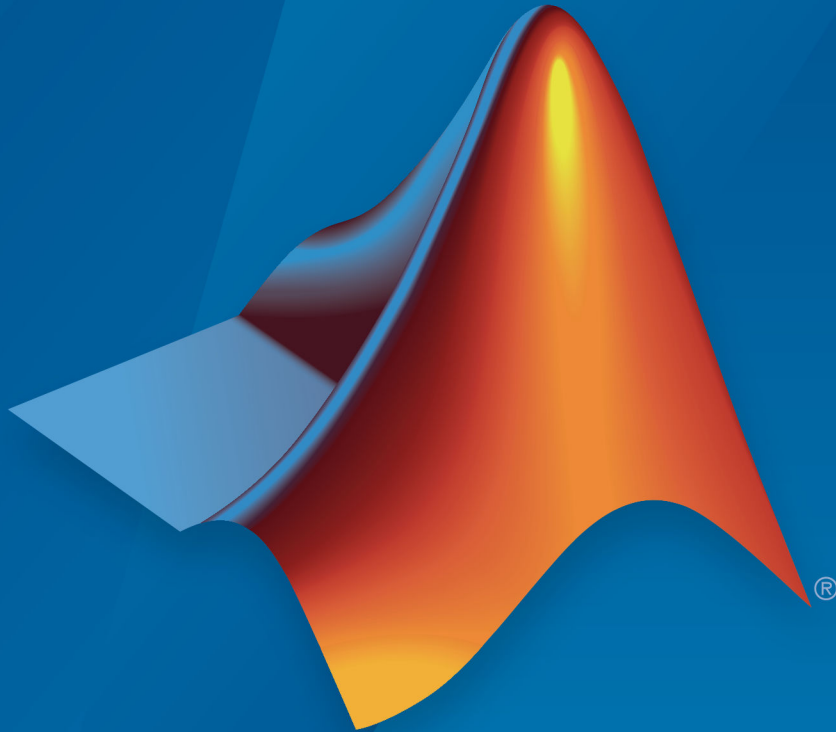


Model Predictive Control Toolbox™ Release Notes



MATLAB®

How to Contact MathWorks



Latest news: www.mathworks.com
Sales and services: www.mathworks.com/sales_and_services
User community: www.mathworks.com/matlabcentral
Technical support: www.mathworks.com/support/contact_us



Phone: 508-647-7000



The MathWorks, Inc.
3 Apple Hill Drive
Natick, MA 01760-2098

Model Predictive Control Toolbox™ Release Notes

© COPYRIGHT 2005–2018 by The MathWorks, Inc.

The software described in this document is furnished under a license agreement. The software may be used or copied only under the terms of the license agreement. No part of this manual may be photocopied or reproduced in any form without prior written consent from The MathWorks, Inc.

FEDERAL ACQUISITION: This provision applies to all acquisitions of the Program and Documentation by, for, or through the federal government of the United States. By accepting delivery of the Program or Documentation, the government hereby agrees that this software or documentation qualifies as commercial computer software or commercial computer software documentation as such terms are used or defined in FAR 12.212, DFARS Part 227.72, and DFARS 252.227-7014. Accordingly, the terms and conditions of this Agreement and only those rights specified in this Agreement, shall pertain to and govern the use, modification, reproduction, release, performance, display, and disclosure of the Program and Documentation by the federal government (or other entity acquiring for or through the federal government) and shall supersede any conflicting contractual terms or conditions. If this License fails to meet the government's needs or is inconsistent in any respect with federal procurement law, the government agrees to return the Program and Documentation, unused, to The MathWorks, Inc.

Trademarks

MATLAB and Simulink are registered trademarks of The MathWorks, Inc. See www.mathworks.com/trademarks for a list of additional trademarks. Other product or brand names may be trademarks or registered trademarks of their respective holders.

Patents

MathWorks products are protected by one or more U.S. patents. Please see www.mathworks.com/patents for more information.

R2018a

ADAS Blocks: Design, simulate, and implement adaptive cruise control and lane-keeping algorithms	1-2
---	------------

R2017b

Economic MPC: Design and simulate model predictive controllers with arbitrary nonlinear cost function and constraints	2-2
Fast MPC: Guarantee worst-case execution time by using approximate QP solution	2-2
Custom QP Solvers: Generate code for third-party QP solvers written in C/C++ or MATLAB code suitable for code generation	2-2
Mixed Input/Output Constraints: Update constraints on linear combinations of inputs and outputs at run time	2-3
ADAS Examples: Design controllers for adaptive cruise control, autonomous vehicle steering, and obstacle avoidance	2-3

R2017a

New Examples: Design and simulate nonlinear model predictive controller in MATLAB and Simulink	3-2
---	------------

R2016b

Multiple Explicit MPC Controllers Block: Implement gain-scheduled explicit MPC controllers in Simulink	4-2
MPC Designer App: Automatically estimate controller sample time when setting internal plant using stable, continuous-time model	4-2
MPC Designer App: Load previously saved session when opening app from command line	4-2
MPC Designer App: Import identified linear models	4-3
MPC Controller Creation Using Identified Linear Models: Discard noise channels by default	4-3
Functionality being removed or changed	4-4

R2016a

Adaptive MPC with Time-Varying Prediction Models: Simulate adaptive MPC controllers with prediction models that change over the prediction horizon	5-2
mpcmoveCodeGeneration Command: Generate C code for computing optimal manipulated variable control moves . . .	5-2

Custom QP Solver: Simulate model predictive controllers with a QP solver of your choice	5-2
--	------------

R2015b

Redesigned MPC Designer App: Design model predictive controllers in MATLAB and Simulink using improved interactive workflows	6-2
MATLAB Script Generation from MPC Designer App: Automatically script model predictive controller design tasks	6-2
Simulink Model Generation from MPC Designer App: Automatically create a Simulink model with an MPC controller and plant model	6-3
mpcqpssolver Command: Develop and generate code for custom model predictive controllers using KWIK quadratic programming solver	6-3
Review model predictive controller design using MPC Designer app	6-3
Comparison of responses for multiple model predictive controllers in the same plot using MPC Designer app	6-4
Interactive tuning of model predictive controller performance objectives	6-4
mpctool command renamed to mpcDesigner	6-5
Functionality being removed or changed	6-5

R2015a

OutputVariables Integrator property of MPC controller being removed	7-2
setoutdist command 'remove' syntax being removed	7-2
Functionality being removed or changed	7-4

R2014b

Explicit MPC control for applications with fast sample times using precomputed solutions	8-2
Adaptive MPC control through run-time changes to internal plant model	8-2
ScaleFactor property for MPC controllers, for making weight tuning independent of the engineering units of input and output variables	8-3
Option to use custom state estimation or measured state values instead of the built-in state estimation in MPC controllers	8-3
Option to specify manipulated variable target	8-4
Run-time weight tuning on manipulated variables	8-4
Run-time weight tuning and performance monitoring in Multiple MPC Controllers block	8-4
getEstimator and setEstimator commands to obtain and change state estimation parameters	8-4
Definition of external MV signal changed	8-5

Unconnected input and output limits imports default changed to match mpc object	8-5
--	------------

R2014a

IEC 61131-3 Structured Text generation from MPC Controller and Multiple MPC Controllers blocks using Simulink PLC Coder	9-2
Reduced RAM usage for C code generated for MPC Controller and Multiple MPC Controllers blocks	9-2
Estimate of data memory size used by deployed MPC controller at run time	9-2

R2013b

Controller design for plant and disturbance models with internal delays	10-2
Single-precision simulation and code generation using MPC Controller and Multiple MPC Controllers blocks	10-2
Conditional execution of MPC Controller and Multiple MPC Controllers blocks using Function-Call Subsystem and Triggered Subsystem blocks	10-3

R2013a

Bug Fixes

R2012b

Bug Fixes

R2012a

Run-Time Preview of Reference and Measured Disturbance Signals with MPC Controller Block	13-2
---	-------------

R2011b

C Code Generation Improvements for All Targets with MPC Controller Block	14-2
Faster QP Solver Algorithm for Improving MPC Controller Performance	14-2
Run-Time Weight Tuning and Constraint Softening for MPC Controller	14-2
Run-Time Monitoring of MPC Controller Performance to Detect When an Optimal Solution Cannot Not Be Found	14-3
review Command for Diagnosing Issues with MPC Controller Parameters That Could Lead to Run-Time Failures	14-3
mpcmove Returns Aligned Time Horizons for Optimal Control, Predicted Output and Estimated State	14-4
Functionality Being Removed or Changed	14-4

R2011a

Support for Custom Constraints on MPC Controller Inputs and Outputs	15-2
Ability to Specify Terminal Constraints and Weights on MPC Controller	15-2
Ability to Access Optimal Cost and Optimal Control Sequence	15-2

R2010b

No New Features or Changes

R2010a

New Ability to Analyze SISO Generalized Predictive Controllers (GPC)	17-2
---	-------------

R2009b

Bug Fixes

R2009a

New Sensitivity Analysis to Determine Effect of Weights on Tuning MPC Controllers	19-2
--	-------------

R2008b

New Multiple MPC Controllers Block in the Model Predictive Control Toolbox Simulink Library	20-2
Tested Code Generation Support for Real-Time Workshop Target Systems	20-2
Ability to Design Controllers with Time-Varying Weights and Constraints Using the GUI	20-3

R2008a

No New Features or Changes

R2007b

New Option for Specifying Time-Varying Constraints	22-2
Ability to Specify Nondiagonal Q and R Weight Matrices in the Cost Function	22-2

R2007a

Bug Fixes

R2006b

No New Features or Changes

R2006a

Bumpless Transfer Added to MPC Block	25-2
New Bumpless Transfer Demo	25-2

R14SP3

No New Features or Changes

R14SP2

No New Features or Changes

R2018a

Version: 6.1

New Features

Bug Fixes

ADAS Blocks: Design, simulate, and implement adaptive cruise control and lane-keeping algorithms

You can now design, simulate, and implement model predictive controllers for automatic cruise control and lane keeping assistance using new Simulink® blocks. These blocks provide simplified application-specific interfaces for configuring model predictive controllers.

For both blocks, you can generate a custom subsystem, which you can modify for your application. This option is useful when you want to:

- Modify default MPC settings or use advanced MPC features.
- Modify the default controller initial conditions.
- Use different application settings, such as a custom safe following distance definition for adaptive cruise control.

For more information, see Adaptive Cruise Control System and Lane Keeping Assist System.

R2017b

Version: 6.0

New Features

Bug Fixes

Economic MPC: Design and simulate model predictive controllers with arbitrary nonlinear cost function and constraints

Model Predictive Control Toolbox software now supports economic MPC; that is, the ability to optimize the controller for an arbitrary cost function under arbitrary nonlinear constraints. Previously, MPC controllers supported only quadratic cost functions with linear constraints. Unlike nonlinear MPC, economic MPC uses linear prediction models and linear state estimation.

Economic MPC requires Optimization Toolbox™ software.

For more information, see Economic MPC.

Fast MPC: Guarantee worst-case execution time by using approximate QP solution

You can now guarantee the worst-case execution time for your MPC controller by applying an approximate (suboptimal) solution after the number of optimization iterations exceeds a specified maximum value. This feature applies when using the built-in QP solver, a custom QP solver, and `fmincon` for economic MPC.

For more information, see Suboptimal QP Solution.

Custom QP Solvers: Generate code for third-party QP solvers written in C/C++ or MATLAB code suitable for code generation

You can now generate code for MPC controllers that use a custom QP solver written in either C/C++ or MATLAB code that is suitable for code generation. The controller calls this solver in place of the built-in QP solver at each control interval. For an example, see Simulate and Generate Code for MPC Controller with Custom QP Solver.

For more information on:

- Custom QP solvers, see Custom QP Solver.
- Code generation, see Generate Code and Deploy Controller to Real-Time Targets.

Generating code for MPC controllers with custom QP solvers:

-
- At the command line requires MATLAB® Coder™ software.
 - In Simulink requires Simulink Coder or Simulink PLC Coder™ software.

Mixed Input/Output Constraints: Update constraints on linear combinations of inputs and outputs at run time

You can now update mixed input/output constraints at run time when simulating your MPC controller at the command line or in Simulink. You can update these constraints for traditional and adaptive MPC controllers. You can also generate code for controllers that use online mixed input/output constraints.

For an example that uses online custom constraints with an adaptive MPC controller, see [Obstacle Avoidance Using Adaptive Model Predictive Control](#). For more information on updating constraints at run time, see [Update Constraints at Run Time](#).

ADAS Examples: Design controllers for adaptive cruise control, autonomous vehicle steering, and obstacle avoidance

New examples show how to design and simulate advanced driver assistance systems (ADAS) using model predictive controllers. The new examples are:

- Adaptive Cruise Control System Using Model Predictive Control
- Autonomous Vehicle Steering Using Model Predictive Control
- Obstacle Avoidance Using Adaptive Model Predictive Control
- Adaptive Cruise Control with Sensor Fusion

R2017a

Version: 5.2.2

New Features

Bug Fixes

New Examples: Design and simulate nonlinear model predictive controller in MATLAB and Simulink

Two new examples show how to design and simulate a nonlinear model predictive controller in MATLAB and Simulink. Like linear MPC, nonlinear MPC also solves a constrained optimization problem at each control interval. However, since the plant model is nonlinear, the nonlinear MPC converts the optimal control problem into a nonlinear optimization problem with a nonlinear cost function and nonlinear constraints. The new examples are:

- Swing-up Control of a Pendulum Using Nonlinear Model Predictive Control
- Nonlinear MPC Control of an Ethylene Oxidation Plant

Both examples require Optimization Toolbox software.

R2016b

Version: 5.2.1

New Features

Bug Fixes

Compatibility Considerations

Multiple Explicit MPC Controllers Block: Implement gain-scheduled explicit MPC controllers in Simulink

You can now use the Multiple Explicit MPC Controllers block to implement gain-scheduled explicit MPC controllers in Simulink. You design an explicit MPC controller for each operating point and specify a switching signal to choose the active controller. During each control interval, the active explicit MPC controller determines control actions using a table-lookup control law. The inactive controllers continue estimating plant states, which allows for bumpless transfer when switching controllers. The Multiple Explicit MPC Controllers block reduces online computational effort compared to the Multiple MPC Controllers block.

For more information, see [Multiple Explicit MPC Controllers](#).

MPC Designer App: Automatically estimate controller sample time when setting internal plant using stable, continuous-time model

To facilitate controller design, **MPC Designer** now automatically estimates the initial controller sample time when you specify a stable continuous-time plant prediction model. In this case, the app sets the controller sample time to $0.1T_r$, where T_r is the average rise time of the plant. Previously, **MPC Designer** set the controller sample time to a default value of 1.

If you specify an unstable continuous-time plant, **MPC Designer** sets the controller sample time to 1 by default. If you specify a discrete-time plant, **MPC Designer** sets the controller sample time to the plant sample time.

For more information on specifying the MPC controller internal model, see [MPC Designer and Design Controller Using MPC Designer](#).

MPC Designer App: Load previously saved session when opening app from command line

You can now load a previously saved session when opening the **MPC Designer** app. The saved session data includes all plants, controllers, and scenarios in the **Data Browser**, the current MPC structure, and the current plot configuration.

To open **MPC Designer** and load the session saved in `savedSession.mat`, type the following at the MATLAB command line.

```
mpcDesigner('savedSession.mat')
```

For more information, see MPC Designer.

MPC Designer App: Import identified linear models

You can now import linear System Identification Toolbox™ models, such as `idss` or `idtf` systems, directly into the MPC Designer app.

MPC Designer converts the specified model to a state-space (`ss`) system and creates a default MPC controller using the state-space system as the internal prediction model. The app discards any noise channels in the identified model.

For more information on designing MPC controllers for identified plants, see Design MPC Controller for Identified Plant Model.

MPC Controller Creation Using Identified Linear Models: Discard noise channels by default

When you create an MPC controller using a linear System Identification Toolbox model with noise channels, the software now discards any noise channels from the model by default. Previously, the noise channels were converted to unmeasured disturbances by default.

Starting in R2016b, to convert noise channels to unmeasured disturbances, first convert the identified model to a state-space model using the `'augmented'` option.

```
ssModel = ss(idModel, 'augmented');
```

This option creates `Measured` and `Noise` input groups in `ssModel`. You can then create an MPC controller using the state-space model.

```
controller = mpc(ssModel, Ts);
```

The channels in the `Noise` input group are converted to unmeasured disturbances.

For more information on designing MPC controllers for identified plants, see Design MPC Controller for Identified Plant Model.

Functionality being removed or changed

Functionality	Result	Use This Instead	Compatibility Considerations
For System Identification Toolbox models with noise channels, <code>controller = mpc(idModel,Ts)</code> now discards noise channels by default.	Still works	<pre>ssModel = ss(idModel, 'augmented') controller = mpc(ssModel, Ts)</pre>	To convert noise channels to unmeasured disturbances, convert the identified model to a state-space model using the 'augmented' option. For more information, see "MPC Controller Creation Using Identified Linear Models: Discard noise channels by default" on page 4-3.
<code>getmpcdata</code>	Error	<ul style="list-style-type: none"> • <code>get</code> • <code>getconstraint</code> • <code>getEstimator</code> • <code>getindist</code> • <code>getoutdist</code> 	Replace all instances of <code>getmpcdata</code> using the command corresponding to your specific data of interest.
<code>setmpcdata</code>	Error	<ul style="list-style-type: none"> • <code>set</code> • <code>setconstraint</code> • <code>setEstimator</code> • <code>setindist</code> • <code>setoutdist</code> 	Replace all instances of <code>setmpcdata</code> using the command corresponding to your specific data of interest.
The fully qualified class name <code>mpcdata.state</code> has changed to <code>mpcstate</code> .	Not applicable	Not applicable	<p>For <code>mpcstate</code> state object <code>x</code>:</p> <ul style="list-style-type: none"> • <code>class(x)</code> now returns 'mpcstate'. • <code>isa(x, 'mpcdata.mpcstate')</code>, now returns <code>false</code>. Use <code>isa(x, 'mpcstate')</code> instead. <p>Otherwise, there is no change in functionality.</p>

R2016a

Version: 5.2

New Features

Bug Fixes

Adaptive MPC with Time-Varying Prediction Models: Simulate adaptive MPC controllers with prediction models that change over the prediction horizon

You can now specify prediction models and nominal conditions that change over the prediction horizon when using adaptive MPC. Use these options if you can predict how the plant and nominal conditions vary in the future.

To vary the prediction model, specify the `Plant` input argument of `mpcmoveAdaptive` as an array of up to $p+1$ delay-free, discrete-time, state-space models, where p is the prediction horizon of your MPC controller. To vary the nominal conditions, specify the `Nominal` input argument of `mpcmoveAdaptive` as an array of up to $p+1$ nominal condition structures.

For more information, see [Time-Varying MPC](#) and [Time-Varying MPC Control of a Time-Varying Plant](#).

mpcmoveCodeGeneration Command: Generate C code for computing optimal manipulated variable control moves

You can now generate C code for computing optimal manipulated variable control moves for any valid implicit or explicit MPC controller using the new `mpcmoveCodeGeneration` command.

Use the new `getCodeGenerationData` command to create the input data structures for `mpcmoveCodeGeneration`.

For an example of how to generate C code for computing optimal MPC control moves, see [Generate Code To Compute Optimal MPC Moves in MATLAB](#).

Custom QP Solver: Simulate model predictive controllers with a QP solver of your choice

You can now define a custom QP solver for your MPC controller. To do so, you must provide a custom `mpcCustomSolver.m` file on the MATLAB path that finds an optimal solution to the general form QP problem. For more information on the MPC QP problem and how to specify a custom solver, see [Custom QP Solver](#).

For an example on how to use a custom QP solver, see [Simulate MPC Controller with a Custom QP Solver](#).

R2015b

Version: 5.1

New Features

Bug Fixes

Compatibility Considerations

Redesigned MPC Designer App: Design model predictive controllers in MATLAB and Simulink using improved interactive workflows

The redesigned MPC Designer app streamlines MATLAB and Simulink workflows for designing model predictive controllers. You can now:

- Generate MATLAB scripts for MPC controller design tasks. See “MATLAB Script Generation from MPC Designer App: Automatically script model predictive controller design tasks” on page 6-2.
- Generate a Simulink model with an MPC controller and plant model. See “Simulink Model Generation from MPC Designer App: Automatically create a Simulink model with an MPC controller and plant model” on page 6-3.
- Compare responses for multiple MPC controllers in the same plot. See “Comparison of responses for multiple model predictive controllers in the same plot using MPC Designer app” on page 6-4.
- Review MPC controllers for design and run-time stability issues. See “Review model predictive controller design using MPC Designer app” on page 6-3.
- Tune controller performance objectives using interactive sliders. See “Interactive tuning of model predictive controller performance objectives” on page 6-4.

To open the MPC Designer app, enter the following:

```
mpcDesigner
```

For examples of using the app from MATLAB and Simulink, see Design Controller Using MPC Designer and Design MPC Controller in Simulink.

MATLAB Script Generation from MPC Designer App: Automatically script model predictive controller design tasks

You can now generate MATLAB scripts for creating and simulating model predictive controllers designed in the **MPC Designer** app. Generated MATLAB scripts are useful when you want to programmatically reproduce designs that you obtained interactively.

For more information, see Generate MATLAB Code from MPC Designer.

Simulink Model Generation from MPC Designer App: Automatically create a Simulink model with an MPC controller and plant model

You can now generate a Simulink model that uses the current model predictive controller to control its internal plant model. You can then use the generated model to validate your controller design and generate code for real-time control applications.

For more information, see [Generate Simulink Model from MPC Designer](#).


mpcqpSolver Command: Develop and generate code for custom model predictive controllers using KWIK quadratic programming solver

You can use the new `mpcqpSolver` command to develop custom model predictive controllers. Use the new `mpcqpSolverOptions` command to specify additional solver options.

You can also use `mpcqpSolver` as a general purpose QP solver that supports code generation.

For more information, see [Solve Custom MPC Quadratic Programming Problem and Generate Code](#).

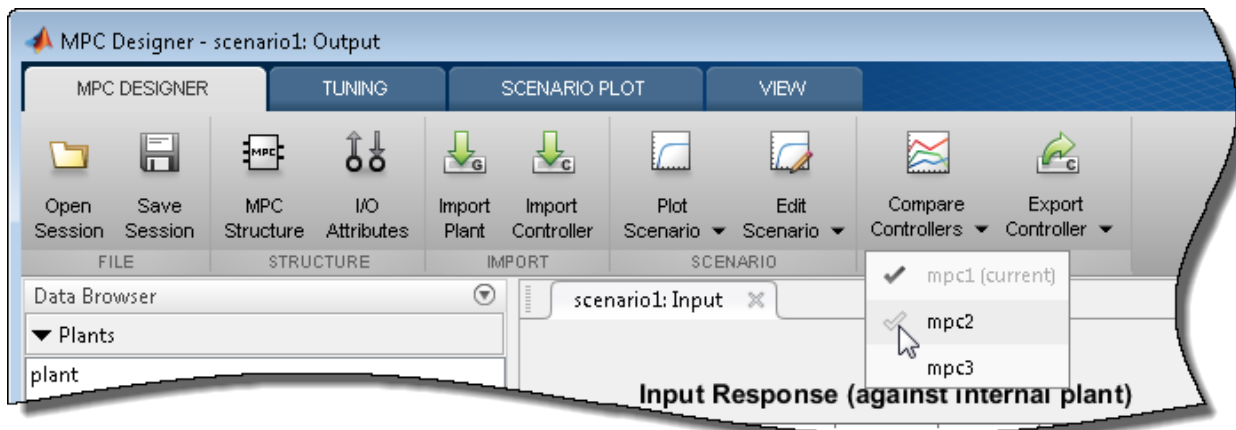
Review model predictive controller design using MPC Designer app

You can now review your model predictive controllers for potential run-time stability and numerical problems from within the **MPC Designer** app. To review the design of your current controller, on the **Tuning** tab, click **Review Design** .



For more information on reviewing model predictive controller designs, see [review and Review Model Predictive Controller for Stability and Robustness Issues](#).

Comparison of responses for multiple model predictive controllers in the same plot using MPC Designer app

You can now simultaneously compare the response plots for multiple model predictive controllers using the **MPC Designer** app. On the **MPC Designer** tab, in the **Compare Controllers** drop-down list, select the controllers to compare.



You can add additional controllers to the MPC Designer **Data Browser** by:

- Importing a controller from the MATLAB workspace — Select **Import Controller** .
- Copying the current controller — Select **Store Controller** .

For more information, see Compare Multiple Controller Responses Using MPC Designer.

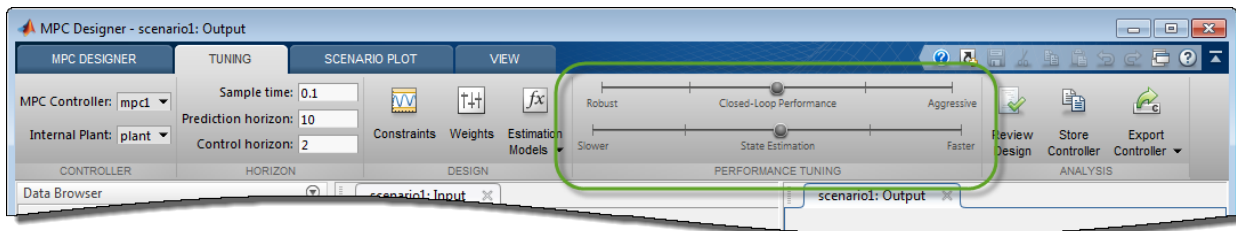
Interactive tuning of model predictive controller performance objectives

You can now tune controller performance objectives using interactive sliders. On the **Tuning** tab, use the **Performance Tuning** sliders to adjust the following:

- **Closed-Loop Performance** objective — Moving towards more aggressive control simultaneously increases OV/MV weights and decreases MV Rate weights, which leads to tighter control of outputs and more aggressive control moves. Moving towards more

robust control decreases OV/MV weights and increases MV Rate weights, which leads to relaxed control of outputs and more conservative control moves.

- **State Estimation** speed — Moving towards faster state estimation simultaneously increases the gains for disturbance models and decreases the gains for noise models, which leads to more aggressive disturbance rejection. Moving towards slower state estimation decreases the gains for disturbance models and increases the gains for noise models, which leads to more conservative disturbance rejection.



mpctool command renamed to mpcDesigner

The `mpctool` command has been renamed. Starting in R2015b, open the **MPC Designer** app using the new `mpcDesigner` command.

For more information, see [MPC Designer](#).

Compatibility Considerations

If you have scripts or functions that use `mpctool`, consider replacing those calls with `mpcDesigner`.

Functionality being removed or changed

Functionality	Result	Use This Instead	Compatibility Considerations
<code>mpctool</code>	Warns	<code>mpcDesigner</code>	Consider replacing <code>mpctool</code> with <code>mpcDesigner</code> .

R2015a

Version: 5.0.1

New Features

Bug Fixes

Compatibility Considerations

OutputVariables Integrator property of MPC controller being removed

The MPC controller property `OutputVariables(i).Integrator`, or `OV(i).Integrator`, is being removed. Previously, you specified custom integrator gains in the default output disturbance model using `OV(i).Integrator`. Starting in R2015a, you directly specify a custom output disturbance model as shown:

```
% Define a 2-by-2 plant model with no direct feedthrough
Plant = rss(2,2,2);
Plant.D = 0;
% Create an MPC object
MPCobj = mpc(Plant,1);
% Retrieve the default output disturbance model
Dmodel = getoutdist(MPCobj);
% Change the integrator gains
Dmodel = Dmodel * [2 0;0 3];
% Use new disturbance model in MPCobj
setoutdist(MPCobj, 'model', Dmodel)
```

Compatibility Considerations

If your code uses the `OV(i).Integrator` property, you can update your code to use `setoutdist` and `getoutdist` for managing MPC controller output disturbance models.

For example, replace:

```
MPCobj.OV(1).Integrator = 2;
MPCobj.OV(2).Integrator = 3;
```

with:

```
Dmodel = getoutdist(MPCobj);
Dmodel = Dmodel * [2 0;0 3];
setoutdist(MPCobj, 'model', Dmodel)
```

Use `tf(getoutdist(MPCobj))` to validate that the results are equivalent.

setoutdist command 'remove' syntax being removed

The `setoutdist(MPCobj, 'remove', channels)` syntax is being removed. Previously, you removed integrators from particular channels in the output disturbance model using

this syntax. Starting in R2015a, you directly specify a custom output disturbance model as shown:

```
% Define a 2-by-2 plant model with no direct feedthrough
Plant = rss(2,2,2);
Plant.D = 0;
% Create an MPC object
MPCobj = mpc(Plant,1);
% Retrieve the default output disturbance model
Dmodel = getoutdist(MPCobj);
% Remove the output disturbance model from output #1
Dmodel = sminreal([0;Dmodel(2,2)]);
% Use new disturbance model in MPCobj
setoutdist(MPCobj, 'model', Dmodel)
```

When removing integrators from output disturbance channels, use `sminreal` to make the custom model structurally minimal.

Compatibility Considerations

If your code uses the `setoutdist(MPCobj, 'remove', channels)` syntax, you can update your code to use `setoutdist` and `getoutdist` for managing MPC controller output disturbance models.

For example, replace:

```
setoutdist(MPCobj, 'remove', 1)
```

with:

```
Dmodel = getoutdist(MPCobj);
Dmodel = sminreal([0;Dmodel(2,2)]);
setoutdist(MPCobj, 'model', Dmodel)
```

Use `tf(getoutdist(MPCobj))` to validate that the results are equivalent.

Functionality being removed or changed

Functionality	What Happens When You Use This Functionality?	Use This Instead	Compatibility Considerations
<code>MPCobj.OV(i).-Integrator = value</code>	Warns	<code>setoutdist(MPCobj, 'model', sys)</code>	Use <code>setoutdist(MPCobj, 'model', sys)</code> to define custom output disturbance models. For more information, see “OutputVariables Integrator property of MPC controller being removed” on page 7-2
<code>value = MPCobj.OV(i).Integrator</code>	Warns	<code>sys = getoutdist(MPCobj)</code>	Use <code>getoutdist(MPCobj)</code> to retrieve MPC output disturbance models. For more information, see “OutputVariables Integrator property of MPC controller being removed” on page 7-2
<code>setoutdist(MPCobj, 'remove', channels)</code>	Warns	<code>setoutdist(MPCobj, 'model', sys)</code>	Use <code>setoutdist(MPCobj, 'model', sys)</code> to define custom output disturbance models. For more information, see “setoutdist command 'remove' syntax being removed” on page 7-2

R2014b

Version: 5.0

New Features

Bug Fixes

Compatibility Considerations

Explicit MPC control for applications with fast sample times using precomputed solutions

You can now design, simulate and deploy explicit MPC controllers for your plant. This functionality is useful for applications with fast sample times using pre-computed solutions.

To obtain an explicit MPC controller, you must first design a traditional MPC (also called implicit MPC) that is able to achieve your control objectives. Use the `generateExplicitMPC` command to design explicit MPC controllers. Use the `mpcmoveExplicit` command and the Explicit MPC Controller block to simulate explicit MPC controllers at the command-line and in Simulink, respectively.

For more information, see the following examples:

- Explicit MPC Control of a Single-Input-Single-Output Plant
- Explicit MPC Control of an Aircraft with Unstable Poles
- Explicit MPC Control of DC Servomotor with Constraint on Unmeasured Output

Adaptive MPC control through run-time changes to internal plant model

You can now simulate and deploy adaptive MPC controllers for your plant. This functionality helps you control a nonlinear plant across a wide operating range when the new linear plant model is available at run time.

To obtain an adaptive MPC controller, you must first design a traditional MPC (also called implicit MPC) that is able to achieve your control objectives at the initial operating condition. Then, update the internal plant model at each control interval at run time. Use the `mpcmoveAdaptive` command and the Adaptive MPC Controller block to simulate adaptive MPC controllers at the command-line and in Simulink, respectively.

For more information, see the following examples:

- Adaptive MPC Control of Nonlinear Chemical Reactor Using Successive Linearization
- Adaptive MPC Control of Nonlinear Chemical Reactor Using Online Model Estimation

ScaleFactor property for MPC controllers, for making weight tuning independent of the engineering units of input and output variables

You can now specify scale factor in MPC controller in engineering units. The scale factors make weights dimensionless. Choosing proper scale factors, i.e. the operating ranges of the variable, makes weight tuning much easier. The default value of this property is 1.

For more information, see [Using Scale Factor to Facilitate Weight Tuning](#).

Option to use custom state estimation or measured state values instead of the built-in state estimation in MPC controllers

In addition to built-in state estimation, MPC controllers can now run custom state estimation. You can specify the state estimation mode by using `setEstimator(mpcobj, 'default')` and `setEstimator(mpcobj, 'custom')`, respectively.

When using custom state estimation, you can use the `Plant`, `Disturbance` and `Noise` properties of the controller state object `mpcstate` to provide custom state values at each control interval. The values can be from direct state measurements or your own state estimation algorithm. You must not programmatically change the `LastMV` property in the `mpcstate` object because it is still automatically updated by `mpcmove`.

For more information, see [Using Custom State Estimation](#).

Compatibility Considerations

If your code changes the `LastMV` property of the state object to provide an external MV at run time, you must update the code to use `mpcmoveopt` and specify the value in the `mpcmoveopt.MVused` field instead.

If your code uses the `Plant`, `Disturbance` and `Noise` properties of the state object to provide external state values, you must use `setEstimator(mpcobj, 'custom')` to specify the controller to use the custom estimation mode before control starts.

Option to specify manipulated variable target

You can now specify targets on the manipulated variables during run time. At the command line, specify the value in the `MVTarget` field of the `mpcmoveopt` object. In the MPC controller blocks, select **Targets on manipulated variables (`mv.target`)** in the **Online Features** tab of the dialog box.

For more information, see [Setting Targets for Manipulated Variables](#).

Run-time weight tuning on manipulated variables

You can now specify weights on the manipulated variables during run time. At the command line, specify the value in the `MVWeights` field of the `mpcmoveopt` object. In the MPC controller blocks, select **Weights on manipulated variables (`u,wt`)** in the **Online Features** tab of the dialog box.

For more information, see [Setting Targets for Manipulated Variables](#).

Run-time weight tuning and performance monitoring in Multiple MPC Controllers block

You use the Multiple MPC Controllers block to implement gain-scheduled MPC control strategy by switching between multiple MPC controllers. You can now use this block to perform all the tasks that you perform with the MPC Controller block, such as online weight tuning, custom state estimation and performance monitoring.

getEstimator and setEstimator commands to obtain and change state estimation parameters

You can now use `getEstimator` to obtain the Kalman filter gains `L` and `M`, and additional parameters of the following observer equation used by the MPC controller:

$$y_m[n|n-1] = C_m * x[n|n-1] + D_v * v[n]$$

$$x[n|n] = x[n|n-1] + M * (y_m[n] - y_m[n|n-1])$$

$$x[n+1|n] = A * x[n|n-1] + B_u * u[n] + B_v * v[n] + L * (y_m[n] - y_m[n|n-1])$$

Similarly, use `setEstimator` to change the parameters. For more information, see the `getEstimator` and `setEstimator` reference pages.

Compatibility Considerations

`getestim` and `setestim` commands warn and will be removed in a future release. Follow the instructions in the warning message to replace all instances with `getEstimator` and `setEstimator`.

Definition of external MV signal changed

The definition of externally supplied MV signals has been changed from $u[k]$ to $u[k-1]$. This implies that MPC controller now expects the external MV signal to be measured at the previous control interval $k-1$ and not at the current interval k .

Compatibility Considerations

If you enabled the `ext.mv` inport in the MPC Controller or Multiple MPC Controllers block, do the following:

- If the connected signal does not come from the same MPC block, add a unit delay or memory block to the signal so that it is converted from $u[k]$ to $u[k-1]$.
- If the connected signal comes directly from the `mv` output of the same MPC block, you see a warning about algebraic loop. To remove the warning, add a unit delay or memory block in the loop.

There is no incompatibility when you use `mpcmove` at the command prompt.

Unconnected input and output limits inports default changed to match mpc object

You can add inports (`umin`, `umax`, `ymin`, `ymax`) to the MPC controller blocks that you can connect to run-time constraint signals.

- If a channel is unconstrained in the `mpc` object, it remains unconstrained even if the inport is connected and the provided value is ignored.
- If a channel is constrained, the original constraint specified in the `mpc` object is used when the corresponding inport is unconnected.

Compatibility Considerations

Previously, when unconnected, MPC Controller block assumed the online constraint are unbounded ($\pm \infty$). In this release, the simulation output may differ from previous releases because of the change in defaults

R2014a

Version: 4.2

New Features

Bug Fixes

IEC 61131-3 Structured Text generation from MPC Controller and Multiple MPC Controllers blocks using Simulink PLC Coder

The MPC Controller and Multiple MPC Controllers blocks support generation of IEC 61131-3 Structured Text using Simulink PLC Coder. You can verify the generated code using the CoDeSys version 2.3 IDE.

For an example of Structured Text generation for an MPC controller see, [Simulation and Structured Text Generation Using PLC Coder](#).

Reduced RAM usage for C code generated for MPC Controller and Multiple MPC Controllers blocks

The C code generated for the MPC Controller and Multiple MPC Controllers blocks reduces RAM usage. This change includes improved handling of memory allocation. For example, now the generated code does not use dynamic memory allocation, thereby extending support to targets that disallow dynamic memory allocation.

Estimate of data memory size used by deployed MPC controller at run time

You can determine if the data memory size required by an MPC controller exceeds the physical memory of the target system. The report generated by the `review` command now includes a platform-independent estimate of the data memory usage of an MPC controller at run time.

For an example, see [Review Model Predictive Controller for Stability and Robustness Issues](#).

R2013b

Version: 4.1.3

New Features

Bug Fixes

Controller design for plant and disturbance models with internal delays

You can now design model predictive controllers for plant models, input (unmeasured) disturbance models, and output disturbance models that have internal delays. Previously, the software supported only input, output, or transport delays for plant and disturbance models.

When designing the MPC controller, the software discretizes the plant and disturbance models to the controller sample time. The software replaces each model delay of K sampling periods with K poles at $z = 0$. This delay absorption increases the model order, which increases the controller order.

If the models contain significant delays, you must specify an appropriate controller sample time. If the controller sample time is too large, you may not achieve the desired controller performance. However, if you sample a model that contains delays too fast, delay absorption leads to a high-order controller. Such a controller can have a large memory footprint, which can cause difficulty if you generate code for a real-time target. Also, high-order controllers can have numerical precision issues.

For more information regarding internal delays, see [Internal Delays](#). To learn more about specifying a plant model, see [Plant Specification](#). To specify the input disturbance model and the output disturbance model, see `setindist` and `setoutdist`.

Single-precision simulation and code generation using MPC Controller and Multiple MPC Controllers blocks

You can now specify the output data type for the MPC Controller and Multiple MPC Controllers blocks as `single`. This change provides the ability to simulate and generate code for model predictive controllers to be used on single-precision targets. Previously, these blocks supported only double-precision outputs.

To specify the output data type, in the block dialog, use the **Output data type** drop-down list.

For more information, see [Simulation and Code Generation Using MPC Controller Block](#), [MPC Controller](#), and [Multiple MPC Controllers](#).

Conditional execution of MPC Controller and Multiple MPC Controllers blocks using Function-Call Subsystem and Triggered Subsystem blocks

MPC Controller and Multiple MPC Controllers blocks can now inherit the parent subsystem's sample time. Therefore, you can conditionally execute these blocks using the Function-Call Subsystem or Triggered Subsystem blocks.

To specify that the output sample time be inherited, in the block dialog, select the **Block uses inherited sample time (-1)** check box.

Note When you place an MPC controller inside a Function-Call Subsystem or Triggered Subsystem block, you must execute the subsystem at the controller's design sample rate. You may see unexpected results if you use an alternate sample rate.

For more information, see Using MPC Controller Block Inside Function-Call and Triggered Subsystems, MPC Controller, and Multiple MPC Controllers.

R2013a

Version: 4.1.2

Bug Fixes

R2012b

Version: 4.1.1

Bug Fixes

R2012a

Version: 4.1

New Features

Bug Fixes

Compatibility Considerations

Run-Time Preview of Reference and Measured Disturbance Signals with MPC Controller Block

This release introduces the ability to preview signals by using the **ref** and **md** inports of the MPC Controller block and the Multiple MPC Controllers block.

The **ref** inport now accepts an N-by-Ny signal, where N is the number of previewing steps and Ny is the number of plant outputs.

The **md** inport now accepts an N-by-Nmd signal, where N is the number of previewing steps and Nmd is the number of measured disturbances.

You cannot preview if the input signal is a vector, unless Ny or Nmd, as appropriate, is 1.

For more information, see:

- Improving Control Performance with Look-Ahead (Previewing)
- Chemical Reactor with Multiple Operating Points

Compatibility Considerations

In the current release, if you have models with the MPC Controller block or the Multiple MPC Controllers block, you will see a warning if your blocks contain:

- A **custom reference signal** specified in the MATLAB workspace.
- A **custom disturbance signal** specified in the MATLAB workspace.

Custom Reference Signal Specified in MATLAB Workspace

You must clear this warning. If you ignore the warning, the block will assume that the **ref** signal is zero. This behavior is equivalent to leaving the **ref** inport unconnected.

- **Without Look-Ahead (Previewing) Option.** To eliminate this warning:
 - 1 Add a From Workspace block to your model.
 - 2 Specify your reference signal variable name as the **Data** parameter of the From Workspace block.
 - 3 Connect the output of the From Workspace block to the **ref** inport of the MPC Controller block or the Multiple MPC Controllers block.

-
- **With Look-Ahead (Previewing) Option.** To eliminate this warning:
 - 1 Copy the Reference Previewer block from the `mpc_preview` model and place it in your model. See Improving Control Performance with Look-Ahead (Previewing) for more information.
 - 2 Specify your reference signal variable name as the **Signal** parameter of the Reference Previewer block. Also specify appropriate values for the **Sampling time** and **Number of previewing steps** parameters.
 - 3 Connect the output of the Reference Previewer block to the **ref** inport of the MPC Controller block or the Multiple MPC Controllers block.

Custom Disturbance Signal Specified in MATLAB Workspace

You must clear this warning. If you ignore the warning, the block will assume that the `md` signal is zero. This behavior is equivalent to leaving the `md` inport unconnected.

- **Without Look-Ahead (Previewing) Option.** To eliminate this warning:
 - 1 Add a From Workspace block to your model.
 - 2 Specify your disturbance signal variable name as the **Data** parameter of the From Workspace block.
 - 3 Connect the output of the From Workspace block to the **md** inport of the MPC Controller block or the Multiple MPC Controllers block.
- **With Look-Ahead (Previewing) Option.** To eliminate this warning:
 - 1 Copy the Measured Disturbance Previewer block from the `mpc_preview` model, and place it in your model. See Improving Control Performance with Look-Ahead (Previewing) for more information.
 - 2 Specify your measured disturbance signal variable name as the **Signal** parameter of the Reference Previewer block. Also specify appropriate values for the **Sampling time** and **Number of previewing steps** parameters.
 - 3 Connect the output of the Measured Disturbance Previewer block to the **md** inport of the MPC Controller block or the Multiple MPC Controllers block.

R2011b

Version: 4.0

New Features

Bug Fixes

Compatibility Considerations

C Code Generation Improvements for All Targets with MPC Controller Block

The MPC Controller block has been re-implemented using a MATLAB Function block and now supports code generation for all Simulink Coder targets.

For more information, see Code Generation with Simulink Coder.

Faster QP Solver Algorithm for Improving MPC Controller Performance

This release implements a new quadratic problem (QP) solver that uses the KWIK algorithm. KWIK is faster and more numerically robust than the previous solver for ill-conditioned QP problems. You can use this solver without default constraints on decision variables.

For more information, see MPC QP Solver.

Run-Time Weight Tuning and Constraint Softening for MPC Controller

This release introduces three new run-time tuning parameters for the MPC Controller block:

- **Weights on plant outputs**
- **Weights on manipulated variables rate**
- **Weight on overall constraints softening**

You can use these parameters to tune the weights on plant outputs, manipulated variables rate, and overall constraint softening. These capabilities are available in real time, without redesigning or re-implementing the MPC controller, and help adjust the controller performance.

For more information, see Tuning Controller Weights.

You can also use an `mpcmovopt` object as an input to `mpcmove` to tune the weights and constraints.

For more information, see the following:

-
- Switching Controllers Based on Optimal Costs
 - Varying Input and Output Constraints

Run-Time Monitoring of MPC Controller Performance to Detect When an Optimal Solution Cannot Not Be Found

This release introduces a new output parameter—**Optimization status** in the MPC Controller block. You can use this output to monitor the status of the optimization and take the necessary action when an optimal solution cannot be found. For more information, see [Monitoring Optimization Status to Detect Controller Failures](#).

You can also use the `Info.QPCode` field of the output of `mpcmove` to monitor the status of the optimization.

For more information, see the `mpcmove` reference page.

review Command for Diagnosing Issues with MPC Controller Parameters That Could Lead to Run-Time Failures

You can now use `review` to detect potential stability and robustness issues (both offline and at run time) with an MPC Controller design. The following aspects of the system are inspected:

- Stability of the model predictive controller and the closed loop
- Potential for contradictory settings in the specified constraints and mitigation of an ill-conditioned QP problem by softening constraints
- Validity of QP Hessian matrix

Use this command before implementing the MPC Controller, in conjunction with simulation.

For more information, see the following:

- `review` reference
- [Reviewing Model Predictive Controller Design for Potential Stability and Robustness Issues](#).

mpcmove Returns Aligned Time Horizons for Optimal Control, Predicted Output and Estimated State

mpcmove now returns Info with a time horizon of $t=k, \dots, k+p$, where k is the current time and p is the prediction horizon for the following fields:

- Info.Uopt — Optimal manipulated variable adjustments
- Info.Yopt — Predicted output
- Info.Xopt — Predicted state
- Info.Topt — Time horizon

You can now plot Info.Uopt, Info.Yopt and Info.Xopt using Info.Topt as the time vector.

For more information, see the mpcmove reference page.

Functionality Being Removed or Changed

Functionality	What Happens When You Use This Functionality?	Use This Instead	Compatibility Considerations
getmpcdata	Still runs	<ul style="list-style-type: none"> • get • getconstraint • getestim • getindist • getoutdist 	Not applicable
pack	Still runs	Not applicable	Not applicable
qpdantz	Warns	quadprog (requires Optimization Toolbox)	Replace all instances of qpdantz with quadprog.

Functionality	What Happens When You Use This Functionality?	Use This Instead	Compatibility Considerations
setmpcdata	Still runs	<ul style="list-style-type: none">• set• setconstraint• setestim• setindist• setoutdist	Not applicable

R2011a

Version: 3.3

New Features

Bug Fixes

Support for Custom Constraints on MPC Controller Inputs and Outputs

In addition to upper and lower bounds, you can now specify constraints on linear combinations of an MPC controller inputs ($u(t)$) and outputs ($y(t)$). Specify custom constraints, such as $u_1 + u_2 < 1$ or $u + y < 2$, in the `mpc` object using `setconstraint`.

For more information, see:

- Custom Constraints on Inputs and Outputs
- Custom Constraints in a Blending Process
- MPC Control with Constraints on a Combination of Input and Output Signals demo

Ability to Specify Terminal Constraints and Weights on MPC Controller

You can now specify weights and constraints on the terminal predicted states of an MPC controller.

Using terminal weights, you can achieve infinite horizon control. For example, you can design an unconstrained MPC controller that behaves in exactly the same way as a Linear-Quadratic Regulator (LQR). You can use terminal constraints as an alternative way to achieve closed-loop stability by defining a terminal region.

You can specify both weights and constraints using the `setterminal` command.

For more information, see:

- Terminal Weights and Constraints
- Using Terminal Penalty to Provide LQR Performance
- Implementing Infinite-Horizon LQR by Setting Terminal Weights in a Finite-Horizon MPC Formulation demo

Ability to Access Optimal Cost and Optimal Control Sequence

This release introduces two new parameters **Enable optimal cost output** and **Enable control sequence output** in the MPC Controller block. Using these parameters, you can access the optimal cost and control sequence along the prediction horizon. This information helps you analyze control performance.

You can also access the optimal cost and control sequence programmatically using the new `Cost` and `Yopt` fields, respectively, of the structure `info` returned by `mpcmove`.

For more information on using optimal cost and control sequence, see the following demos:

- MPC Control with Input Quantization Based on Comparing the Optimal Costs
- Analysis of Control Sequences Optimized by MPC on a Double Integrator System

R2010b

Version: 3.2.1

No New Features or Changes

R2010a

Version: 3.2

New Features

Bug Fixes

New Ability to Analyze SISO Generalized Predictive Controllers (GPC)

You can now use `gpc2mpc` to convert your SISO GPC controller to an MPC controller. Analyze and simulate the resulting MPC controller using available Model Predictive Control Toolbox commands.

For more information, see the `gpc2mpc` reference page.

R2009b

Version: 3.1.1

Bug Fixes

R2009a

Version: 3.1

New Features

Bug Fixes

New Sensitivity Analysis to Determine Effect of Weights on Tuning MPC Controllers

You can now perform sensitivity analysis to determine the effect of weights on the closed-loop performance of your system. You can perform sensitivity analysis using the following:

- MPC Tuning Advisor. See Tuning Advisor in the *Model Predictive Control User's Guide*.
- `sensitivity` command. See the sensitivity reference page.

R2008b

Version: 3.0

New Features

Bug Fixes

New Multiple MPC Controllers Block in the Model Predictive Control Toolbox Simulink Library

You can now use the Multiple MPC Controllers block in Simulink software to control a nonlinear process over a range of operating points. You include an MPC controller for each operating point in the Multiple MPC Controllers block and specify switching between these controllers in real-time based on the input scheduling signal to the block. If you need to change the design of a specific controller, you can open the MPC Design Tool GUI directly from the Multiple MPC Controllers block.

During model simulation, Model Predictive Control Toolbox provides bumpless transfer when the system transitions between operating points.

To learn more about configuring the new block, see the Multiple MPC Controllers block reference page.

Tested Code Generation Support for Real-Time Workshop Target Systems

After designing an MPC controller in Simulink software using the MPC Controller block, you can use Real-Time Workshop® software to build this controller and deploy it to the following target systems for real-time control:

- Generic Real-Time Target
- Real-Time Workshop Embedded Coder™
- Real-Time Windows Target
- Rapid Simulation Target
- Target Support Package FM5
- xPC Target
- dSpace Target
- Target for Infineon TriCore

The following target systems are either not supported or not recommended because they result in significant performance issues:

- Embedded Target for TI C2000 DSP
- Embedded Target for TI C6000 DSP

-
- Target Support Package IC1 (for Infineon C166)
 - Tornado (VxWorks) Real-Time Target

Note The Multiple MPC Controllers block has not been tested with the target systems supported by Real-Time Workshop software.

Ability to Design Controllers with Time-Varying Weights and Constraints Using the GUI

While you design an MPC controller using the MPC Design Tool graphical user interface (GUI), you can specify time-varying weights and constraints for manipulated variables, rate of change of manipulated variables, and output variables. In the previous version, you could only specify the time-varying weights and constraints at the command line.

Furthermore, you can load an MPC controller with time-varying information from the command line into the MPC Design Tool GUI.

To learn more about the new options in the MPC Design Tool GUI, see the Model Predictive Control Toolbox documentation.

R2008a

Version: 2.3.1

No New Features or Changes

R2007b

Version: 2.3

New Features

New Option for Specifying Time-Varying Constraints

You can now configure the Model Predictive Controller block in Simulink to accept time-varying constraint signals that are generated by other blocks. To add inports to which you can connect time-varying constraint specifications, select the new **Enable input port for input and output limits** check box in the MPC Controller block. See also the `mpcvarbounds` demo.

In the previous version, you could only specify the constraints during the design phase and these constraints remained constant for the duration of the simulation.

For more information about the new **Enable input port for input and output limits** check box in the Model Predictive Controller block, see the MPC Controller block reference page.

Ability to Specify Nondiagonal Q and R Weight Matrices in the Cost Function

You can now specify off-diagonal weights in the cost function. In the previous release, only diagonal Q and R matrices were supported.

To learn more about specifying off-diagonal weights, see the discussion about weights in the MPC Controller block reference pages.

To access a new demo that shows how to use nondiagonal weight matrices, type the following command at the MATLAB prompt:

```
showdemo('mpcweightsdemo')
```

R2007a

Version: 2.2.4

Bug Fixes

R2006b

Version: 2.2.3

No New Features or Changes

R2006a

Version: 2.2.2

New Features

Bumpless Transfer Added to MPC Block

Bumpless transfer between manual and automatic operation or from one controller to another has been added to the Model Predictive Controller block in Simulink. This block now allows feedback of the true manipulated variable signals, which allows the controller to maintain an accurate state estimate during periods when its calculated adjustments are not being sent to the plant. For example, the controller's output might be ignored during a startup period or during temporary intervention by a (simulated) plant operator. If the controller assumes that its adjustments are being implemented (the default behavior), its state estimate will be incorrect, leading to a “bump” when the controller is reconnected to the plant. A tutorial example has been added to the documentation.

New Bumpless Transfer Demo

A new demo illustrating bumpless transfer has been added to the toolbox.

R14SP3

Version: 2.2.1

No New Features or Changes

R14SP2

Version: 2.2

No New Features or Changes

