

## **ADAMS/Insight Application in Motorsports**

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### **Abstract**

Mechanical Dynamics, Inc's ADAMS/Insight software provides experimental design and response fitting capability with broad application potential in motorsports. This tool enables a timely and in-depth understanding of the influence of design and setup variables on the performance of the vehicle or subsystem. Applications include simulations with both ADAMS and third-party software and physical testing. This paper discusses actual and potential uses of ADAMS/Insight in motorsports. The process of using Insight with a third-party application is described.

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### **Introduction**

The application of experimental design and response surface methods (DOE and RSM) to a motorsports vehicle or subsystem model is a productive means to gaining an enhanced understanding of its behavior. Using these methods, the complex relationship between design and setup variables (factors) and performance metrics (responses) can be approximated and analyzed. ADAMS/Insight software provides the functionality and tools for all phases of this process.

The flexibility designed into ADAMS/Insight enables it to be used with ADAMS simulation products, third-party applications, and stand-alone for physical experiments. This is advantageous for a racing team, as many applications are used in the design and development of a racing car.

### **Simulation Applications**

#### ADAMS Simulations

The interface between ADAMS/Insight and ADAMS simulation products is well-developed. It allows for efficient execution of experiments involving a large number of simulations as well as post-processing and importing of response data. Shorter simulation events are typically used with designs requiring a large number of trials. Typical ADAMS simulation events for motorsport DOE's are:

- Steady-state cornering
- Step-steer
- Mini-maneuvers: acceleration, braking, etc.

The responses from these events are generally used as metrics for vehicle performance and controllability. Normally, some combination of these responses is used. Typical Scalar Responses from these events are:

- Load transfer
- Understeer gradients
- Ride heights
- Steering wheel angle and torque
- Suspension position and load
- Aerodynamic forces

Composite Responses (polynomial coefficient fit responses) allow the user to extract additional information from a response surface fit beyond scalar values. The polynomial coefficient fits can be used to plot nonlinear response relationships (figure 1) and extract gradient data. Examples of polynomial fits are:

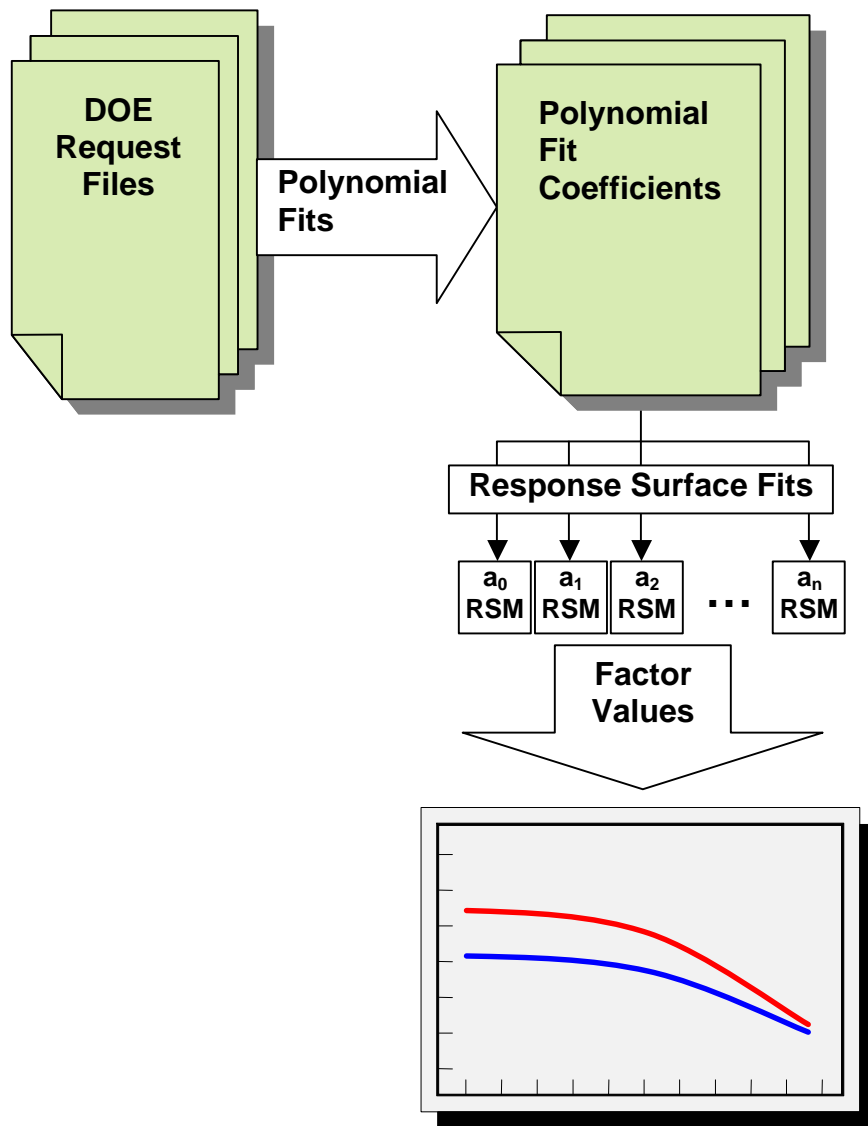
- Ride height vs. speed
- Damper displacements vs. speed
- Aerodynamic forces vs. lateral acceleration
- Dynamic toe, caster, and camber curves

### Third-party Simulation Applications

ADAMS/Insight can be used independently of ADAMS simulation applications to perform experiments using third-party simulation models and tools. The potential uses are many, given the variety of applications and tools used in the design and development of a racing car. Insight's DOE and RSM capability can be applied to a full range of investigations from simple kinematics applications to complex FEA studies. A full example is given later.

### **Physical Testing**

As originally developed, experimental design techniques can be applied to physical testing of racing cars and components. With physical experiments, measurement noise can be a problem in regressing response data. This is certainly true with full-vehicle testing where true responses can be masked by tire wear, environmental conditions, and subjective driver evaluation.



**Figure 1**  
**Polynomial Response Fits**

However, these techniques can be applied to component testing to increase yield and understanding of physical test data. Some examples are listed below.

- Determining modifications to tire model coefficients (responses) as a function of operating conditions (factors). I.e. factors such as pressure, temperature, and wear.
- Incorporating damper adjuster settings (factors) into a damper model.
- Multi-post shaker testing

## Lap Simulation DOE/RSM Example

One example of using Insight with a third-party application is performing lap simulation experiments. Experiments can be designed to study the effect of gearing, power curves, and aerodynamic trims on laptime and other lap-based responses. This section will document the procedure of using Insight with a third-party application for this purpose.

### Workspace Generation

The first step in the DOE process is defining the workspace. This includes defining factors, responses, and experiment design. An Insight file from a previous DOE can be used as a starting point. Factors and responses may be added and deleted or promoted and demoted to suit the current objectives.

### Workspace Export/Import

Once the workspace is generated, it must now be exported for use by the third-party application or intermediate software. Insight exports a workspace table in comma-separated-value (CSV) format. In this same manner, the completed workspace is imported once the response data is obtained.

### Interfacing with third-party application

Obviously, this phase is heavily dependent on the simulation application. In most cases, a pre-processor is required to parse the workspace data, generate simulation inputs, execute simulations, parse simulation output data, and complete the workspace response table. This process is graphically depicted in figure 2 below.

### Fitting Response Surfaces

Once the response data has been imported back into Insight, response surfaces are fit to the results according to the user-defined model order. The quality of the response surface fits can be evaluated from many fronts. Initially, the goodness-of-fit statistics ( $R^2$ ,  $R^2_{adj}$ , and P) give a good indication of the fit quality. Actual residual values are important as well.

The quality of fit can be investigated or refined in a number of ways. The user may wish to remove outlying data points. Outlying data points may be a result of an un-converged or problematic simulation. In addition, factor combinations may result in responses that are outside a physically acceptable or possible range. In this lap simulation example, combinations of adjacent gear ratios may result in an rpm drop

between shifts that is unacceptable to the driver. The responses to this combination may skew the response fit, so the user may wish to remove these instances.

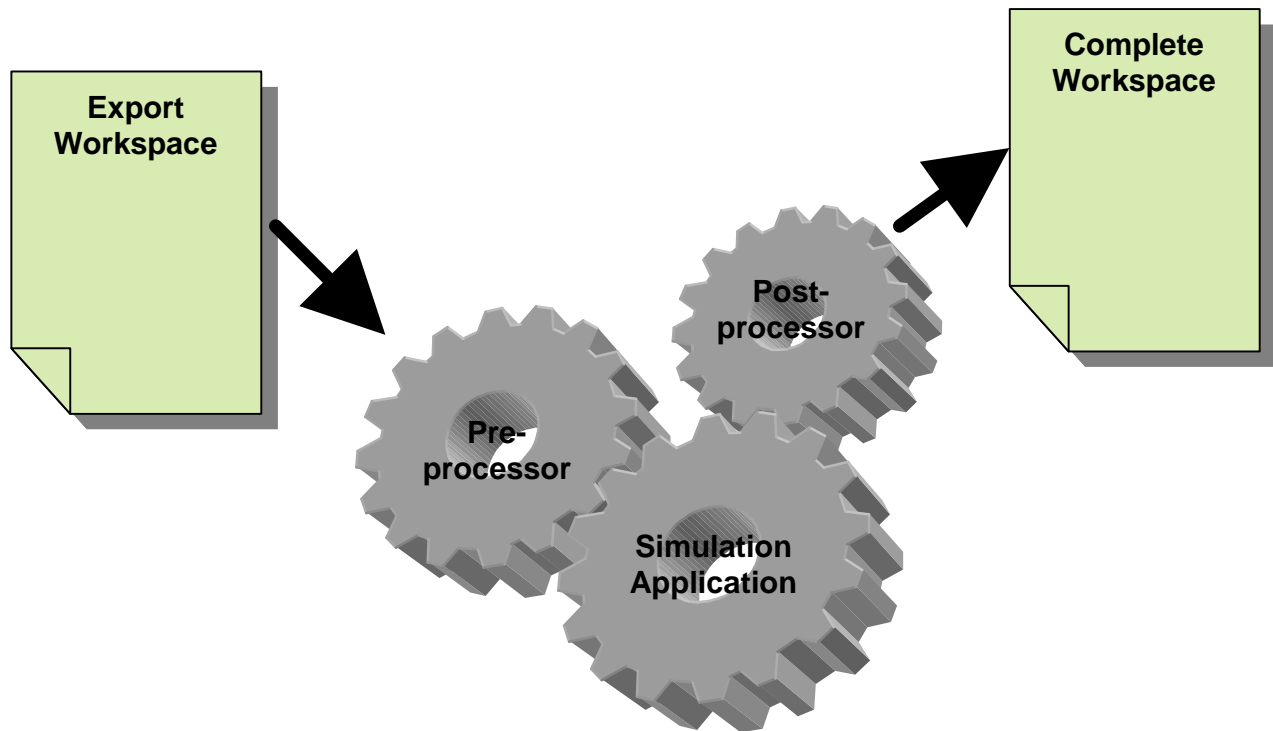


Figure 2  
Interfacing with Third-party Application

ADAMS/Insight 12.0 gives the user graphical displays of the response variables which aid in this process. The scatter plot in figure 3 shows rpm drops between 1<sup>st</sup> and 2<sup>nd</sup> gear. The trials resulting in rpm drops above or below realistic thresholds may be removed to potentially improve the response surface fit within the acceptable rpm drop range. Additionally, the user may refine the response surface fits by removing terms that do not have a significant effect on the regression fit, or even changing the order of the fit.

### Analyzing Results

Results of the experiment can be analyzed and distributed in many forms. ADAMS/Insight 12.0 provides exported results in three formats: HTML, SYLK, and Visual Basic response surface functions. Both SYLK files and VB functions can be imported into Microsoft Excel for further study of 'what if scenarios', plotting the response surfaces or the composite responses, optimizing the responses, and formatting the results for reports.

Optimization tools can be used to search the design space for minima, maxima, or targets meeting user-defined criteria. Insight 12.0 has this functionality built-in.

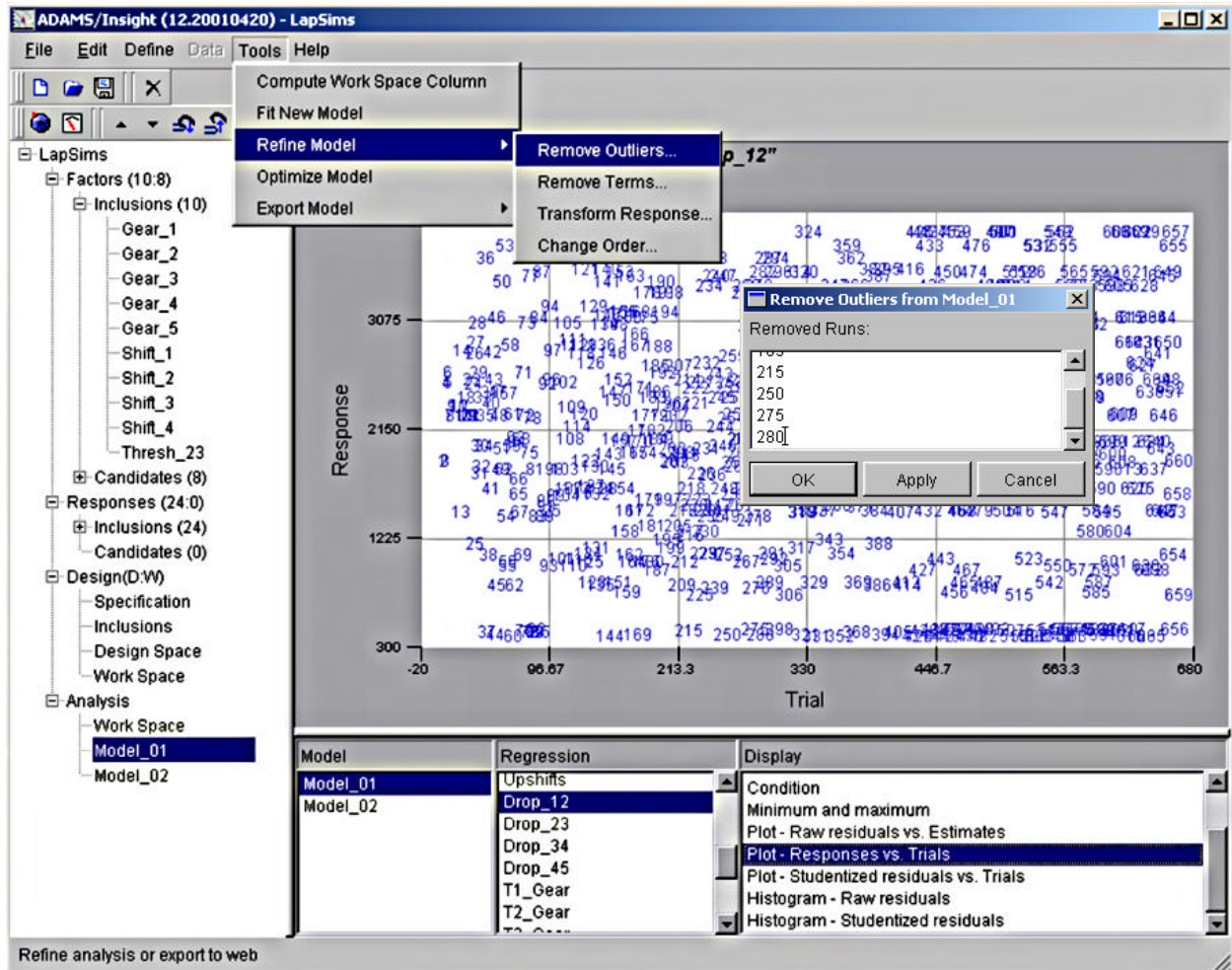


Figure 3  
 ADAMS/Insight Scatter-Plot

## Conclusions

ADAMS/Insight is an effective tool for gaining an enhanced understanding of race car and component behavior. DOE and RSM techniques can be applied using Insight with ADAMS and third-party simulations, and physical testing. Insight 12.0 provides graphical displays of the design space, multiple export formats, and optimization capability resulting in a comprehensive and flexible tool.