BAE SYSTEMS

Weapon System Fault Detection, Isolation, and Analysis using Stateflow®

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Agenda

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- The challenge
- Types of faults
- Fault detection, isolation, and analysis
- Benefits of Stateflow®

System Overview

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- Non-Line of Sight Cannon (NLOS Cannon) Concept Technology Demonstrator (CTD)
  - Proof-of-principle test-bed
  - Drawing board to fully operational demonstrator in 7 months

- NLOS Cannon is part of the Future Combat Systems (FCS) family of Manned Ground Vehicles (MGV)
  - Begin initial production by 2008 with initial NLOS Cannon fielding by 2012
  - 27-ton, large-caliber, self-propelled cannon system with automated ammunition handling

The Challenge

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- Maximize code reuse while supporting the following additional requirements
  - Propellant carried on vehicle increased by 10%
  - Firing rate increased by 66%
  - Support Multi Round Simultaneous Impact (MRSI) capability
  - Redesign propellant handling system
  - Support next-generation of servo motor controllers

Software Overview

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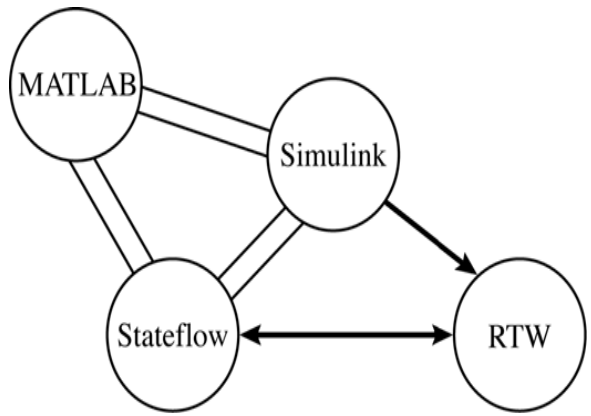
- MATLAB® and Simulink ®
  - Modeling of algorithmic behavior, control system development and analysis
  - Model-Based Design, plant models
- Stateflow
  - Modeling of logic behavior
  - Fault detection, isolation and analysis
- Real-Time Workshop
  - Automatic code generation
  - Hardware in the loop integration and test
  - Requirements development
  - Document design



Types of faults

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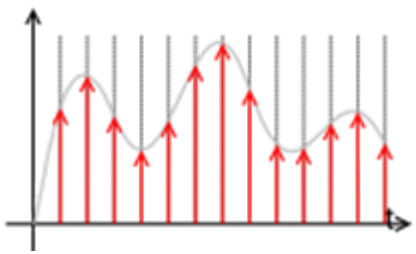
- Analog Signals
  - Monitoring for out of range condition, higher or lower than a predetermined threshold
- Resolver Signals
  - Monitoring for correct alignment, stroke length, move completion, and position errors
- Discrete Signals
  - Monitoring health of subsystems and electronics, including interlocks, switches, and other discrete feedback



Fault Detection

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- Sensor signals
  - Hardware -> Simulink -> Stateflow
- Sensor signals monitored continuously for satisfactory conditions
- Using parallel state charts, each fault condition is checked every sample time
- Sensor faults are monitored and reported independently

Fault Detection Overview

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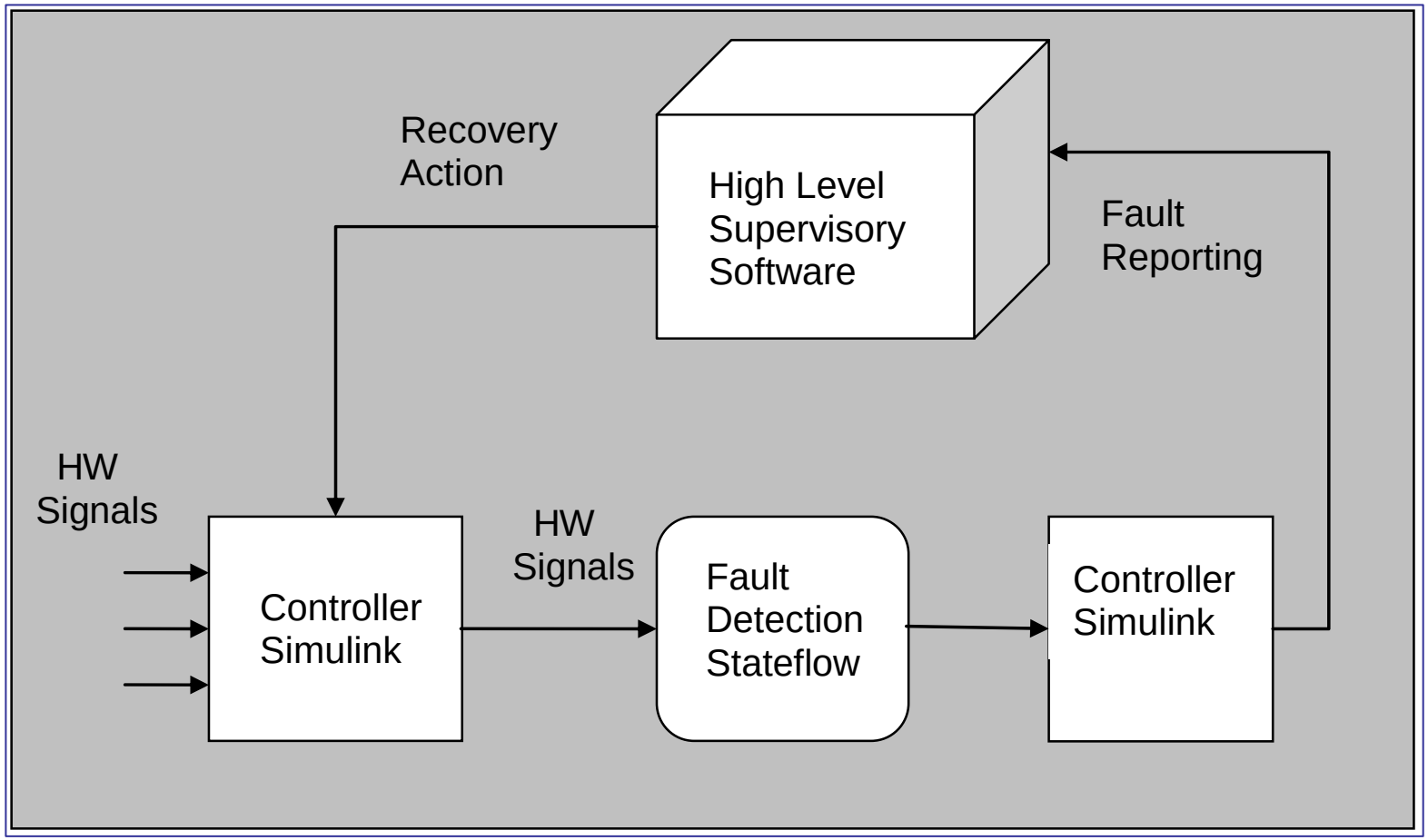

Fault Detection

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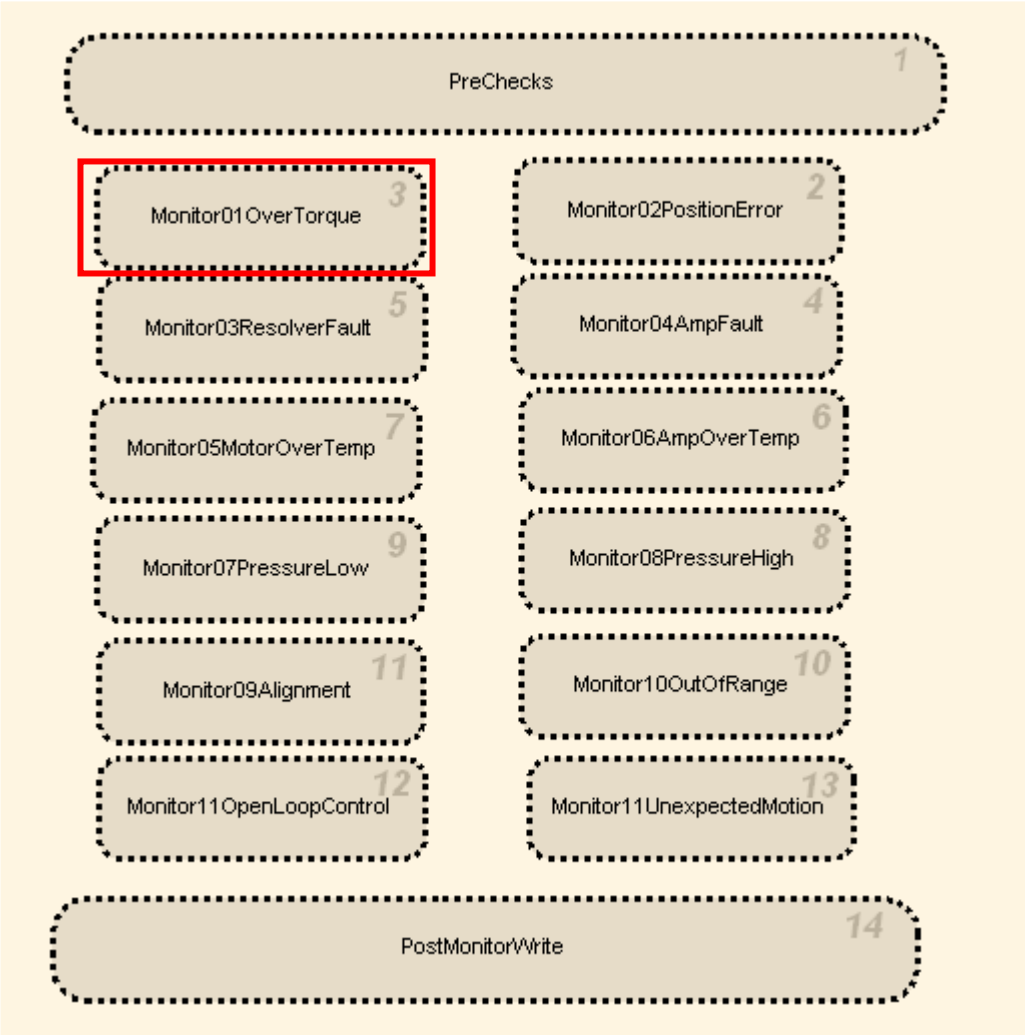
- Fault monitors labeled and organized
- Faults isolated



Fault Detection

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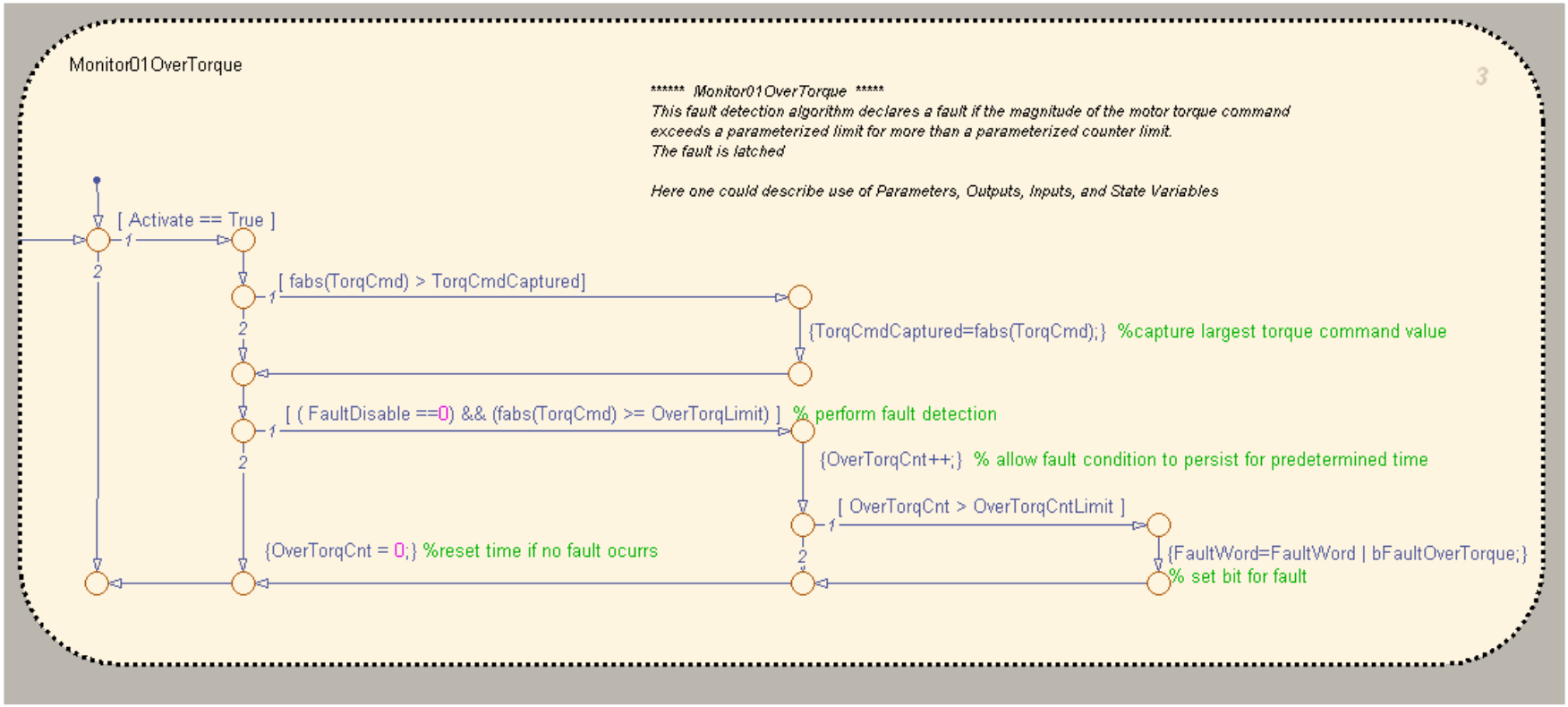

Fault Detection

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- Faults can be triggered with timing constraints specific to the sensor or measurement
  - i.e. Allow analog signal A to be out of range for no more than 20 ms while signal B can be out of range for 2 ms
- Failure modes can be constructed using complex logic on multiple signals
  - i.e. (Analog Signal A > Predetermined threshold) AND (Discrete Signal B == 1)
- Pre-check logic can set and reset flags that will skip specific faults according to user settings or current conditions in system
  - i.e. Check for fault condition only if fault check is not disabled
  - i.e. Check only if drive is active and aligned

Fault Isolation and Analysis

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- Faults are reported to higher level controller for isolation and further analysis
  - Each sensor checked for fault
  - Controller determines failure mode i.e. collision, improper use, working device outside of limits, electronics problems
  - Controller determines course of action i.e. E-Stop or warning
  - Fault is isolated and relayed to GUI for user action
    - Fault stays triggered until explicitly reset by controller
- Ability to log events for later playback and diagnosis off-line

Fault Recovery

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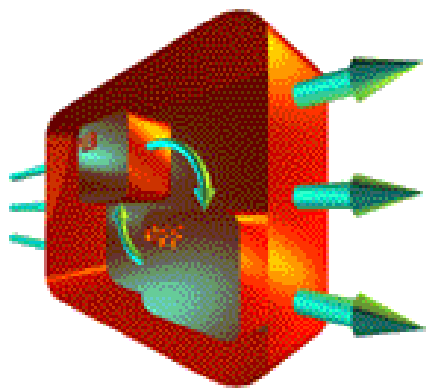
- User receives notification of fault through higher level supervisory software, decides course of action i.e. fault reset
- Reset logic is fed back through the controller to Simulink, then to the fault monitor in Stateflow
- The fault reset signal goes into the fault monitor which clears the fault



Stateflow Benefits

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- Fault monitor Stateflow chart can be saved in a library, allowing for code reuse

- Graphical representation helps to locate faults and bugs faster
  - Fault detection states are organized and easy to find
  - The logic transitions allow others besides the programmer to understand and debug code

- Comparison to hand code
  - Stateflow provides a natural graphical environment for complex logic transitions
  - Flow charts and parallel states are easier to implement, understand and maintain
  - Animation of transitions allows user to verify detection logic during development

Stateflow Benefits

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- Seamless integration with…
  - MATLAB and Simulink
  - Systems Integration software and hardware
    - Data acquisition hardware (analog and digital)
  - Graphical User Interface development software
  - Hardware and software used for rapid prototyping and hardware in the loop simulations
- Decrease in software development time of 80%
- Stateflow and Real-Time Workshop suite can be used to
  - Develop requirements
  - Document design
  - Support testing
  - Automatically generate portable C code

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Q and A