

# **System Identification Toolbox™ Release Notes**

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*System Identification Toolbox™ Release Notes*

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**R14SP3**

No New Features or Changes

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**R14SP2**

No New Features or Changes





# R2014a

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**Version: 9.0**

**New Features: Yes**

**Bug Fixes: Yes**

## **Recursive Least Squares Estimator and Recursive Polynomial Model Estimator blocks for online model parameter estimation**

**Compatibility Considerations: Yes**

Use the Recursive Least Squares Estimator and Recursive Polynomial Model Estimator blocks to perform online model parameter estimation in Simulink®. Online parameter estimation, also known as *online estimation* or *online tuning*, refers to estimating model parameters as new data becomes available during the operation of the model. You can generate code for these blocks using code generation products such as Simulink Coder™. For example, you can estimate the coefficients of a time-varying plant from measured input-output data and feed them to an adaptive controller. After validating the online estimation in simulation, you can generate code for your Simulink model and deploy the same to an embedded target.

These blocks are in the Estimators library.

For examples of how to use these blocks, see “Preprocess Online Estimation Data” and “Validate Online Estimation Results”.

### **Compatibility Considerations**

The following blocks will be removed in a future release: AR Estimator, ARMAX Estimator, ARX Estimator, BJ Estimator, OE Estimator, and PEM Estimator.

## **Interactive identification of single-input/single-output plants from measured data in PID Tuner app**

As a part of the control design workflow, you can interactively identify a plant using measured data in the PID Tuner app in Control System Toolbox™. For example, to design a PID controller for a manufacturing process, you can start with response data from a bump test on your system. You can import this data instead of a plant model in the tuner. You can then interactively identify a linear plant model whose response fits the response data.

The PID Tuner automatically tunes a PID controller for the identified model. You can then interactively adjust the PID controller gains, and save the identified plant and tuned controller. For more information, see “System Identification for PID Control”.

To access the PID Tuner, enter `pidtool` at the MATLAB® command line. For an example, see “Interactively Estimate Plant Parameters from Response Data”.

## **Interactive identification of single-input/single-output plants from simulation data when tuning PID Controller blocks using Simulink Control Design**

You can obtain a linear representation of a Simulink model and tune the gains of a PID Controller block for the plant in the PID Tuner app. The identification-based approach serves as an alternative to the linearization-based approach and is useful where linearization fails to yield a good plant model. This functionality requires Simulink Control Design™ software.

The identification works by simulating the Simulink model and then using the simulated input-output data to obtain a plant model. You identify the plant using interactive graphical tools in the PID Tuner app. Next, you use the identified model to tune your PID Controller block. For example, suppose you want to tune the PID Controller block in a model that contains a Triggered Subsystem block. The analytical block-by-block linearization algorithm does not support event-based subsystems, and therefore the model linearizes to zero. Now, you can simulate the Simulink model for a chosen input and use the simulated data to identify a plant model. The PID Tuner automatically tunes the PID controller for the identified model. You can then interactively adjust the performance of the tuned control system, and save the identified plant and tuned controller. For more information, see “System Identification for PID Control”.

To access the PID Tuner, in the PID Controller block dialog box, click **Tune**. For an example, see “Design a PID Controller Using Simulated I/O Data” in the Simulink Control Design documentation.

## **ssregest, a regularization-based state-space model estimator, for improved accuracy on short, noisy data sets**

You can use `ssregest` to estimate state-space models. This estimator is known to perform better than `n4sid` for short, noisy data sets. For some problems, the quality of fit using `n4sid` is sensitive to options, such as `N4Horizon`, whose values can be difficult to determine. In comparison, the quality of fit with `ssregest` is less sensitive to its options, which makes `ssregest` simpler to use.

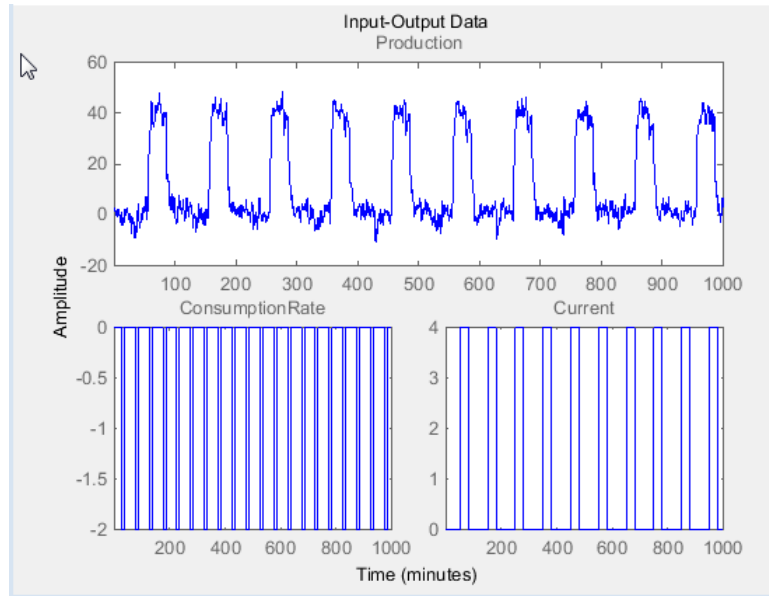
`ssregest` estimates a regularized ARX model and converts the ARX model to a state-space model. The software then uses balanced model reduction techniques to reduce the state-space model to the specified order. You can specify estimation options for `ssregest` using `ssregestOptions`.

You can also select this estimator in the System Identification Tool. In the State Space Models dialog box, expand **Estimation Options** and select **Regularized Reduction** from the **Estimation Method** drop-down list.

## **plot command for iddata object enhanced**

The `plot` command for input-output data `iddata` has the following enhancements:

- Multiexperiment data or datasets with more than one input or output channels are plotted on a single plot
- Input and output channels can be grouped together



You can customize the plot, such as group and ungroup channels, and explore data characteristics, such as peak and mean value, using the right-click menu.

You can also customize the plot, such as specify axes labels, using `iddataPlotOptions`.

## Options set and specification of input delay and noise source integrator for arxRegu1 command

**Compatibility Considerations: Yes**

You can now use `arxRegu1Options` to specify regularization options for `arxRegu1`. Regularization options include the regularization kernel to use, such as 'TC' and 'SE', and search method for estimating regularization constants.

You can also specify input delay and presence of a noise source integrator as Name-Value pair arguments in `arxRegu1`.

## Compatibility Considerations

Replace `[lambda,R] = arxRegul(data,orders,kernel)` and `[lambda,R] = arxRegul(data,orders,kernel,max_size)` syntaxes with `[lambda,R] = arxRegul(data,orders,options)` syntax. Specify `kernel` and `max_size` in the options set created using `arxRegulOptions`.

# R2013b

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**Version: 8.3**

**New Features: Yes**

**Bug Fixes: Yes**

## Regularized estimation of linear and nonlinear models for obtaining parameter values with less variance

You can now obtain regularized estimates of parameters for linear and nonlinear models. Previously, you could specify this option for correlation model estimation only, using `impulseestOptions`.

Regularization reduces variance of estimated model parameters by trading variance for bias. Regularization is useful for:

- Identifying overparameterized models, such as nonlinear ARX models
- Imposing apriori knowledge of model parameters in structured models, such as grey-box models
- Incorporating knowledge of system behavior in ARX and FIR models

Using regularization adds a penalty proportional to the parameter dimension and values in the cost function that is minimized for estimation. Without regularization, the parameter estimates are obtained by minimizing a weighted quadratic norm of the prediction errors  $\varepsilon(t, \theta)$ :

$$V_N(\theta) = \sum_{t=1}^N \varepsilon^2(t, \theta)$$

where  $t$  is the time variable,  $N$  is the number of data samples and  $\varepsilon(t, \theta)$  is the predicted error computed as the difference between the observed output and the predicted output of the model.

A regularized estimation minimizes:

$$\hat{V}_N(\theta) = \sum_{t=1}^N \varepsilon^2(t, \theta) + \lambda \theta^T R \theta,$$

where  $\lambda$  is a constant that trades off variance for bias in the estimated values of parameters  $\theta$ .  $R$  is an associated weighting matrix.



For more information on regularization, see Regularized Estimates of Model Parameters.

You can specify the regularization constants `Lambda`, `R`, and `Nominal` at the command line or in the System Identification Tool:

- At the command line, use the `Regularization` option available in the estimation options set (`tfestOptions`, `ssestOptions`,...) for linear models.

For nonlinear models, the option is available in the `Algorithm` property of `idnlarx`, `idnlhw`, and `idnlgrey` models.

For ARX models, you can generate `Lambda` and `R` values automatically from a given regularization kernel using the `arxRegul` command.

See the estimator reference pages and Regularized Identification of Dynamic Systems for examples.

- In the System Identification Tool, click **Regularization** in the linear model estimation dialog box or click **Estimation Options** in the Nonlinear Models dialog box.

For an example, see Estimate Regularized ARX Model Using System Identification Tool.

## **ssarx subspace identification method for robust estimation of state-space models using closed-loop data**

`N4Weight`, which represents the weighting scheme used for singular-value decomposition by the `N4SID` algorithm, now includes a `ssarx` option. This option is an ARX estimation-based algorithm to compute the weighting. Specifying this option allows the `N4SID` algorithm to compute unbiased estimates of the model parameters when using data that is collected in a closed-loop operation. For more information about the algorithm, see Jansson, M., "Subspace identification and ARX modeling", *13th IFAC Symposium on System Identification*, Rotterdam, The Netherlands, 2003.

To specify this option:

- At the command line, set the `N4Weight` option in `n4sidOptions` or `ssestOptions` to '`ssarx`'.

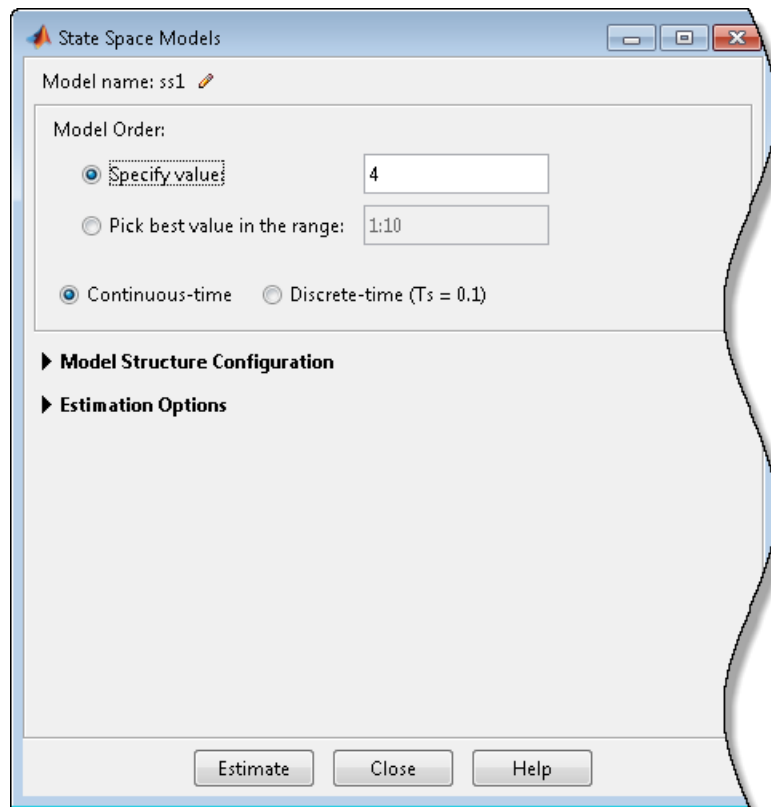
- In the System Identification Tool, in the State Space Models dialog box, expand **Estimation Options** and select SSARX from the **N4Weight** drop-down list.

For an example of using the subspace algorithm for closed-loop data, see the `n4sid` reference page.

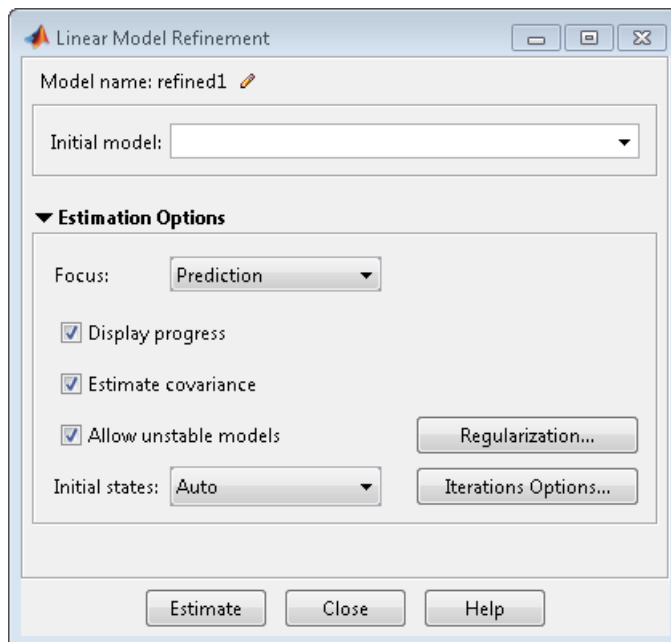
## **Redesigned state-space model and initial model refinement dialog boxes**

The State Space Models and Linear Model Refinement dialog boxes have been redesigned to improve state-space model estimation and initial model refinement workflows.

To open the State Space Models dialog box, select **Estimate > State Space Models** in the System Identification Tool.



To access the redesigned Linear Model Refinement dialog box, in the System Identification Tool, select **Estimate > Refine Existing Models**.



The initial model must be in the Model Board of the System Identification Tool or a variable in the MATLAB workspace. This model can be a state-space, polynomial, process, or transfer function model.

For more information, click **Help** in the dialog boxes.

## **getpar and setpar commands to obtain and set parameter attributes of identified linear models**

You can now use `getpar` with identified linear models to obtain parameter values, free or fixed status, minimum/maximum bounds, and labels. Identified linear models include process, input-output polynomial, state-space, transfer function, and grey-box models.

Similarly, use `setpar` to set these parameter attributes.

## Unstable models option added to System Identification Tool

You can now estimate unstable models in the System Identification Tool. You can use this option to:

- Estimate transfer function models using frequency-domain data.
- Estimate state-space models using time- or frequency-domain data.
- Refine linear models using time- and frequency-domain data.

This functionality is the same as setting the estimation option `Focus` to 'prediction' at the command line.

The option allows the estimation process to use parameter values that might lead to unstable models. An unstable model is delivered only if it produces a better fit to the data than other stable models computed during the estimation process. Such an unstable model might be useful, if, for example, you plan to design a controller for the model.

To set this option in the Transfer Function dialog box, expand **Estimation Options** and select the **Allow unstable models** check box. In the State Space Models and Linear Model Refinement dialog boxes, this option is selected by default.

## SamplingGrid property for tracking dependence of array of sampled models on variable values

For arrays of identified linear (IDLTI) models that are derived by sampling one or more independent variables, the new `SamplingGrid` property keeps track of the variable values associated with each model in the array. This information is shown when displaying or plotting the model array. The information is useful to trace results back to the independent variables.

Set this property to a structure whose fields are named after the sampling variables and contain the sample values associated with each model. All sampling variables should be numeric and scalar valued, and all arrays of sample values should be commensurate with the model array.

For example, if you collect data at various operating points of a system, you can identify a model for each operating point separately and then stack the results together into a single system array. You can tag the individual models in the array with information regarding the operating point:

```
nominal_engine_rpm = [1000 5000 10000];  
sys.SamplingGrid = struct('rpm',nominal_engine_rpm)
```

where `sys` is an array containing three identified models obtained at rpms 1000, 5000, and 10000, respectively.

# R2013a

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**Version: 8.2**

**New Features: No**

**Bug Fixes: Yes**





# R2012b

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**Version: 8.1**

**New Features: Yes**

**Bug Fixes: Yes**

## **Regularized estimates of impulse response, specification of transport delays and estimation options using `impulseest`**

**Compatibility Considerations: Yes**

You can obtain regularized estimates of impulse response using the regularization kernel (`RegulKernel`) estimation option. Regularization reduces variance of estimated model coefficients and produces a smoother response by trading variance for bias. You can also configure estimation options such as prefilter order and data offsets. You use `impulseeestOptions` to specify the estimation options and pass them as an input to `impulseeest`.

You can also specify filter orders and transport delays as inputs to `impulseeest`.

### **Compatibility Considerations**

- Using a time vector as an input to `impulseeest` or specifying the 'noncausal' flag warns and will be removed in a future version. Specify the order of the impulse response model instead.
- To compute the acausal part of the response up to a negative lag  $L$ , set the input delay input argument to  $-L$ .

## **`translatecov` command for translating model covariance across transformations**

You can use `translatecov` to translate model covariance across model transformations such as continuous- and discrete-time conversions, concatenation and conversions to different model types. Previously, model covariance was lost when you performed such operations on a model directly. `translatecov` lets you perform these operations while also translating the covariance data. For example, transform an estimated continuous-time model `mc` to discrete-time:

```
md = c2d(mc, Ts);  
md2 = translatecov(@(x)c2d(x, Ts), mc)
```

The first operation produces a discrete-time model, `md`, which does not contain parameter covariance data. The second operation produces the model, `md2`, which has the same structure and parameter values as `md` but contains parameter covariance data.

## ssform command for quick configuration of state-space model structure

You can use `ssform` to configure model parameterization, feedthrough and disturbance dynamics. This command lets you quickly configure these properties when estimating state-space models in a structured way. You can use this command as a simpler alternative to explicitly modifying the `Structure` property of the `idss` model for some commonly applied changes. For example, typing `ssform(model, 'Form', 'canonical', 'DisturbanceModel', 'estimate')` configures the model structure such that:

- Its `A`, `B`, and `C` matrices are in observability canonical form
- The `K` matrix entries are all treated as free parameters

## Feedthrough specification for discrete-time transfer function model estimation

When estimating a discrete-time transfer function model, you can specify whether the model has feedthrough. Use the `Feedthrough` name-value pair in `tfest` or click **Feedthrough** in the graphical interface. For MIMO systems, you can specify feedthrough for individual channels or a common value across all channels.



# R2012a

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**Version: 8.0**

**New Features: Yes**

**Bug Fixes: Yes**

## Summary

Important new features and changes in the System Identification Toolbox™ software for this release include:

- New functions that perform continuous-time estimation for state-space and transfer function models.
- Support for multi-output estimation for polynomial models (such as ARMAX, OE, and BJ) and process models.
- A new, uniform design for linear, parametric models. You can specify whether a coefficient should be estimated and now impose minimum/maximum bounds on estimated coefficients in a standardized manner.
- Consolidation of the functions dealing with linear time-invariant systems in the Control System Toolbox software. This unification of code allows for a streamlined workflow in estimating models and analyzing them and improves numerical accuracy and consistency.
- Many commands now have a more unified syntax, but, with few exceptions, old syntax continues to work in this release for backward compatibility. Incompatibilities introduced this release mainly involve configuration of estimation options, translation of parameter covariance, reordering of output arguments for some functions and the treatment of certain model properties.

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**Note** Instances where the changes will break existing code or yield different results have been marked as "Backward incompatibility".

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## New Features in This Version

### Compatibility Considerations: Yes

New features this release include:

- “Continuous-Time Transfer Function Identification for Time- and Frequency-Domain Data ” on page 23

- “Time-Series Modeling and Forecasting, Including Generating ARIMA Models” on page 24
- “Estimation of Multi-Output Polynomial and Process Models” on page 24
- “Interactive Response Plots with Better Look and Feel” on page 25
- “Models Created with System Identification Toolbox Can Be Used Directly with Control System Toolbox Functions” on page 25
- “Improved Reliability of Numerical Computations” on page 26
- “Estimating Functions and Estimation Option Sets” on page 26
- “Model Analysis and Validation Option Sets” on page 28
- “Identified Linear Models” on page 29
- “System Identification Tool GUI” on page 39

### **Continuous-Time Transfer Function Identification for Time- and Frequency-Domain Data**

A new function, `tfest`, lets you estimate a linear transfer function based on a system’s response. `tfest` can be used for time- and frequency-domain data.

The output of `tfest` is an `idtf` model, which is a new identified linear model. An `idtf` model stores the identified numerator, denominator, and any transport delays using its `num`, `den`, and `ioDelay` properties, respectively.

For information regarding estimating a continuous-time transfer function using time-domain data, see [How to Estimate Transfer Function Models by Specifying Number of Poles](#).

For information regarding estimating a continuous-time transfer function using frequency-domain data, see [How to Estimate Transfer Function Models with Transport Delay to Fit Given Frequency Response Data](#).

## **Time-Series Modeling and Forecasting, Including Generating ARIMA Models**

### **Forecasting**

A new function, `forecast`, lets you forecast the response of an identified linear model for a specified future time interval. You may also specify the future inputs for models that are not time-series models.

`forecast` complements the functionality of `predict`, which evaluates fixed-step ahead predictions on historic data.

Use `forecastOptions` to create an option set to specify forecasting options.

For more information, see `forecast` and `forecastOptions`.

### **Generating ARIMA Models**

A new property for `idpoly` models, `IntegrateNoise`, designates if a model output contains an integrator in its noise source. Use the `IntegrateNoise` property to create, for example, ARI, ARIMA, ARIX, and ARIMAX models.

The `IntegrateNoise` property takes a logical vector of length `Ny`, where `Ny` is the number of outputs.

For more information, see `Estimating ARIMA Models`.

## **Estimation of Multi-Output Polynomial and Process Models**

### **Multi-Output Polynomial Models**

`idpoly` models can now represent multi-output polynomial models. Use `idpoly` to create a multi-output polynomial model. You can also use the various estimator functions (`ar`, `arx`, `bj`, `oe`, and `armax`) to estimate a multi-output `idpoly` model.

A new function, `polyest`, may also be used to estimate a multi-output polynomial model of arbitrary structure. For more information, see `polyest` and `polyestOptions`.



**Compatibility Consideration: Backward incompatibility.** See “idarx Models No Longer Returned in Multi-Output Model Estimation” on page 43.

## Multi-Output Process Models

`idproc` models can now represent multi-output process models. Use `idproc` to create a multi-output process model. You can also use the new process model estimator function, `procest`, to estimate a multi-output `idproc` model.

For more information, see `procest` and `procestOptions`.

## Interactive Response Plots with Better Look and Feel

Enhanced response plots for identified linear models allow you to interactively:

- Choose the system characteristics that are displayed. To view a system characteristic, right-click on the plot, select **Characteristics**, and then select the system characteristic of interest.
- Modify plot properties, such as whether the grid is on or off, axes labels and units, advanced plot options, etc. To modify the plot properties, right-click on the plot, and select **Properties**. The Property Editor dialog box opens. Modify the plot property of interest.

You can plot the confidence intervals associated with identified linear models. You can now plot the confidence interval interactively, by right-clicking on the plot and selecting **Characteristics > Confidence Region**. You can also use the new function, `showConfidence`, to display the confidence region on a plot via the command line.

## Models Created with System Identification Toolbox Can Be Used Directly with Control System Toolbox Functions

Identified linear models that you create using System Identification Toolbox software can now be used directly with Control System Toolbox analysis and compensator design commands. In previous releases, doing so required conversion to Control System Toolbox model types.

Identified linear models include `idfrd`, `idss`, `idproc`, `idtf`, `idgrey`, and `idpoly` models.

Identified linear models can be used directly with:

- Any Control System Toolbox or Robust Control Toolbox™ functions that operate on dynamic systems, including:
  - Response plots — `nichols`, `margin`, and `rlocus`.
  - Model simplification — `pade`, `balred`, and `minreal`.
  - System interconnections — `series`, `parallel`, `feedback`, and `connect`

For a complete list of these functions, type:

```
methods('DynamicSystem')
```

- Analysis and design tools such as `ltiview`, `sisotool`, and `pidtool`.
- The LTI System block in Simulink models.

## Improved Reliability of Numerical Computations

Algorithm sharing between the System Identification Toolbox and the Control System Toolbox products increase the accuracy and consistency of results for various operations. Operations affected include frequency-response and pole-zero computation, model conversion, settling-time deduction, and model discretization (`c2d` and `d2c`).

The handling of parameter covariance for over-parameterized systems has also improved. You can now fetch parameter covariance data in a factored form for over-parameterized systems, where the raw covariance matrix is ill-defined.

## Estimating Functions and Estimation Option Sets

You can use the new estimating functions `tfest`, `ssest`, `procest`, `greyest`, `polyest`, and `impulseeest` to estimate various model types. The new functions are based on the prediction error method, PEM.

Also, you can now configure model estimation objective functions and search schemes using dedicated option sets. To create and configure the option set for a model estimating function, use the corresponding option set function:

<b>Model Estimating Function</b>	<b>Options Set Function</b>	<b>Estimated Linear Model Type</b>
ar	arOptions	idpoly (AR structure polynomial)
armax	armaxOptions	idpoly (ARMAX structure polynomial)
arx	arxOptions	idpoly (ARX structure polynomial)
bj	bjOptions	idpoly (Box-Jenkins polynomial)
greyest	greyestOptions	idgrey
iv4	iv4Options	idpoly
n4sid	n4sidOptions	idss
oe	oeOptions	idpoly (Output-error polynomial)
polyest	polyestOptions	idpoly
procest	procestOptions	idproc
ssest	ssestOptions	idss
tfest	tfestOptions	idtf

For more information regarding these functions, enter `doc function_name` at the MATLAB command prompt.

## Compatibility Considerations

The option sets replace the Algorithm model property.

The Algorithm property is no longer supported. The fields of Algorithm map to estimation options as follows:

<b>Algorithm Property Field</b>	<b>Options Set Field</b>
LimitError	Advanced.ErrorThreshold
Advanced.Threshold.Zstability	Advanced.StabilityThreshold.z

<b>Algorithm Property Field</b>	<b>Options Set Field</b>
Advanced.Threshold.Sstability	Advanced.StabilityThreshold.s
Advanced.Threshold.AutoInitThreshold	Advanced.AutoInitThreshold
Criterion/Weighting	OutputWeight <ul style="list-style-type: none"> <li>• If, Algorithm.Criterion was 'det', use OutputWeight = 'noise'.</li> <li>• If, Algorithm.Criterion was 'trace', use OutputWeight = Algorithm.Weighting.</li> </ul>
FixedParameter	No replacement. Use the Structure property of the identified linear model to designate its fixed parameters.
MaxIter	SearchOption.MaxIter
Tolerance	SearchOption.Tolerance
MaxSize	Advanced.MaxSize
Advanced.Search	SearchMethod and SearchOptions. These fields are available for only iterative estimation methods, such as tfestOptions.

## Model Analysis and Validation Option Sets

You can now use option sets to configure the various attributes of model simulation and prediction commands. The option sets configure, among other things, how the initial conditions and data offsets are handled. They replace the property-value pairs used by the analysis commands as input arguments. To create and configure the option set for an analysis or validation function, use the corresponding option set creating function:

<b>Analysis/Validation Function</b>	<b>Options Set Function</b>
predict	predictOptions
compare	compareOptions
sim	simOptions

<b>Analysis/Validation Function</b>	<b>Options Set Function</b>
simstd	simstdOptions
forecast	forecastOptions
findstates	findstatesOptions
pe	peOptions

For more information regarding these functions, enter `doc function_name` at the MATLAB command prompt.

## Compatibility Considerations

**Specifying Initial Conditions and Noise Data** To specify the initial conditions and noise specifications for `sim` or `simstd`, use the corresponding option set with the `InitialCondition`, `AddNoise`, and `NoiseData` options set appropriately. In previous releases, you could use name and value pair input arguments to specify these options.

## Identified Linear Models

### Support for Constraining and Fixing Parameters in All Identified Linear Models

You can now specify minimum/maximum bounds for, and fix or free for estimation, any parameter of an identified linear model. You use the new model property, `Structure`, to access a parameter and configure it.

### Support for Model Arrays

You can now create arrays of identified linear models to analyze multiple models simultaneously. You can create an array using array subassignment. For example, `sys(:, :, k) = new sys;`

You can also use the `stack` function to create an identified linear model array. For more information, see `stack`.

You can also use the new function, `rsample`, to create an array of models that sample an identified linear model within the uncertainty limits of its parameters. For more information see `rsample`.

### **Estimation Report**

You can use the new `Report` property of identified linear models for information regarding the estimation performed to obtain the model.

For more information, see “Reorganization of Estimation Reports” on page 41.

### **Convert Time-Series Model to Input-Output Model for Analysis**

Use the new function, `noise2meas`, to convert a time-series model, which has no measured inputs, to an input-output model for linear analysis. `noise2meas` complements the functionality of `noisecnv`, which converts an identified model with noise channels to a model with only measured inputs.

For more information, see `noise2meas`.

### **Specify Input/Output Pairs Using Subsystems**

You can now specify subsystems as input/output models for all identified linear models, except `idgrey` models.

For example, `sys(i,j) = sys0;`

### **Group Inputs and Outputs**

You can now group inputs and outputs for identified linear models using the `InputGroup` and `OutputGroup` properties, respectively.

For more information regarding specifying input groups, enter `help idlti.InputGroup` at the MATLAB command prompt.

For more information regarding specifying output groups, enter `help idlti.OutputGroup` at the MATLAB command prompt.

## Model Parameter Interaction

New commands for interacting with the parameters of identified linear models include:

- `getpvec` — Fetch the model parameters.
- `setpvec` — Set the model parameters.
- `getcov` — Fetch the parameter covariance matrix.
- `setcov` — Set the parameter covariance matrix.
- `nparams` — Fetch number of model parameters.

For more information regarding these functions, enter `doc function_name` at the MATLAB command prompt.

## Random Sampling

The new `rsample` function creates a set of perturbed systems corresponding to an identified linear model. Use this random sampling of an identified linear model for Monte-Carlo analysis.

For more information see `rsample`.

## Compatibility Considerations

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflows may not be supported in the future.

The following table lists affected model properties:

<b>Property</b>	<b>Model Types Affected</b>	<b>What Happens in R2012a</b>	<b>Use This Instead</b>
ParameterVector	idss, idpoly, idgrey, and idproc	Still available.	Use the new function <code>getpvec</code> to access model parameters. The list of parameters obtained from <code>ParameterVector</code> may differ from the list of parameters returned by <code>getpvec</code> .
PName	idss, idpoly, idgrey, and idproc	Still available.	Each identified linear model now has a <code>Structure</code> property, which consists of the parameters relevant to the model. Each of the parameters has an <code>Info</code> field, which may be used to store information regarding the parameter. To store the parameter name, use <code>Info.Label</code> .
Algorithm	idss, idpoly, idgrey, and idproc	Still available.	See “Estimating Functions and Estimation Option Sets” on

page 26.



Property	Model Types Affected	What Happens in R2012a	Use This Instead
CovarianceMatrix	idss, idpoly, idgrey, and idproc	Still available.	Use the new functions, <code>getcov</code> and <code>setcov</code> , to interact with the covariance matrix of the model. Also, after a model, <code>sys</code> , is estimated, you may access the estimated covariance matrix using <code>sys.Report.Parameters</code> .
	All identified linear models.	<p><b>Backward incompatibility.</b> Parameter covariance is no longer translated for the following operations with identified linear models:</p> <ul style="list-style-type: none"> <li>• Model discretization</li> <li>• Model conversion</li> <li>• Model concatenation</li> </ul>	N/A

Property	Model Types Affected	What Happens in R2012a	Use This Instead
EstimationInfo	idss, idpoly, idgrey, and idproc	Still available.	Replaced by the new model property, Report. For more information, see “Reorganization of Estimation Reports” on page 41.
InputName, OutputName	All identified linear models.	<p><b>Backward incompatibility.</b> By default, the input/output channel names are set to ''.</p> <p>In previous releases, the default channel names were set to {'u1', ...} and {'y1', ...} for input and output channels, respectively.</p> <p>When an identified linear model is estimated using an iddata object, it will inherit the input/output channels names from the iddata object.</p>	N/A

Property	Model Types Affected	What Happens in R2012a	Use This Instead
TimeUnit	All identified models.	You can now specify the TimeUnit as only one of the supported units. Supported units include: 'nanoseconds', 'microseconds', 'milliseconds', 'seconds', 'minutes', 'hours', 'days', 'weeks', 'months', and 'years'.	N/A
Ts	idss and idpoly	<b>Backward incompatibility.</b> For discrete-time models, default is $T_s = -1$ , which indicates an unspecified sample time. In previous releases, the default value of $T_s$ was 1.	N/A

### Noise Channel Treatment When Converting Identified Linear Model to Numeric LTI Model

**Backward incompatibility.** You can convert an identified linear model to a numeric LTI model for use in Control System Toolbox. When you do so, the model returned contains only the measured components of the original

model. In previous releases, the noise channels of the original model were also returned as extra inputs of the resulting model.

For example, consider the following polynomial model:

```
sys = idpoly([1 1],[1 2 3],[1 2])
```

In previous releases, executing `sys_tf = tf(sys)` returned a transfer function model with two inputs. The first input corresponded to the measured component, B/A. The second input corresponded to the noise component, C/A. `size(sys,2)` is 1 but `size(sys_tf,2)` is 2. Thus, `sys` had one input, while `sys_tf` had two inputs.

In this release, `sys_tf = tf(sys)` returns a SISO transfer function with one input. This input corresponds to the measured component, B/A. `sys` and `sys_tf` both have the same number of inputs.

To obtain the noise input channels in addition to the measured inputs, as in previous releases, use the string 'augmented' as an additional input.

```
sys_tf = tf(sys,'augmented');
```

The inputs of `sys_tf` are grouped in the `InputGroup` property. The inputs from the measured dynamics belong to the `Measured` input group, and the noise-related inputs belong to the `Noise` input group.

To obtain a model containing just the noise component of the original model, use the string 'noise' as an additional input:

```
sys_tf = tf(sys,'noise');
```

### **Conversion to Identified Linear Model of Numeric LTI Models Ignores Input Groups**

**Backward incompatibility.** In previous releases, when you converted a numeric LTI model that had an input group named 'noise' into an identified linear model, the corresponding inputs were converted to noise channels in the resulting model. This behavior is no longer supported. You can use the 'split' input argument when you convert a numeric LTI model to an identified model. Using the 'split' input argument results in the last  $N_y$

inputs being treated as noise channels in the identified model. Here,  $N_y$  is the number of outputs.

For example, in previous releases:

```
sys = rss(2,2,5);  
sys.InputGroup = struct('noise',4:5);  
sys_idss = idss(sys);
```

resulted in `sys_idss` having the fourth and fifth inputs of `sys` being treated as noise channels.

In this release, use:

```
sys_idss = idss(sys,'split');
```

As `sys` has two outputs and five inputs, its last two input channels are converted to noise channels in `sys_idss`. `sys_idss` has three measured input channels.

### **Input Channel Referencing for Measured Components**

You can configure an estimated model to be free of the influence of noise by setting the `NoiseVariance` property value to 0. In previous releases, you achieved this result by subreferencing the inputs of the model using the 'measured' string, as in `sys(:, 'measured')`. This type of subreferencing is provided in this release for backward compatibility only and may not be supported in the future.

### **Input Channel Referencing for Noise Components**

You can now extract only the noise components of an identified linear model using the syntax:

```
sys_noise_only = sys(:,[]);
```

Here, the `:` indexes all the outputs and `[]` specifies that none of the measured inputs are extracted. `sys_noise_only` has zero measured inputs and is consequently a noise model.

In previous releases, you achieved this result by subreferencing the inputs of the model using the 'noise' string, as in `sys(:, 'noise')`. This type of subreferencing is provided in this release for backward compatibility only and may not be supported in the future.

### **Model Precedence Rules**

The precedence order among identified linear models is `idfrd > idss > idpoly > idtf > idproc` and `idss > idgrey`.

When you combine a numeric LTI model with an identified model, the resulting model is a numeric LTI model. Interconnecting and combining identified linear models using functions such as `series`, `parallel`, and `feedback`, and performing model addition results in a numeric LTI model. Input-output concatenation and model stacking of identified models returns an identified model object.

### **Simultaneous Model-Type Conversion and Property Value Setting**

Model conversion functions will not support setting model property values in the future.

Replace calls such as:

```
sys_idfrd = idfrd(sys,w, 'InputName', 'u1', 'InputDelay', 3);
```

With:

```
sys_idfrd = idfrd(sys,w);  
set(sys_idfrd, 'InputName', 'u1', 'InputDelay', 3);
```

### **Replace `inpd2nk` with `absorbDelay`**

The `inpd2nk` is now obsolete. Use `absorbDelay` instead to absorb all time delays of a dynamic system model into the system dynamics or the frequency response data. In this release, calling `inpd2nk` results in the toolbox making an internal call to `absorbDelay`.

For more information, see `absorbDelay`.

## System Identification Tool GUI

### Transfer Function Models

You can now estimate transfer functions using the System Identification Tool GUI.

To open the Transfer Function dialog box:

- 1 Import a data set into the System Identification Tool GUI.
- 2 In the **Estimate** list, select **Transfer Function Models**.

For more information regarding transfer function estimation, open the Transfer Function dialog box, and click **Help**.

### Process Models

You can now estimate multi-output process models using the System Identification Tool GUI.

To open the Process Models dialog box:

- 1 Import a data set into the System Identification Tool GUI.
- 2 In the **Estimate** list, select **Process Models**.

For more information regarding process model estimation, open the Process Model dialog box and click **Help**.

### State-Space Models

You can now use the System Identification Tool GUI for these operations:

- Estimate continuous-time state-space models.
- Specify the parameterization form, such as canonical or modal.
- Specify feedthrough, which determines whether the D matrix of the state-space model is treated as free estimation parameter or fixed to zero.
- Specify input delay.

To open the Polynomial and State Space Models dialog box:

- 1 Import a data set into the System Identification Tool GUI.
- 2 In the **Estimate** list, select **State Space Models**.

For more information regarding state-space estimation, open the Polynomial and State Space Models dialog box and click **Help**.

### **Polynomial Models**

You can now specify noise integration and input delays when estimating polynomial models using the System Identification Tool GUI.

You can also estimate multi-output polynomial models by specifying the appropriate model order.

To open the Polynomial and State Space Models dialog box:

- 1 Import a data set into the System Identification Tool GUI.
- 2 In the **Estimate** list, select **Polynomial Models**.

For more information regarding polynomial estimation, open the Polynomial and State Space Models dialog box and click **Help**.

**Compatibility Consideration:** You no longer select **Linear parameteric models** to open the Polynomial and State Space Models dialog box.

## **Changes Introduced in This Version**

### **Compatibility Considerations: Yes**

Changes introduced in this version:

- “Reorganization of Estimation Reports” on page 41
- “Polynomial Models” on page 42
- “State-Space Models” on page 48
- “Process Models” on page 52



- “Linear Grey-Box Models” on page 57
- “Identified Frequency-Response Data Models” on page 61
- “Identification Data Objects” on page 62
- “Analysis Commands” on page 63
- “Other Functionality Being Removed or Changed” on page 73

## Reorganization of Estimation Reports

A new property of identified linear models, `Report`, provides information regarding the performed estimation. This property replaces the `EstimationInfo` property and provides additional information regarding:

- All estimated quantities — Parameter values and covariance, initiate state values for state-space models and values of input levels for process models.
- The option set used for estimation.
- Additional fit criteria — Percentage fit to estimation data and the mean square error.

The `Report` field is mostly uniform for the various identified linear models. However, certain fields of `Report` are model dependent.

To access the `Report` property of an identified linear model, `sys`, use `sys.Report`.

## Compatibility Considerations

`Report` replaces the `EstimationInfo` property. The fields of `EstimationInfo` map to those of `Report` as:

<b>EstimationInfo Field</b>	<b>Report Field</b>
<code>LossFcn</code>	<code>Fit.LossFcn</code>
<code>FPE</code>	<code>Fit.FPE</code>
<code>DataName</code>	<code>DataUsed.Name</code>
<code>DataLength</code>	<code>DataUsed.Length</code>

<b>EstimationInfo Field</b>	<b>Report Field</b>
DataTs	DataUsed.Ts
DataDomain	DataUsed.Type
DataInterSample	DataUsed.InterSample
WhyStop	Termination.WhyStop Termination information is not provided for models estimated using a noniterative estimation function, such as arx or n4sid.
UpdateNorm	Termination.UpdateNorm Termination information is not provided for models estimated using a noniterative estimation function, such as arx or n4sid.
LastImprovement	Termination.LastImprovement Termination information is not provided for models estimated using a noniterative estimation function, such as arx or n4sid.
Iterations	Termination.Iterations Termination information is not provided for models estimated using a non-iterative estimation function, such as arx or n4sid.
InitialState	Either: <ul style="list-style-type: none"> <li>• InitialState (state-space models)</li> <li>• InitialCondition (other identified linear models)</li> </ul>
Warning	No replacement.

## Polynomial Models

### Polynomial Model Estimators

Use the new function, `polyest`, to estimate a polynomial model containing an arbitrary subset of A, B, C, D, and F polynomials.

For more information, see `polyest` and `polyestOptions`.

Also, the functions `ar`, `arx`, `bj`, `oe`, and `armax` now support multi-output polynomial estimation.

### **Integration on Noise Models (ARIMA models)**

You can now introduce integrators in the dynamics of the disturbances added to the output of the model.

For more information, see “Generating ARIMA Models” on page 24.

### **idarx Models No Longer Returned in Multi-Output Model Estimation**

`idarx` models are no longer returned when you use estimating functions for multi-output ARX models. Support for `idarx` models may not be provided in the future. Use `idpoly` models to estimate and represent multi-output ARX models instead.

**Compatibility Consideration: Backward incompatibility.** `arx`, `iv4`, and `ivx` now return `idpoly` models for multi-output estimation. In previous releases, they returned `idarx` models.

To convert an existing `idarx` model, `sys_idarx`, to an `idpoly` model, use `idpoly(sys_idarx)`.

Similarly, to convert an existing `idpoly` model, `sys_idpoly`, to an `idarx` model, use `idarx(sys_idpoly)`.

### **Specify Transport Delays**

Use the new `idpoly` property, `ioDelay` to specify the transport delays for individual input/output pairs.

You can use `ioDelay` as an alternative to the `nk` order when estimating polynomial models. Using `ioDelay` reduces the complexity of the model by factoring out the leading zeros of the `B` polynomials, controlled by `nk`.

For example:

```
load iddata1 z1
load iddata2 z2
```

```

data = [z1 z2(1:300)];
na = [2 3; 1 2];
nb = [1 2; 2 2];
nk = [2 1; 7 0];
sys1 = arx(data,[na nb nk]);
sys2 = arx(data,[na nb zeros(2)],'ioDelay',nk);

```

In this case, `sys1` and `sys2` are equivalent, but `sys2.b` shows fewer terms in each B polynomial than `sys1.b`.

For more information, see `idpoly`.

### Specify Display Variable

You can now specify the variable used to display model equations for `idpoly` models. Use the new model property, `Variable`. For continuous-time models, specify either 's' or 'p' as the variable. For discrete-time models, use either 'z<sup>-1</sup>' or 'q<sup>-1</sup>' as the lag variable.

For more information, see `idpoly`.

### Multi-Output Weighting Using `arx`

For estimating multi-output ARX models, use the `OutputWeight` estimation option to specify the output weighting. You create the option set for ARX model estimation using `arxOptions`. In previous releases, to do so you specified a `NoiseVariance` name-value pair for `arx`.

`arx` uses the following syntaxes for assigning output weight:

Syntax	Output Weight Value
<code>arx(data,[na,bk,nk])</code>	<code>eye(Ny)</code> , where <code>Ny</code> is the number of outputs
<code>arx(data,[na nb nk],opt)</code> , where <code>opt</code> is an option set created using <code>arxOptions</code>	<code>opt.OutputWeightIf</code> <code>opt.OutputWeight = []</code> , then <code>eye(Ny)</code> .

Syntax	Output Weight Value
<code>arx(data,init_model)</code> , where <code>init_model</code> is an estimation initialization model	<code>init_model.NoiseVariance</code>
<code>arx(data,init_model,opt)</code>	<code>opt.OutputWeightIf</code> <code>opt.OutputWeight = []</code> , then <code>init_model.NoiseVariance</code> .

## Polynomial Structure

The new `Structure` property of `idpoly` models stores the adjustable parameters, which include:

- The active polynomials

For example, consider the ARX model:

```
A = [1 2 1];
B = [0 3 4];
sys = idpoly(A,B);
```

`sys.Structure` lists the polynomials A and B as parameters. You can specify nominal values and constraints for these parameters.

`sys.Structure` does not list the C, D, and F polynomials.

- The transport delays and integrate noise flag

You can set these delays and the flag for models of any polynomial configuration.

You interact with the `Structure` property to specify constraints (such as maximum/minimum bounds) for the various parameters. To change only the values of the polynomials or the transport delays, use the relevant `idpoly` model property, viz `a`, `b`, `c`, `d`, `f`, `ioDelay`, and `IntegrateNoise`.

For more information, see `idpoly`.

## Compatibility Considerations

The recommended usage and workflow has changed for some model parameters and functionality. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected functionality:

Functionality	What Happens in R2012a	Use This Instead
Model properties that store the polynomial order — <code>na</code> , <code>nb</code> , <code>nc</code> , <code>nd</code> , <code>nf</code> , and <code>nk</code>	You may still modify the value of these properties as long as their sizes are compatibility with the input/output sizes. The estimation commands for polynomial models will continue to support the specification of “in-model” delays using <code>nk</code> .	Use <code>idpoly</code> to create a new model of desired orders. Use <code>ioDelay</code> and <code>InputDelay</code> to specify delays separate from the B polynomial.
Model properties that store standard deviation information — <code>da</code> , <code>db</code> , <code>dc</code> , <code>dd</code> , and <code>df</code>	You may still access these model properties using dot notation. For example, <code>sys.da</code> .	Use the functions <code>getpvec</code> and <code>polydata</code> to access parameters and their standard deviations.
Treatment of the leading zeros of the B polynomials	If you have a discrete-time <code>idpoly</code> model that has <code>nk</code> leading zeros, then <code>nk-1</code> of them are treated as delays. When you convert such a model into another linear model, these delays are set to the appropriate delay related property. For example,  <pre>sys = idpoly([1 2],... [0 0 0 4]); % nk = 3 sys2 = tf(sys);</pre>	N/A

Functionality	What Happens in R2012a	Use This Instead
	The <code>ioDelay</code> property of <code>sys2</code> is 2, and the numerator is <code>{[0 4]}</code> .	
Model property — <code>InitialState</code>	Still works.	Use the option, <code>InitialCondition</code> , when creating the relevant option set for estimation, prediction, simulation, and comparison.
Storage of the <code>B</code> and <code>F</code> polynomials	For multi-input models, the <code>b</code> and <code>f</code> properties are no longer saved as a matrix of doubles. These properties will now be saved using cell arrays. To continue storing these properties as a matrix of doubles, use <code>setPolyFormat</code>	N/A
Treatment of the trailing zeros of the <code>B</code> and <code>F</code> polynomials	Trailing zeros in the <code>B</code> and <code>F</code> polynomials of a discrete-time <code>idpoly</code> model are not discarded. For example, in previous releases:  <pre>sys = idpoly([1 2],... [2 4 0 0 0]);</pre> resulted in <code>[2 4]</code> as the <code>B</code> polynomial for <code>sys</code> . Now, the same code gives <code>[2 4 0 0 0]</code> as the <code>B</code> polynomial for <code>sys</code> . Similar considerations apply to leading zeros of <code>B</code> , <code>F</code> polynomials of a continuous-time model.	N/A

## State-Space Models

### State-Space Model Estimator

The new function, `ssest`, can be used to estimate a discrete-time or continuous-time identified state-space model. You can use time-domain or frequency-domain data with `ssest` and perform both structured and unstructured model estimation. You can also choose a canonical form of the identified state-space model.

To configure the handling of initial conditions and other initialization choices, data offsets and search algorithm, use the associated option command, `ssestOptions`.

For more information, see `ssest` and `ssestOptions`.

For a structured state-space model, which is an `idss` model with finite parameters, you can use either `pem` or `ssest` to update the values of those parameters for measured input-output data.

### n4sid Supports Canonical Forms

The subspace estimator function, `n4sid`, now supports new parameterization options, such as modal and companion canonical forms and the presence of feedthrough.

To configure the handling of initial conditions and other initialization choices and data offsets, use the associated option command, `n4sidOptions`.

For more information, see `n4sid` and `n4sidOptions`.

### State-Space Structure

The new `Structure` property of `idss` models stores the adjustable parameters, which include the `a`, `b`, `c`, `d` and `k` matrices.

You interact with the `Structure` property to specify constraints (such as maximum/minimum bounds) for the various parameters. To only change the values of the matrices, use the relevant `idss` model property, viz `a`, `b`, `c`, `d`, and `k`.



For more information, see `idss`.

## Compatibility Considerations

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected model properties:

Model Property	What Happens in R2012a	Use This Instead
X0, InitialState	Still available.	Use the <code>InitialState</code> option for estimation and the <code>InitialCondition</code> option for prediction, simulation, and comparison. For example, replace: <pre>sys = n4sid(data,2,... 'InitialState','estimate');</pre> with: <pre>opt = n4sidOptions(... 'InitialState','estimate');</pre> <code>sys = n4sid(data,2,opt);</code>
As, Bs, Cs, Ds, Ks, and X0s	Still available.	Use the <code>Structure</code> property to specify constraints (such as maximum/minimum bounds) for A, B, C, D, and K. Use the <code>InitialState</code> estimation option to specify constraints on the initial state vector. For example, instead of: <pre>sys = idss(A,B,C,D,K); sys.X0s = [nan;1]</pre>

Model Property	What Happens in R2012a	Use This Instead
		<pre>syse = pem(data, sys);</pre> <p>Use:</p> <pre>opt = ssestOptions; X0 = idpar([nan; 1]); X0.Free(2) = false; opt.InitialState = X0; sys = idss(A,B,C,D,K); syse = ssest(data, sys, opt);</pre>
da, db, dc, dd, and dk	Still available.	Use the new function <code>idssdata</code> to obtain the state-space matrix standard deviations.
nk	<p>Still available but <b>may cause a backward incompatibility</b>. If you previously specified both <code>nk</code> and <code>InputDelay</code>, you could see different results in this release.</p> <p>For example,</p> <pre>load iddata1 z1; sys = pem(z1,4,... 'nk',5,'InputDelay,2);</pre> <p>In this release, <code>sys.nk</code> is 3, whereas <code>sys.nk</code> was 5 in earlier releases.</p>	<p>For estimation, use the <code>InputDelay</code> and <code>Feedthrough</code> estimation properties instead. When creating an <code>idss</code> model, specify the <code>InputDelay</code> and <code>Structure.d</code> properties. <code>nk</code>, <code>InputDelay</code>, and <code>Feedthrough</code> are related:</p> <ul style="list-style-type: none"> <li>• <code>nk(j) = 0</code> means that the model has no delay for the <math>j^{\text{th}}</math> input. Therefore, <code>InputDelay</code> is 0, and <code>Structure.d.Free(:,j)</code> is true.</li> <li>• <code>nk(j) = 1</code> means that the model has zero delay for the <math>j^{\text{th}}</math> input. Therefore, <code>InputDelay</code> is 0, and there is no feedthrough. <code>Structure.d.Free(:,j)</code> is false, and <code>Structure.d.Value(:,j)</code> is zero.</li> </ul>

Model Property	What Happens in R2012a	Use This Instead
		<ul style="list-style-type: none"> <li>• <math>nk(j) = N</math>, <math>N &gt; 1</math> means that the model has nonzero delay for the <math>j^{\text{th}}</math> input. Therefore, <code>InputDelay</code> is <math>N-1</math>, and there is no feedthrough. <code>Structure.d.Free(:,j)</code> is false, and <code>Structure.d.Value(:,j)</code> is 0.</li> </ul> <p><math>nk &gt; 1</math> can only be used for a discrete-time model.</p>
SSParameterization	Still available. However, when you use <code>get</code> to obtain the value of <code>SSParameterization</code> , the software may report a canonical form as the structured form.	<ul style="list-style-type: none"> <li>• Use the 'form'/value name-value pair when estimating using either <code>n4sid</code> or <code>ssest</code> to specify the form of the estimated model.</li> <li>• To change the structure of an existing model, use one of these methods: <ul style="list-style-type: none"> <li>▪ Change each matrix individually using the <code>Structure</code> property.</li> <li>▪ Use <code>canon</code> to specify a canonical form.</li> <li>▪ Use <code>ss2ss</code> and specify a transformation matrix.</li> </ul> </li> </ul> <hr/> <p><b>Note</b> Parameter covariance is not translated in these operations.</p> <hr/>

<b>Model Property</b>	<b>What Happens in R2012a</b>	<b>Use This Instead</b>
DisturbanceModel	Still available.	For estimation, specify DisturbanceModel as an option for estimation. For changing the model structure, for its disturbance component, use Structure.k.Value and Structure.k.Free instead. For example, DisturbanceModel = 'none' corresponds to setting model.Structure.k.Value to zeros and model.Structure.k.Free to false.
CanonicalIndices	Still available if the model is in canonical form.	Use canon and ss2ss to change the state-space form.

## Process Models

### Process Model Estimator

The new function, `procest`, lets you estimate process models using time-domain or frequency-domain data. You can also specify the handling of input offsets and disturbances using an option set for this function using `procestOptions`.

For more information, see `procest` and `procestOptions`.

### Multi-Output Support

You can now create and estimate multi-output process models.

For more information, see “Multi-Output Process Models” on page 25

## Noise Transfer Function

Use the new property `NoiseTF` of `idproc` models to specify the value of the noise transfer function in numerical form. `NoiseTF` is a structure with the fields `num` (numerator) and `den` (denominator) representing the noise-transfer function. This property replaces the `DisturbanceModel` property.

## Input Delay

The `InputDelay` property of `idproc` model represents input delays and is now independent of the `Td` property.

The `Td` property represents the transport delay, which is thus similar to the `ioDelay` property of `idpoly` and `idtf` models.

For more information, see `idproc`.

## Process Model Structure

The `Structure` property of `idproc` models houses active parameters. These parameters are a subset of `Kp`, `Tp1`, `Tp2`, `Tp3`, `Tw`, `Zeta`, `Td`, and `Tz`, depending on the `Type` option used to create the model. `Structure` also contains the `Integration` property whose value determines if the model structure contains an integrator.

You use the `Structure` property to specify constraints (such as maximum/minimum bounds) for the various active parameters.

`Structure` is an  $N_y$ -by- $N_u$  array, where  $N_y$  is the number of outputs and  $N_u$  is the number of inputs. The array specifies a transfer function for each input/output pair.

For example:

```
sys = idproc({'p2u' 'p0' 'p3zi'; 'p1' 'p2d' 'p2uz'});
```

In this case, `sys.Structure` is a 2-by-3 array. `sys.Structure(1,1).Zeta` is a parameter, while `sys.Structure(1,2)` does not have a `Zeta` field, as this parameter is inactive for the (1,2) output-input pair.

To change the list of active parameters, you must create a new model. However, you may change the `Integration` property at any time.

## Lower Bound on Time Constants

The minimum value permitted for the time constants of an `idproc` model, `Tp1`, `Tp2`, `Tp3`, `Tw`, and `Zeta` is now 0. In previous releases, you could not specify for these constraints a value smaller than 0.001. For well-conditioned estimations, it is still recommended that you specify reasonable upper and lower bounds around the time-constant values.

## Compatibility Considerations

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected model properties:

Model Property	What Happens in R2012a	Use This Instead
<code>InputLevel</code>	Still available.	Use the <code>InputOffset</code> option for estimation using <code>procestOptions</code> . For advanced control, you can specify the <code>InputOffset</code> option as <code>'estimate'</code> or a <code>param.Continuous</code> object.
<code>InitialState</code>	Still available.	Use the <code>InitialCondition</code> option for estimation, prediction, simulation and comparison. For example, replace:  <pre>sys = pem(data,'pid',... 'InitialState','estimate');</pre> with:  <pre>opt = procestOptions(... 'InitialCondition','estimate');</pre>

Model Property	What Happens in R2012a	Use This Instead
DisturbanceModel	Still available.	<pre>sys = procest(data,... 'p1d',opt);</pre> <p>The <code>DisturbanceModel</code> property of <code>idproc</code> models in previous releases represented both the estimation flag and as the actual value of the noise transfer function. The <code>DisturbanceModel</code> property has now been replaced by:</p> <ul style="list-style-type: none"> <li>• The <code>NoiseTF</code> property, which represents the value of the noise transfer function.</li> <li>• The <code>DisturbanceModel</code> estimation option, which is contained in the <code>procestOptions</code> option set. This option stores the flag, which determines how the noise transfer function is estimated.</li> </ul> <p>For example, replace:</p> <pre>load iddata1 z1; sys = pem(z1,'p1d',... 'DisturbanceModel','arma1'); NoiseTF = sys.DisturbanceModel{2};</pre> <p>with:</p> <pre>load iddata1 z1; opt = procestOptions(... 'DisturbanceModel','arma1'); sys = pem(z1,'p1d',opt); NoiseTF = sys.NoiseTF;</pre>

Model Property	What Happens in R2012a	Use This Instead
		For more information, see <code>procestOptions</code> .
X0	Still available.	There is no replacement for this model property as <code>idproc</code> is not a state-space model. Continuing to use X0 may produce bad results.
Kp, Tp1, Tp2, Tp3, Tw, Zeta, Td, and Tz	<p><b>Backward incompatibility.</b> These properties are now saved as double matrices. In previous releases, they were stored as structures.</p> <p>Assigning the value of these parameters to structures will continue to work:</p> <pre>model = idproc('p1','Tp1',1,'Kp',2) model.Tp1.value = 5;</pre> <p>In previous releases, you could obtain the value of a parameter as a structure and access its fields. Now, you will receive an error.</p> <pre>model = idproc('p1','Tp1',1,'Kp',2) Tp1 = model.Tp1; Tp1.status % throws error</pre> <p>However, subreferencing for a field of the old parameter structure will continue to work:</p> <pre>model = idproc('p1','Tp1',1,'Kp',2) model.Tp1.status</pre>	Use the <code>Structure</code> property to specify parameter constraints. <code>Structure</code> replaces the specification of process model parameter bounds. See Call Replacements on page 57.



Model Property	What Happens in R2012a	Use This Instead
	% returns {'estimate'}	

## Call Replacements

Replace a Call Like...	With...
<code>model.Tp1.status = {'estimate'}</code>	<code>model.Structure.Tp1.Free = true;</code>
<code>model.Tp1.status = {'zero'}</code>	<code>model.Structure.Tp1.Free = false;</code> <code>model.Structure.Tp1.Value = 0;</code>
<code>model.Tp1.status = {'fixed'}</code>	<code>model.Structure.Tp1.Free = false;</code>
<code>model.Tp1.min = value</code>	<code>model.Structure.Tp1.Minimum = value</code>
<code>model.Tp1.max = value</code>	<code>model.Structure.Tp1.Maximum = value</code>
<code>model.Tp1.value = value</code>	<code>model.Structure.Tp1.Value = value</code>
For multi-input models: <code>model.Tp1.status{2} = 'estimate'</code>	<code>model.Structure(1,2).Tp1.Free = true;</code>
For multi-input models: <code>model.Tp1.value(2) = value</code>	<code>model.Structure(1,2).Tp1.Value = value</code>

## Linear Grey-Box Models

### Linear Grey-Box Model Estimator

The new function `greyest` lets you estimate the parameters of a linear grey-box model. You can specify an option set for the estimation by using the function, `greyestOptions`.

For more information, see `greyest` and `greyestOptions`.

### **Complex Parameters Support**

You can now parameterize a real system using complex-conjugate pairs of parameters in an `idgrey` model.

When the parameters of such a system are estimated, they continue to be complex conjugates. Thus, symmetry is maintained across the real axis.

For more information, see the related example in the `greyest` reference page.

### **ODE file API**

You can now specify an arbitrary number of parameters as independent input arguments to the ODE file. In previous releases, the parameters of the model had to be consolidated into a single vector that was then passed as the first input argument of the ODE file. Now, you can pass independent parameters as separate input arguments. The same holds true for the optional input arguments.

Old syntax:

```
ODEFUN(ParameterVector, Ts, OptionalArg)
```

New syntax:

```
ODEFUN(Par1, Par2, ..., ParN, Ts, OptArg1, OptArg2, ...)
```

If all the model parameters are scalars, you can still combine them into a single vector and pass them as a single input argument to the ODE file.

Also, specifying the value for the output arguments `K` and `X0` is now optional. In earlier releases, you were required to set a value for `K` and `X0` even if you did not want to parameterize them. Now, you can omit them entirely from the output argument list. For more information, see `idgrey`.

### **Linear Grey-Box Model Structure**

The `Structure` property of the `idgrey` model stores information on the ODE function and its parameters. `Structure` contains the following properties:

Property	Role
FcnType	<p>The sample time handling behavior of the linear ODE model. FcnType specifies whether the ODE file returns state-space data that corresponds to one of the following:</p> <ul style="list-style-type: none"> <li>• 'c' — A continuous-time model.</li> <li>• 'd' — A discrete-time model.</li> <li>• 'cd' — A continuous-time model if the sample time is 0 and a discrete-time model if the sample time greater than 0.</li> </ul> <p><b>Compatibility Consideration:</b> Use instead of the CDMfile property.</p>
Function	<p>Name or function handle to the MATLAB function that parameterizes the state-space structure.<b>Compatibility Consideration:</b> Use instead of the MfileName property.</p>
Parameters	<p>Vector of parameter objects, with an entry for each model parameter. Use the parameter object to specify initial values and minimum/maximum constraints. You can also indicate whether the parameter is a free- or fixed- estimation parameter.</p>
ExtraArgs	<p>Option input arguments used by the ODE file to compute the state-space data.<b>Compatibility Consideration:</b> Use instead of the FileArgument property.</p>
StateName	<p>Model state names.</p>
StateUnit	<p>Model state units.</p>

## Compatibility Considerations

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected model properties:

<b>Model Property</b>	<b>What Happens in R2012a</b>	<b>Use This Instead</b>
MfileName	Still available.	Use the <code>Structure.Function</code> property to specify the ODE function name or function handle instead.
X0	Still available.	Use the <code>InitialState</code> option when you create an estimation option set using <code>greyestOptions</code> .
dA, dB, dC, dD, dK and dX0	Still available.	Use the functions <code>getpvec</code> and <code>idssdata</code> to access parameters and their standard deviations.
FileArgument	Still available.	Use the <code>Structure.ExtraArgs</code> property to specify the additional ODE function arguments.

<b>Model Property</b>	<b>What Happens in R2012a</b>	<b>Use This Instead</b>
CDmfile	Still available.	Use the <code>Structure.FcnType</code> property to specify sample time handling behavior.
InitialState	Still available.	Use the <code>InitialState</code> option for estimation and the <code>InitialCondition</code> option for prediction, simulation and comparison.
DisturbanceModel	Still available.	Use the <code>DisturbanceModel</code> estimation option in the option set created using <code>greyestOptions</code> .

## Identified Frequency-Response Data Models

### Specify InterSample Behavior of Inputs

You can use the new `InterSample` property of `idfrd` models to specify the behavior of the input signals between samples for model transformations between discrete-time and continuous-time. This property is relevant only for discrete-time `idfrd` models.

For more information, see the `InterSample` property information in `idfrd`.

### Frequency Unit

Use the new property `FrequencyUnit` of `idfrd` models to specify the units for frequency-domain data.

For a list of the supported units for `FrequencyUnit`, see `idfrd`.

**Compatibility Consideration:** The `FrequencyUnit` property replaces the `Unit` property.

## Compatibility Considerations

**Input Delay Treatment (Backward incompatibility.)** When you convert an identified model into an `idfrd` model, its `InputDelay` and `ioDelay` properties are translated into the corresponding properties of the `idfrd` model. In previous releases, the delays were absorbed into the `ResponseData` property as additional phase lag.

The `OutputDelay` property of an identified model is converted to the `ioDelay` property of an `idfrd` model.

## Identification Data Objects

### Frequency-Domain Data Units

Use the new property `FrequencyUnit` of `iddata` objects to specify the units for frequency-domain data.

For a list of the supported units for `FrequencyUnit`, see `iddata`.

**Compatibility Consideration:** The `FrequencyUnit` property replaces the `Unit` property.

### Impulse and Step Response Plots

Plot the impulse or step response for `iddata` objects by estimating a discrete-time transfer function model using `impzest`. Use the resulting model as the input argument for `impz` or `step`.

In the previous release, you could plot the step response without first estimating a discrete-time transfer function model:

```
load iddata1 z1;  
step(z1);
```

where `z1` is an `iddata` object.

Now, you must use `impulseest` to estimate a discrete-time transfer function. Then, plot the appropriate response for the model. For example:

```
load iddata1 z1;
sys = impulseest(z1);
step(sys);
```

For more information, see `impulseest`.

**Compatibility Consideration: Backward incompatibility.** To see the step or impulse response for negative time values, use the `noncausal` input argument with `impulseest`. In previous releases, you could call `impulse(data)` to do this.

## Compatibility Considerations

**Supported Units for TimeUnit Property** You can now specify the `TimeUnit` property of an `iddata` object as only one of the supported units. Supported units include: 'nanoseconds', 'microseconds', 'milliseconds', 'seconds', 'minutes', 'hours', 'days', 'weeks', 'months', and 'years'.

## Analysis Commands

Function	What Has Changed in R2012a
predict	<ul style="list-style-type: none"> <li>• <code>predict</code> now returns a data object of the same type as the input data.</li> <li>• You can now specify an infinite prediction horizon with time-series models. When you specify the prediction horizon as <code>Inf</code>, <code>predict</code> returns the initial condition response of the model.</li> <li>• <b>Compatibility Consideration:</b> For a multi-output system, the predictor model is now returned as a dynamic system. In</li> </ul>

Function	What Has Changed in R2012a
	<p>previous releases it was returned as a cell array.</p>
compare	<ul style="list-style-type: none"> <li>• When using FRD validation data, compare plots the magnitude and phase response. The fit percentage shown corresponds to the closeness of the complex frequency response of the system to that of the data (using normalized root mean square, NRMSE).</li> <li>• For complex-valued validation data or model, compare plots the real and imaginary parts on separate axes.</li> <li>• You can now use compare to compare data sets. The data sets may be either <code>iddata</code> or <code>frd</code> objects.</li> <li>• You can interactively change the prediction horizon for time-domain comparison plots. You can also interactively change the initial conditions. Right-click on the plot to select the appropriate option.</li> <li>• You can now compare arrays of systems to a validation data set.</li> <li>• You can now specify the initial conditions and sample range for comparison using the option set created by the new function <code>compareOptions</code>. For more information, see <code>compareOptions</code>.</li> <li>• <b>Compatibility Consideration: Backward incompatibility.</b> The format of the outputs has changed when you call <code>compare</code> using the syntax: <p style="margin-left: 20px;"><code>[yh,fit,x0] = compare(data,...                           sys1,...,sysn,m,options)</code></p> </li> </ul>



Function	What Has Changed in R2012a
	<p>For example, <code>fit</code> is a cell array rather than a 3-d numeric array when comparing responses of multiple systems or when using multi-experiment validation data.</p>
step	<ul style="list-style-type: none"> <li>• You can specify an option set for the generated plot using the function <code>stepDataOptions</code>.</li> <li>• You can customize a step plot by creating a plot using <code>stepplot</code>. Then, to display confidence intervals on the plot programmatically, use <code>showConfidence</code>.</li> <li>• <b>Compatibility Considerations:</b> <ul style="list-style-type: none"> <li>▪ Specify the number of standard deviations for the confidence region using the new <code>ConfidenceRegionNumberSD</code> option in the corresponding option set. In previous releases, you used the 'sd' /N name-value pair to specify the number of standard deviations.</li> <li>▪ <b>Backward incompatibility.</b> Using a 2-element double vector to indicate the plot time range is no longer supported. You can only specify a scalar, the final time, or a vector containing the time instants to be plotted.</li> <li>▪ <b>Backward incompatibility.</b> The third output argument now returns the state trajectory. In previous releases, the third output argument was the response standard deviation, which is now returned as the fourth output argument.</li> </ul> </li> </ul>

Function	What Has Changed in R2012a
impulse	<ul style="list-style-type: none"> <li>• You can specify an option set for the generated plot using the function, <code>timeoptions</code>. For more information, see <code>timeoptions</code>.</li> <li>• You can customize an impulse plot by creating a plot using <code>impulsetplot</code>. Then, to display confidence intervals on the plot programmatically, use <code>showConfidence</code>.</li> <li>• <b>Compatibility Considerations:</b> <ul style="list-style-type: none"> <li>▪ Specify the number of standard deviations for the confidence region using the new <code>ConfidenceRegionNumberSD</code> option in the corresponding option set. In previous releases, you used the 'sd' /N name-value pair to specify the number of standard deviations.</li> <li>▪ <b>Backward incompatibility.</b> Using a 2-element double vector to indicate the plot time range is no longer supported. You can only specify a scalar, the final time, or a vector containing the time instants to be plotted.</li> <li>▪ <b>Backward incompatibility.</b> The third output argument now returns the state trajectory. In previous releases, the third output argument was the response standard deviation, which is now returned as the fourth output argument.</li> </ul> </li> </ul>

Function	What Has Changed in R2012a
bode	<ul style="list-style-type: none"> <li>• To customize a bode plot, use <code>bodeplot</code>. You can specify an option set for the generated plot using the function <code>bodeoptions</code>. For more information, see <code>bodeplot</code> and <code>bodeoptions</code>.  To display confidence intervals on a bode plot programmatically, use <code>showConfidence</code>.</li> <li>• <b>Compatibility Considerations:</b> <ul style="list-style-type: none"> <li>▪ Specify the number of standard deviations for the confidence region using the new <code>ConfidenceRegionNumberSD</code> option in the corresponding option set. In previous releases, you used the 'sd' /N name-value pair to specify the number of standard deviations.</li> <li>▪ The plot input arguments 'fill', 'mode', and 'AP' are no longer supported. Use the plot options, <code>bodeoptions</code>, <code>getoptions</code> and <code>setoptions</code>, instead. Alternatively, you may interactively change these options by right-clicking on the plot and choosing the appropriate options.</li> <li>▪ <b>Backward incompatibility.</b> You can no longer specify the frequency range using <code>w = {wmin, wmax, np}</code>. Instead, use <code>logspace(wmin, wmax, np)</code>.</li> <li>▪ Do not use <code>bode</code> for plotting time-series models. Instead, use the new function <code>spectrum</code>. For more information, see <code>spectrum</code>.</li> </ul> </li> </ul>

Function	What Has Changed in R2012a
pzmap	<p><b>Compatibility Considerations:</b></p> <ul style="list-style-type: none"> <li>• <b>Backward incompatibility.</b> For multi-input, multi-output systems, pzmap now shows the system poles and transmission zeros. In previous releases, pzmap showed the poles and zeros of individual input/output pairs.</li> </ul> <p>To plot the poles and zeros for individual input/output pairs, use iopzmap and iopzplot. For more information, enter help function_name at the MATLAB command prompt.</p> <ul style="list-style-type: none"> <li>• The 'sd/N' name-value input argument for displaying the pole-zero confidence regions is no longer supported. Instead, use iopzmap and its corresponding options set (pzoptions). Use the ConfidenceRegionNumberSD option to specify the standard deviations for the confidence regions. You can also use the showConfidence command to view the confidence regions programmatically.</li> </ul>
nyquist	<ul style="list-style-type: none"> <li>• You can customize a nyquist plot by creating the plot using nyquistplot. Then, to display confidence intervals on the plot programmatically, use showConfidence.</li> <li>• <b>Compatibility Considerations:</b> <ul style="list-style-type: none"> <li>▪ The 'sd/N' name-value input argument for displaying the confidence ellipses is no longer supported. Create an option set using nyquistoptions. Use the ConfidenceRegionNumberSD option to specify the standard deviations for the confidence ellipses. Use the ConfidenceRegionDisplaySpacing</li> </ul> </li> </ul>

Function	What Has Changed in R2012a
	<p>option to specify the spacing of the confidence ellipses. For more information, see <code>nyquistoptions</code>.</p> <ul style="list-style-type: none"> <li>▪ <b>Backward incompatibility.</b> You can no longer obtain the complex frequency response and its uncertainty as the outputs of <code>nyquist</code>. Instead, use <code>freqresp</code> to obtain these values.</li> </ul> <p><code>nyquist</code> now returns the real and imaginary parts of the frequency response and their individual uncertainties. For more information, see <code>nyquist</code>.</p> <ul style="list-style-type: none"> <li>▪ <b>Backward incompatibility.</b> You can no longer specify the frequency range using <code>w = {wmin, wmax, np}</code>. Instead, use <code>logspace(wmin, wmax, np)</code>.</li> <li>▪ The plot input name-value pair <code>'mode' / 'same'</code> is no longer supported. Use the plot options instead (see <code>nyquistoptions</code>, <code>getoptions</code> and <code>setoptions</code>). Alternatively, you may interactively change these options by right-clicking on the plot and choosing the appropriate options.</li> </ul>
c2d	<ul style="list-style-type: none"> <li>• You can now use the conversion methods <code>'tustin'</code>, <code>'matched'</code> and <code>'impulse'</code> without requiring the Control System Toolbox software.</li> <li>• You can specify the conversion method and associated option for <code>c2d</code> using <code>c2dOptions</code>. For more information, see <code>c2dOptions</code>.</li> <li>• <b>Compatibility Considerations:</b> <ul style="list-style-type: none"> <li>▪ Parameter covariance translation is no longer supported by <code>c2d</code>. Therefore,</li> </ul> </li> </ul>

Function	What Has Changed in R2012a
	<p>the 'CovarianceMatrix' - 'none' name-value pair is no longer supported.</p> <ul style="list-style-type: none"> <li>▪ <b>Backward incompatibility.</b> Grey-box models of FcnType 'c' cannot be discretized directly. Instead, convert such models to idss models before using c2d.</li> <li>▪ <b>Backward incompatibility.</b> Process models cannot be discretized directly. You must first convert your process model to an idpoly model or an idtf model and then discretize the new model.</li> </ul>
d2c	<ul style="list-style-type: none"> <li>• You can now use the conversion methods 'tustin' and 'matched' without requiring the Control System Toolbox software.</li> <li>• You can specify the conversion method and associated option for d2c using d2cOptions. For more information, see d2cOptions.</li> <li>• <b>Compatibility Consideration:</b> <ul style="list-style-type: none"> <li>▪ Parameter covariance translation is no longer supported by d2c. Therefore, the 'CovarianceMatrix' - 'none' name-value pair is no longer supported.</li> <li>▪ <b>Backward incompatibility.</b> Grey box models of FcnType 'd' cannot be converted into continuous-time models directly. Instead, convert such models to idss models before using d2c.</li> <li>▪ The input name-value pair 'InputDelay' / 0 are no longer supported. Input delays are now handled uniformly, as described in Continuous-Discrete Conversion Methods.</li> </ul> </li> </ul>

Function	What Has Changed in R2012a
ssdata	<ul style="list-style-type: none"> <li>• Use the new function <code>idssdata</code> to fetch state-space matrices for identified linear models. If <code>idssdata</code> is used for a model other than <code>idss</code> or <code>idgrey</code>, it returns empty matrices for uncertainty outputs.  For more information, see <code>idssdata</code>.</li> <li>• You can still call the <code>ssdata</code> command with six or more output arguments to fetch the state-space matrices and related uncertainty information. However, this syntax of <code>ssdata</code> may be removed in the future and it is recommended to use <code>idssdata</code> instead.</li> <li>• <b>Compatibility Consideration: Backward incompatibility.</b> <code>ssdata</code> now returns the sampling time, <math>T_s</math>, as the fifth output when it is called with five outputs. In previous releases, <code>ssdata</code> returned the disturbance matrix, <math>K</math>, as the fifth output.</li> </ul>
tfdata	<p><b>Compatibility Consideration: Backward incompatibility.</b> <code>tfdata</code> now returns the sampling time, <math>T_s</math>, as the third output. In previous releases, <code>tfdata</code> returned the numerator standard deviation as the third output.</p> <p>The new syntax is:</p> <pre>[num,den,Ts,sdnum,sdden] = tfdata(sys);</pre> <p><code>sdnum</code> and <code>sdden</code> are <code>[]</code> if <code>sys</code> does not contain uncertainty information or for multi-output polynomial models with a nondiagonal <math>A</math> polynomial array.</p>

Function	What Has Changed in R2012a
zpkdata	<p><b>Compatibility Consideration: Backward incompatibility.</b> zpkdata now returns the sampling time, Ts, as its fourth output argument. In previous releases, zpkdata returned the standard deviations of the zeros.</p> <p>The new syntax is:</p> <pre>[z,p,k,z,Ts,covz,covp,covk] = zpkdata(sys)</pre> <p>where covz, covp and covk are the covariance of the zeros, poles and gain of sys.</p>
canon	<p>You can use the new function canon to transform idss models into various canonical forms. For more information, see canon.</p>
findstates(idParametric)	<p>You can now specify arbitrary prediction horizons for findstates. You can use an option set to specify the option for findstates. Use the new function findstatesOptions to create the option set. For more information, see findstatesOptions.</p>
ffplot	<p>ffplot is no longer supported. Use bodeplot instead. Use bodeoptions to set the frequency units and scale.</p>
setstruc	<p>setstruct is no longer supported. Use the Structure property of the idss model to configure the model parameters.</p>
setpname	<p>setpname is no longer supported. Use the Info.Label field of the Structure property associated with the model parameter.</p>
idprops	<p>idprops is no longer supported. For information regarding a model, enter doc model_name.</p>
idhelp	<p>idhelp is no longer supported. For information regarding a model or function, enter doc model_or_function_name.</p>



**Other Functionality Being Removed or Changed**

<b>Functionality</b>	<b>What Happens When You Use This Functionality?</b>	<b>Use This Instead</b>	<b>Compatibility Considerations</b>
<code>sys.LinearModel</code> , for <code>idnlhw</code> model, <code>sys</code>	Returns an <code>idpoly</code> model.	N/A	The <code>LinearModel</code> property of <code>idnlhw</code> models is no longer returned as a state-space model for multi-output models. Instead, <code>idnlhw</code> returns an <code>idpoly</code> model.



# R2011b

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**Version: 7.4.3**

**New Features: No**

**Bug Fixes: Yes**



# R2011a

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**Version: 7.4.2**

**New Features: No**

**Bug Fixes: Yes**



# R2010b

---

**Version: 7.4.1**

**New Features: No**

**Bug Fixes: No**

**No New Features or Changes**





# R2010a

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**Version: 7.4**

**New Features: Yes**

**Bug Fixes: No**

## New Ability to Use Discrete-Time Linear Models for Nonlinear Black-Box Estimation

You can now use the following discrete-time linear models for initializing a nonlinear black-box estimation.

Discrete-time Linear Model	Use for Initializing...
Single-output polynomial model of ARX structure ( <code>idpoly</code> )	Single-output nonlinear ARX model estimation
Multi-output polynomial model of ARX structure ( <code>idarx</code> )	Multi-output nonlinear ARX model estimation
Single-output polynomial model of Output-Error (OE) structure ( <code>idpoly</code> ) or state-space model with no disturbance component ( <code>idss</code> ) object with $K = 0$	Single-output Hammerstein-Wiener model estimation
State-space model with no disturbance component ( <code>idss</code> object with $K = 0$ )	Multi-output Hammerstein-Wiener model estimation

During estimation, the software uses the linear model orders and delay as initial values of the nonlinear model orders and delay. For nonlinear ARX models, this initialization always provides a better fit to the estimation data than the linear ARX model.

You can use a linear model as an alternative approach to using model orders and delay for nonlinear estimation of the same system.

You can estimate or construct the linear model and then use this model for constructing (see `idnlarx` and `idnlhw`) or estimating (see `nlarx` or `nlhw`) the nonlinear model. For more information, see *Using Linear Model for Nonlinear ARX Estimation*, and *Using Linear Model for Hammerstein-Wiener Estimation* in the *System Identification Toolbox User's Guide*.

## New Cell Array Support for B and F Polynomials of Multi-Input Polynomial Models

You can now use cell arrays to specify the  $B$  and  $F$  polynomials of multi-input polynomial models. The  $B$  and  $F$  polynomials are represented by the `b` and `f` properties of an `idpoly` object. These properties are currently double matrices.

For multi-input polynomial models, these polynomials will be represented by cell arrays only in a future version. If your code performs operations on the `b` and `f` properties, make one of the following changes in the code:

- When you construct the model using the `idpoly` command, use cell arrays to specify the  $B$  and  $F$  polynomials. Using cell arrays causes the `b` and `f` properties to be represented by cell arrays.
- After you construct or estimate the model, use the new `setPolyFormat` command to:
  - Convert `b` and `f` properties to cell arrays.
  - Make the model backward compatible to continue using double matrices for `b` and `f` properties. This operation ensures that operations on `b` and `f` properties that use matrix syntax continue to work without errors in a future version.

When you use cell arrays, you must also update your code to use cell array syntax on `b` and `f` properties instead of matrix syntax.

---

**Note** For single-input polynomial models, the `b` and `f` properties continue to be double row vectors.

---

## Functions and Function Elements Being Removed

**Compatibility Considerations: Yes**

<b>Function or Function Element Name</b>	<b>What Happens When you Use the Function or Element?</b>	<b>Use This Instead</b>	<b>Compatibility Considerations</b>
Double matrix support for <b>b</b> and <b>f</b> properties of multi-input <code>idpoly</code> models.	Warns	Use cell array to specify the <b>b</b> and <b>f</b> properties of multi-input polynomial models.	If your code performs operations on the <b>b</b> and <b>f</b> properties, update the code to be compatible with a future release. See “New Cell Array Support for B and F Polynomials of Multi-Input Polynomial Models” on page 83.

# R2009b

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**Version: 7.3.1**

**New Features: No**

**Bug Fixes: No**

**No New Features or Changes**



# R2009a

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**Version: 7.3**

**New Features: Yes**

**Bug Fixes: No**

## Enhanced Handling of Offsets and Trends in Signals

This version of the product includes new and expanded functionality for handling offsets and trends in signals. This data processing operation is necessary for estimating more accurate linear models because linear models cannot capture arbitrary differences between the input and output signal levels.

The previous version of the product let you remove mean values or linear trends from steady-state signals using the GUI and the `detrend` function. For transient signals, you had to remove offsets and trends using matrix manipulation.

The GUI functionality for removing means and linear trends from signals is unchanged. However, you can now do the following at the command line:

- Save the values of means or linear trends removed during detrending using a new `detrend` output argument. You can use this saved trend information to detrend other data sets. You can also restore subtracted trends to the output simulated by a linear model that was estimated from detrended data.

For example, this syntax computes and removes mean values from the data, and saves these values to the output variable `T`:  
`[data_d, T]=detrend(data)`. `T` is an object with properties that store offset and slope information for input and output signals.

- Remove any offset or linear trend from the data using a new `detrend` input argument. This is useful for removing arbitrary nonzero offsets from transient data or applying previously saved trend information to any data set.

For example, this syntax removes an offset or trend specified by `T`: `data_d = detrend(data, T)`.

- Add an arbitrary offset or linear trend to data signals. This is useful when you want to simulate the response of a linear model about a nonzero equilibrium input-output level and this model was estimated from detrended data.



For example, this syntax adds trend information to a simulated model output `y_sim`, which is an `iddata` object: `y = retrend(y_sim,T)`. `T` specifies the offset and slope information for inputs and outputs.

For more information, see [Handling Offsets and Trends in Data](#).

## **Ability to Get Regressor Values in Nonlinear ARX Models**

The `getreg` command can now return the numerical values of regressors in nonlinear ARX models and provides an intermediate output of nonlinear ARX models.

This advanced functionality converts input and output values to regressors, and passes the regressor values to the `evaluate` command to compute the model response. This incremental step lets you gain insight into the propagation of information through the nonlinear ARX model.

For more information, see the `getreg` reference page. To learn more about the nonlinear ARX model structure, see [Nonlinear Black-Box Model Identification](#).



# R2008b

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**Version: 7.2.1**

**New Features: No**

**Bug Fixes: No**

## Functions and Properties Being Removed

Compatibility Considerations: Yes

Function or Property Name	What Happens When You Use Function or Property?	Use This Instead	Compatibility Considerations
model.Algorithm.Trace	Still runs	model.Algorithm.Display	Using model.Algorithm.Trace results in a warning.

# R2008a

---

**Version: 7.2**

**New Features: Yes**

**Bug Fixes: No**

## Simulating Nonlinear Black-Box Models in Simulink Software

You can now simulate nonlinear ARX and Hammerstein-Wiener models in Simulink using the nonlinear ARX and the Hammerstein-Wiener model blocks in the System Identification Toolbox block library. This is useful in the following situations:

- Representing dynamics of a physical component in a Simulink model using a data-based nonlinear model
- Replacing a complex Simulink subsystem with a simpler data-based nonlinear model

---

**Note** Nonlinear ARX Model and Hammerstein-Wiener Model blocks read variables from the MATLAB (base) workspace or model workspace. When the MATLAB workspace and model workspace contain a variable with the same name and this variable is referenced by a Simulink block, the variable in the model workspace takes precedence.

---

If you have installed Real-Time Workshop® software, you can generate code from models containing nonlinear ARX and the Hammerstein-Wiener model blocks. However, you cannot generate code when:

- Hammerstein-Wiener models use the `customnet` estimator for input or output nonlinearity.
- Nonlinear ARX models use custom regressors or use the `customnet` or `neuralnet` nonlinearity estimator.

You can access the new System Identification Toolbox blocks from the Simulink Library Browser. For more information about these blocks, see the IDNLARX Model (nonlinear ARX model) and the IDNLHW Model (Hammerstein-Wiener model) block reference pages.

## Linearizing Nonlinear Black-Box Models at User-Specified Operating Points

You can now use the `linearize` command to linearize nonlinear black-box models, including nonlinear ARX and Hammerstein-Wiener models, at specified operating points. Linearization produces a first-order Taylor series approximation of the system about an operating point. An *operating point* is defined by the set of constant input and state values for the model.

If you do not know the operating point, you can use the `findop` command to compute it from specifications, such as steady-state requirements or values of these quantities at a given time instant from the simulation of the model.

For nonlinear ARX models, if all of the steady-state input and output values are known, you can map these values to the model state values using the `data2state` command.

`linearize` replaces `lintan` and removes the restriction for linearizing models containing custom regressors or specific nonlinearity estimators, such as `neuralnet` and `treepartition`.

If you have installed Simulink Control Design software, you can linearize nonlinear ARX and Hammerstein-Wiener models in Simulink after importing them into Simulink.

For more information, see:

- Linear Approximation of Nonlinear Black-Box Models about computing operating points and linearizing models
- Simulating Identified Model Output in Simulink about importing nonlinear black-box models into Simulink

## Estimating Multiple-Output Models Using Weighted Sum of Least Squares Minimization Criterion

You can now specify a custom weighted trace criterion for minimization when estimating linear and nonlinear black-box models for multiple-output systems. This feature is useful for controlling the relative importance of output channels during the estimation process.

The `Algorithm` property of linear and nonlinear models now provides the `Criterion` field for choosing the minimization criterion. This new field can have the following values:

- `det` — (Default) Specify this option to minimize the determinant of the prediction error covariance. This choice leads to maximum likelihood estimates of model parameters. It implicitly uses the inverse of estimated noise variance as the weighting function. This option was already available in previous releases.
- `trace` — Specify this option to define your own weighing function that controls the relative weights of output signals during the estimation. This criterion minimizes the weighted sum of least square prediction errors. You can specify the relative weighting of prediction errors for each output using the new `Weighting` field of the `Algorithm` property. By default, `Weighting` is an identity matrix, which means that all outputs are weighed equally. Set `Weighting` to a positive semidefinite symmetric matrix.

For more information about `Algorithm` fields for nonlinear estimation, see the `idnlarx` and `idnlhw` reference pages.

---

**Note** If you are estimating a single-output model, `det` and `trace` values of the `Criterion` field produce the same estimation results.

---

## Improved Handling of Initial States for Linear and Nonlinear Models

The following are new options to handle initial states for nonlinear models:

- For nonlinear ARX models (`idnlarx`), you can now specify a numerical vector for initial states when using `sim` or `predict` by setting the `Init` argument. For example:

```
predict(model,data,'init',[1;2;3;4])
```

where the last argument is the state vector.

For more information, see the `sim` and `predict` reference pages.



- For Hammerstein-Wiener models (`idnlhw`), you can now choose to estimate the initial states when using `predict` or `nlhw` by setting `INIT= 'e'`.

For more information, see the `predict` and `nlhw` reference pages.

If you want to specify your own initial states, see the corresponding model reference pages for a definition of the states for each model type.

If you do not know the states, you can use the `findop` or the `findstates` command to compute the states. For more information about using these commands, see the `findop(idnlarx)`, `findop(idnlhw)`, `findstates(idnlarx)`, and `findstates(idnlhw)` reference pages.

To help you interpret the states of a nonlinear ARX model, you can use the `getDelayInfo` command. For more information, see the `getDelayInfo` reference page.

The `findstates` command is available for all linear and nonlinear models. Also see the `findstates(idnlgrey)` reference page.

## Improved Algorithm Options for Linear Models

The following improvements are available for the `Algorithm` property of linear models to align linear and nonlinear models (where appropriate) and improve robustness for default settings:

- The `SearchDirection` field (`model.Algorithm.SearchDirection`) has been renamed to `SeachMethod` (`model.Algorithm.SearchMethod`) to be consistent with the nonlinear models, where the corresponding field is `SeachMethod`.
- The new `lsqnonlin` option for specifying `SearchMethod` is available. `model.Algorithm.SearchMethod='lsqnonlin'` uses the `lsqnonlin` optimizer from the Optimization Toolbox™ software. You must have Optimization Toolbox software installed to use this option.
- The improved `gn` algorithm (subspace Gauss-Newton method) is available for specifying `SearchDirection`. The updated `gn` algorithm better handles the scale of the parameter Jacobians and is also consistent with the algorithm used for nonlinear model estimation.

- The default values for the `LimitError` field of the `Algorithm` property (`modelName.Algorithm.LimitError`) is changed to 0, which is consistent with the corresponding option for estimating nonlinear models. In previous releases, `LimitError` default value was 1.6, which robustified the estimation process against data outliers by associating a linear penalty for large errors, rather than a quadratic penalty. Now, there is no robustification by default (`LimitError=0`). You can estimate the model with the default setting and plot the prediction errors using `pe(data.model)`. If the resulting plot shows occasional large values, repeat the estimation with `model.Algorithm.LimitError` set to a value between 1 and 2.
- The `model.Algorithm.Advanced` property has a new tolerance field `GnPinvConst` corresponding to the `gn SearchMethod`. `GnPinvConst` specifies that singular values of the Jacobian that are smaller than `GnPinvConst*max(size(J))*norm(J)*eps` are discarded when computing the search direction. You can assign a positive real value for this field. Default value is `1e4`.
- The default value of `model.Algorithm.Advanced.Zstability` property has been changed from 1.01 to `1+sqrt(eps)`. The new default reduces the possibility of a situation where the estimation algorithm does not converge (predictor becomes unstable) while still allowing enough flexibility to capture lightly damped modes.

## **New Block Reference Pages**

New documentation for System Identification Toolbox blocks is provided. For more information, see Block Reference in the System Identification Toolbox reference documentation.

## **Functions and Properties Being Removed**

**Compatibility Considerations: Yes**

<b>Function or Property Name</b>	<b>What Happens When You Use Function or Property?</b>	<b>Use This Instead</b>	<b>Compatibility Considerations</b>
lntan	Still runs	linearize(idnlhw) linearize(idnlrx)	See “Linearizing Nonlinear Black-Box Models at User-Specified Operating Points” on page 95.
model.Algorithm.SearchDirection	Still runs	model.Algorithm.SearchMethod	See “Improved Algorithm Options for Linear Models” on page 97.
gns option of model.Algorithm.SearchDirection	Still runs	gn	See “Improved Algorithm Options for Linear Models” on page 97.
GnsPinvTol of model.Algorithm.Advanced	Still runs	GnPinvConst	See “Improved Algorithm Options for Linear Models” on page 97.



# R2007b

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**Version: 7.1**

**New Features: Yes**

**Bug Fixes: No**

## **New Polynomial Nonlinearity Estimator for Hammerstein-Wiener Models**

You can now estimate nonlinearities for Hammerstein-Wiener models using a single-variable polynomial at either the input or the output. This nonlinearity estimator is available at the command line.

For more information, see the `poly1d` reference pages. For more information about estimating Hammerstein-Wiener models, see *Identifying Hammerstein-Wiener Models* in the System Identification Toolbox documentation.

# R2007a

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**Version: 7.0**

**New Features: Yes**

**Bug Fixes: No**

- “New Nonlinear Black-Box Modeling Options” on page 104
- “New Nonlinear Grey-Box Modeling Option” on page 104
- “New Getting Started Guide” on page 105
- “Revised and Expanded User’s Guide” on page 106

## New Nonlinear Black-Box Modeling Options

You can now estimate nonlinear discrete-time black-box models for both single-output and multiple-output time-domain data. The System Identification Toolbox product supports the following types of nonlinear black-box models:

- Hammerstein-Wiener
- Nonlinear ARX

To learn how to estimate nonlinear black-box models using the System Identification Tool GUI or commands in the MATLAB Command Window, see the System Identification Toolbox documentation.

---

**Note** You can estimate Hammerstein-Wiener black-box models from input-output data only. These models do not support time-series data, where there is no input.

---

New demos are available to help you explore nonlinear black-box functions. For more information, see the collection of demos in the Tutorials on Nonlinear ARX and Hammerstein-Wiener Model Identification category.

## New Nonlinear Grey-Box Modeling Option

You can now estimate nonlinear discrete-time and continuous-time models for arbitrary nonlinear ordinary differential equations using single-output and multiple-output time-domain data, or time-series data (no measured inputs). Models that you can specify as a set of nonlinear ordinary differential equations (ODEs) are called *grey-box models*.

To learn how to estimate nonlinear grey-box models using the commands in the MATLAB Command Window, see System Identification Toolbox documentation.

Specify the ODE in a function or a MEX-file. The template file for writing the MEX-file, `IDNLGREY_MODEL_TEMPLATE.c`, is located in `matlab/toolbox/ident/nlident`.



To estimate the equation parameters, first construct an `idnlgrey` object to specify the ODE file and the parameters you want to estimate. Use `pem` to estimate the ODE parameters. For more information, see the `idnlgrey` and `pem` reference pages.

New demos are available to help you explore nonlinear grey-box functions. For more information, see the collection of demos in the Tutorials on Nonlinear Grey-Box Model Identification category.

## Optimization Toolbox Search Method for Nonlinear Estimation Is Supported

If you have Optimization Toolbox software installed, you can specify the `lsqnonlin` search method for estimating black-box and grey-box nonlinear models in the MATLAB Command Window.

```
model.algorithm.searchmethod='lsqnonlin'
```

For more information, see the `idnlarx`, `idnlhw`, and `idnlgrey` reference pages.

## New Getting Started Guide

The System Identification Toolbox product now provides a new Getting Started Guide. This guide introduces fundamental identification concepts and provides the following tutorials to help you get started quickly:

- Tutorial – Identifying Linear Models Using the GUI — Tutorial for using the System Identification Tool graphical user interface (GUI) to estimate linear black-box models for single-input and single-output (SISO) data.
- Tutorial – Identifying Low-Order Transfer Functions (Process Models) Using the GUI — Tutorial for using the System Identification Tool graphical user interface (GUI) to estimate low-order transfer functions to fit single-input and single-output (SISO) data.
- Tutorial – Identifying Linear Models Using the Command Line — Tutorial for estimating models using System Identification Toolbox objects and methods for multiple-input and single-output (MISO) data.

## **Revised and Expanded User's Guide**

The System Identification Toolbox documentation has been revised and expanded.

# R2006b

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**Version: 6.2**

**New Features: Yes**

**Bug Fixes: No**

## **MATLAB Compiler Support**

The System Identification Toolbox product now supports the MATLAB Compiler™ product.

You can use MATLAB Compiler to take MATLAB files as input and generate redistributable, standalone applications that include System Identification Toolbox functionality, including the following:

- Creating data and model objects
- Preprocessing and manipulating data
- Simulating models
- Transforming models, including conversions between continuous and discrete time and model reduction
- Plotting transient and frequency response

To use these features, write a function that uses System Identification Toolbox commands. Use the MATLAB Compiler software to create a standalone application from the MATLAB Compiler file. For more information, see the MATLAB Compiler documentation.

Standalone applications that include System Identification Toolbox functionality have the following limitations:

- No access to the System Identification library in the Simulink software (slident)
- No support for model estimation



# R2006a

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**Version: 6.1.3**

**New Features: Yes**

**Bug Fixes: No**

- “balred Introduced for Model Reduction” on page 112
- “Search Direction for Minimizing Criteria Can Be Computed by Adaptive Gauss-Newton Method” on page 112
- “Maximum Number of Bisections Used by Line Search Is Increased” on page 112

## **balred Introduced for Model Reduction**

Use `balred` to perform model reduction instead of `idmodred`.

## **Search Direction for Minimizing Criteria Can Be Computed by Adaptive Gauss-Newton Method**

An adaptive Gauss-Newton method is now available for computing the direction of the line search for cost-function minimization. Use this method when you observe convergence problems in the estimation results, or as an alternative to the Levenberg-Marquard (`lm`) method.

The `gna` search method was suggested by Adrian Wills, Brett Ninness, and Stuart Gibson in their paper "On Gradient-Based Search for Multivariable System Estimates", presented at the IFAC World Congress in Prague in 2005. `gna` is an adaptive version of `gns` and uses a cutoff value for the singular values of the criterion Hessian, which is adjusted adaptively depending on the success of the line search.

Specify the `gna` method by setting the `SearchDirection` property to `'gna'`. For example:

```
m = pem(data,model_structure,'se','gna')
```

The default initial value of `gamma` in the `gna` search is  $10^{-4}$ . You can set a different value using the `InitGnaTol` property.

## **Maximum Number of Bisections Used by Line Search Is Increased**

The default value for the `MaxBisections` property, which is the maximum number of bisections along the search direction used by line search, is increased from 10 to 25. This increases the number of attempts to find a lower criterion value along the search vector.

## **Functions and Properties Being Removed**



**Compatibility Considerations: Yes**

<b>Function or Property Name</b>	<b>What Happens When You Use Function or Property?</b>	<b>Use This Instead</b>	<b>Compatibility Considerations</b>
idmodred	Still runs	balred	See “balred Introduced for Model Reduction” on page 112.



# R14SP3

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**Version: 6.1.2**

**New Features: No**

**Bug Fixes: No**

**No New Features or Changes**



# R14SP2

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**Version: 6.1.1**

**New Features: No**

**Bug Fixes: No**

**No New Features or Changes**