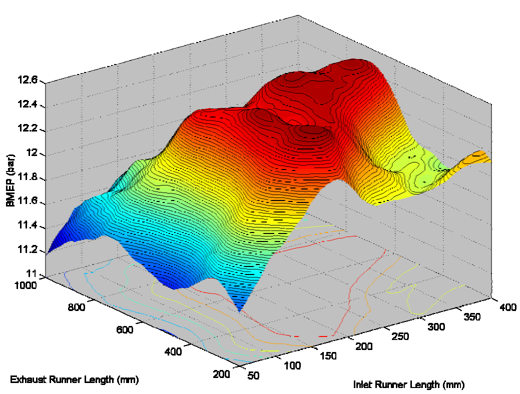
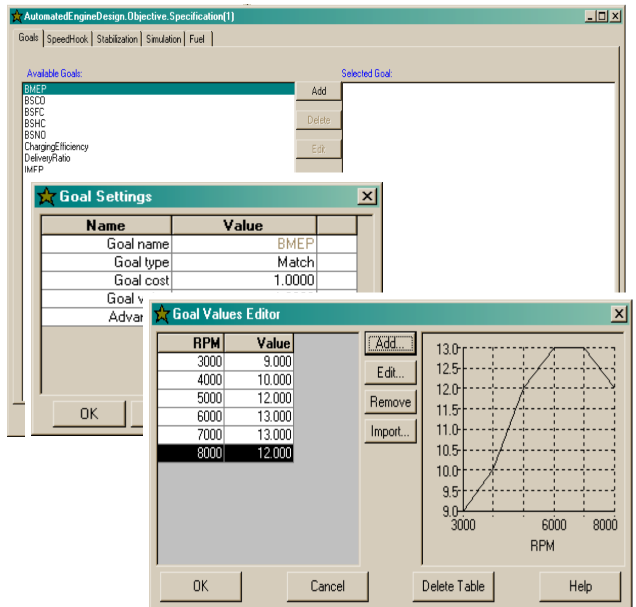
AUTOMATED DESIGN (Patents Pending)

AUTOMATED DESIGN with Virtual Engines is a revolutionary software product, **the world's 1st engine design expert system**, that:

- ❑ Can be trained to solve your engine performance design problems much faster than is currently possible
- ❑ Has the ability to do extensive design space analysis and select the best of several alternative engine designs, all of which meet specified design requirements
- ❑ Offers quality improvements in every new design project by leveraging the expertise of a companies best engineers

Consider a typical four-stroke engine. There are many critical parameters that can influence performance including valve timing, lift, and profile, intake manifold lengths and diameters, and exhaust system dimensions to name but a few. It is a seemingly impossible design task to find the best combination of these parameters that satisfies the entire engine's performance requirements (power, torque, fuel consumption etc). Even with only five parameters and 10 possible values for each parameter, there are 100,000 unique designs. How can the engine designer ever hope to find an optimum solution in such a large design space? Building on the parametric capabilities of Virtual Engines, AUTOMATED DESIGN delivers the benefits of optimized "virtual prototyping". Its simple intuitive user interface masks the complexity of its powerful Design of Experiments (DOE) and optimization techniques and enables every designer to easily create new optimized engines.





OBJECTIVE - Match Target Goal

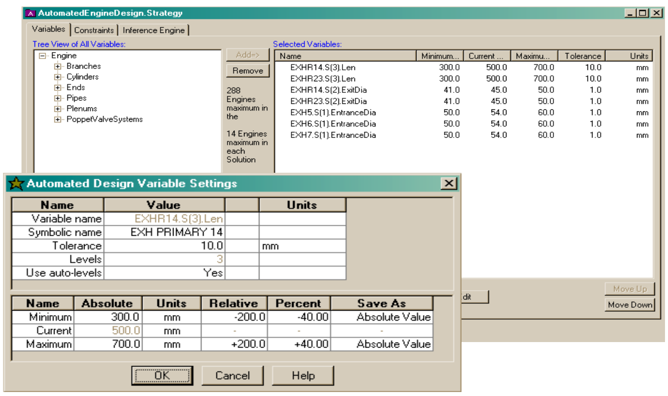
The AUTOMATED DESIGN expert system can be thought of as a diligent tireless assistant, thoroughly analyzing a predefined design space in search of the best solutions to your engine design problems. An Automated Engine Design consists of three elements:

- ❑ A base engine
- ❑ OBJECTIVE rules
- ❑ STRATEGY rules

The base engine is the reference point for the Automated Engine Design. It defines all of the dimensions and parameters of the engine that will not change during the optimization process, and it determines all of the baseline engine performance characteristics.

An OBJECTIVE explicitly defines the goals of an Automated Engine Design with the rules that the expert system uses to rank alternative designs. Each OBJECTIVE specification may contain multiple goals, each of which can be to Minimize, Maximize, Match or Limit a performance characteristic of the new engine. Each goal in a multiple goal OBJECTIVE is normalized, relative to that characteristic of the base engine, so that the expert system can properly rank alternative designs. In addition, the importance of each goal can be weighted to further guide the expert system during the optimization process.

The Match goal is a particularly powerful rule that permits a desired performance characteristic, as a function of engine speed, to be defined as a design target. During the optimization process, the expert system will minimize the error relative to the target for that goal.



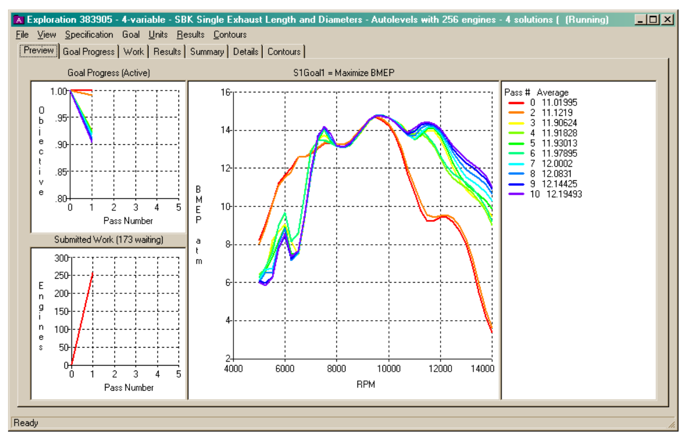
STRATEGY

The STRATEGY describes the process by which the design OBJECTIVE will be achieved. It defines the rules that the expert system will use to create new alternative designs. The STRATEGY includes the engine parameters that can be changed during the Automated Engine Design process, together with their limits and tolerances in the design space. Additional parametric design constraints may also be specified in the STRATEGY. Descriptive "Symbolic Names" are assigned to each parameter, allowing the STRATEGY to be easily reused on different engine designs with little or no modification. The STRATEGY also includes "Inference Engine" rules, which allow the designer to tailor the optimization process to meet deadlines with the available computational resources.

The "Inference Engine" performs Automated Engine Designs using a (patents pending) two-stage process. During the first stage, called Exploration, the "Inference Engine" simulates a reasonable number of engines within the design space and uses surface response analysis to identify unique regions that may contain local optima. Using rules specified by the designer, it then determines the best new base engines to use for second stage Solutions. During these optimizations, the interactions between parameters are assessed at each step of the process using a dynamic method that efficiently manages the size of the experiment. This technology permits previously impractical large multi-variable optimization strategies to be applied to any engine design project. When AUTOMATED DESIGN is used in conjunction with the OPTIMUM Network Supercomputer, ten's of thousand's of alternative engine designs can be quickly evaluated in the process of creating a new optimized engine design.

All OBJECTIVES and STRATEGIES are automatically stored in the AUTOMATED DESIGN Knowledge Base. As such, the Expert System becomes more and more powerful as the skill of every engine designer gets added to the Knowledge Base where it can be easily reused again and again on new projects.

The progress of any Automated Engine Design can be assessed, in real-time, through a Status display accessible from Design Explorer. Both the Exploration stage and the Solution stage can be examined in detail. Comparisons to



Real-time Design progress monitoring

the base engine with respect to any engine performance characteristic can be seen at the click of a button, and changes to engine parameter can be viewed easily.

In summary, AUTOMATED DESIGN can accelerate the design phase of any engine development project by orders of magnitude, and yield a substantially better design in the process.