AND CONTROL

The last version of the library, 3.4, includes the most important dynamic effects such as shaft inertia, heat soakage, tip clearance, volume dynamics and/or sensor and actuator dynamics. This way, dynamic engine models can be easily simulated together with the control system, developed within PROOSIS (CONTROL library), including different setpoint controllers, protection logic, sensors and actuators for fuel injection, Variable Bleed Valves (VBV) and Variable Geometry Vanes (VGV)



Unmixed flow turbofan engine model with control system