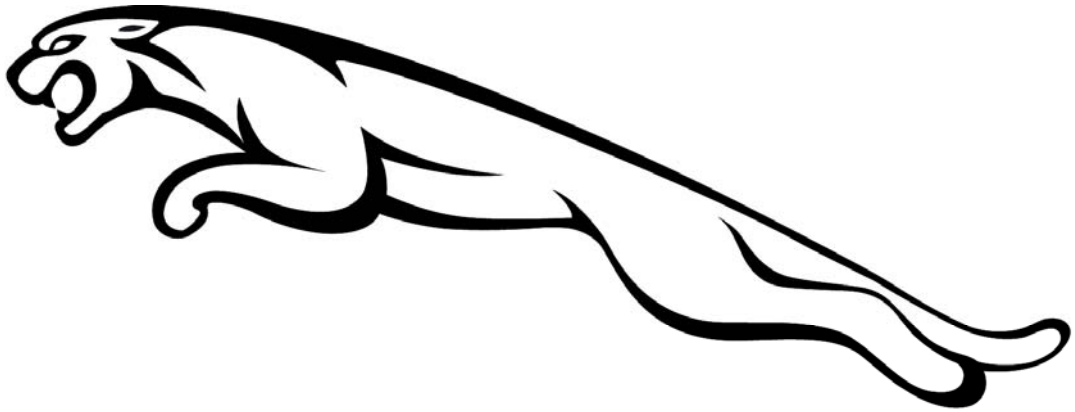

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Design and Calibration of the Jaguar XK Adaptive Cruise Control System

Tim Jagger

MathWorks International Automotive Conference 2006

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JAGUAR XK

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ADAPTIVE CRUISE CONTROL(ACC) MODEL BASED CALIBRATION

- Adaptive Cruise Control – The Driver's Perspective
- The Adaptive Cruise Control System – Control Aspects
- Jaguar XK Adaptive Cruise Control System
- Jaguar XK Adaptive Cruise Control Virtual Vehicle Model
- Model Correlation
- Jaguar XK Adaptive Cruise Control Calibration Development
- Queue Assist Development

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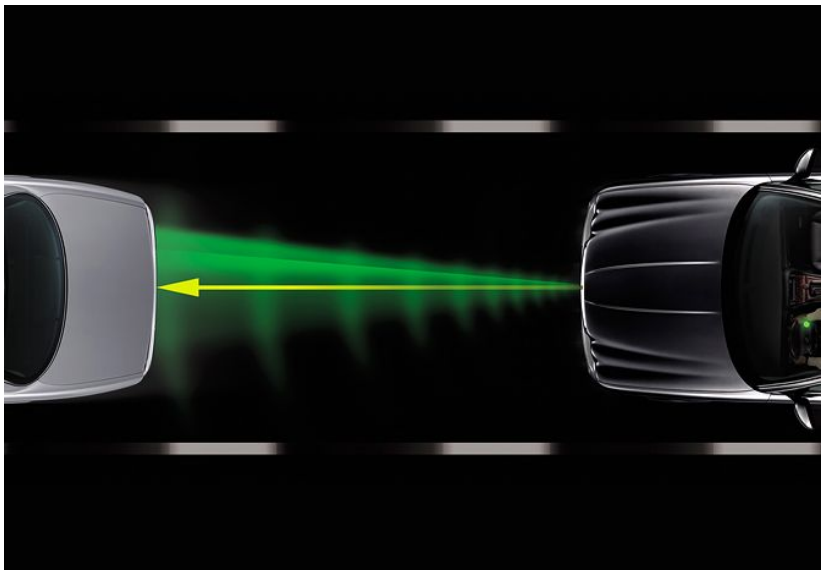
ADAPTIVE CRUISE CONTROL
THE DRIVER'S PERSPECTIVE

- Driver Comfort Feature
- Allows Host Vehicle to follow a target vehicle
- Automatically Resumes to set speed in absence of target vehicle
- Driver selects headway
- Available Headways
  - 1.0s, 1.4s, 1.8s, 2.2s
- Driver Selects Cruise Speed
  - Min. 20mph, Max. 112mph



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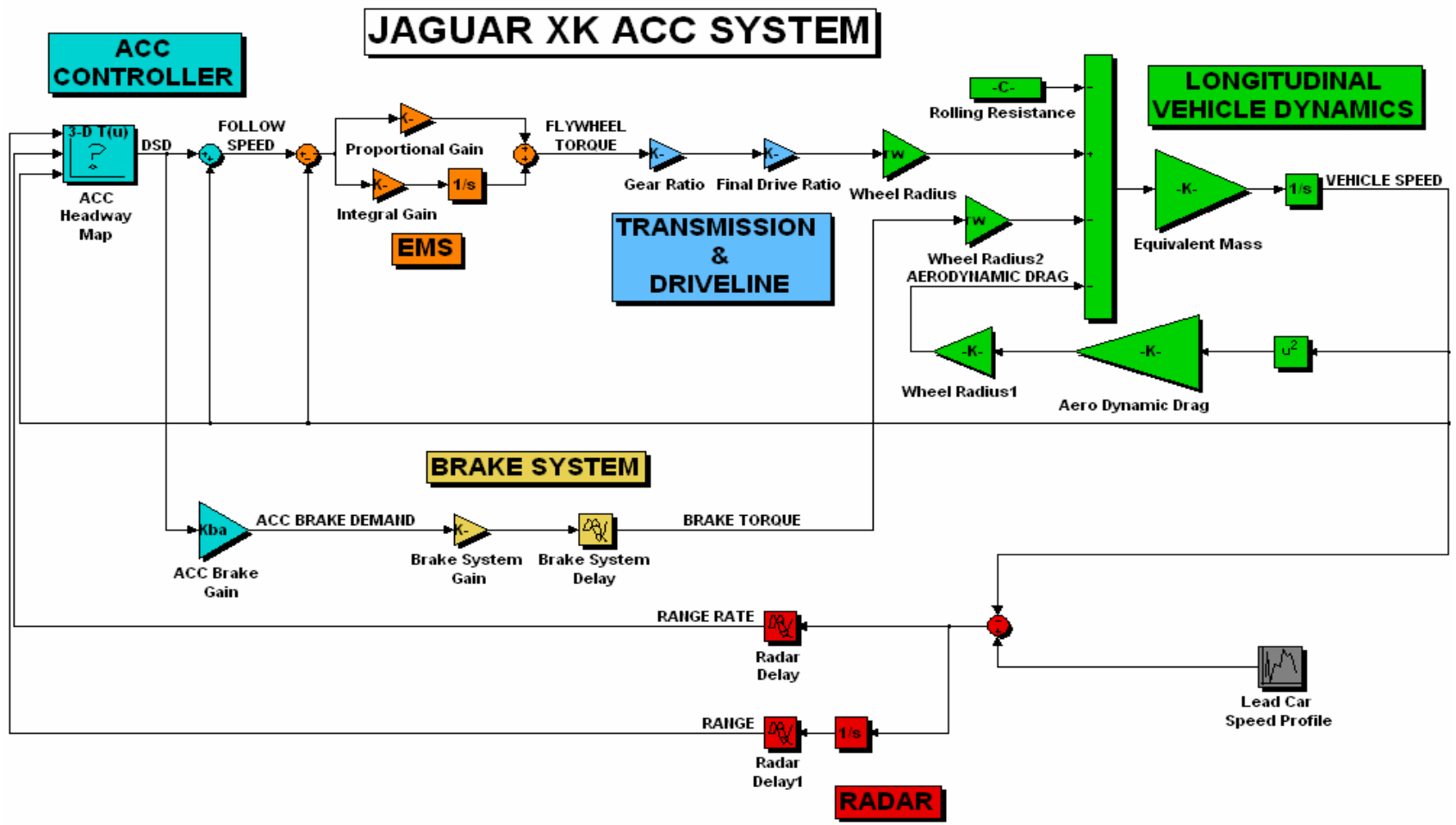
ADAPTIVE CRUISE CONTROL
CONTROL APSECTS



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JAGUAR XK ADAPTIVE CRUISE CONTROL

- New Adaptive Cruise Control Algorithms for XK
- New Features
  - Queue Assist Algorithms
  - Lead Vehicle Acceleration Algorithm (LVA)
- Initial Functional Testing – April 2005
- Initial Calibration Testing – May 2005
- Unexpected Results ….

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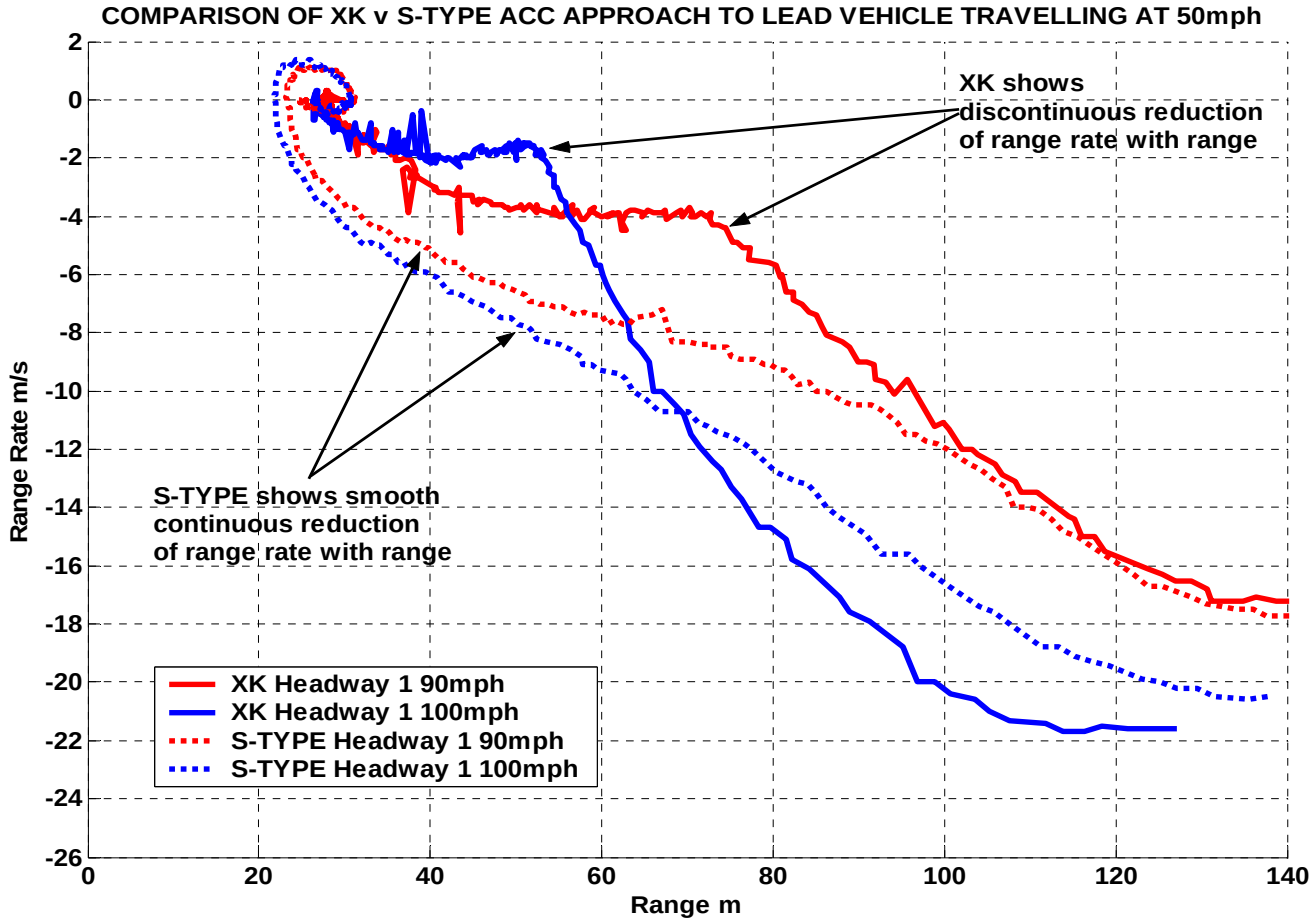
APPROACH XK v S-TYPE



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TEST & DEVELOPMENT

- Results from 1st ACC Test Session
  - Harsh Early Brake Intervention
  - LVA Algorithm gave unpredictable results
  - Generally unrefined ACC Performance
- Expectation was that XK ACC would only need small scale refining
  - Developed from ACC3

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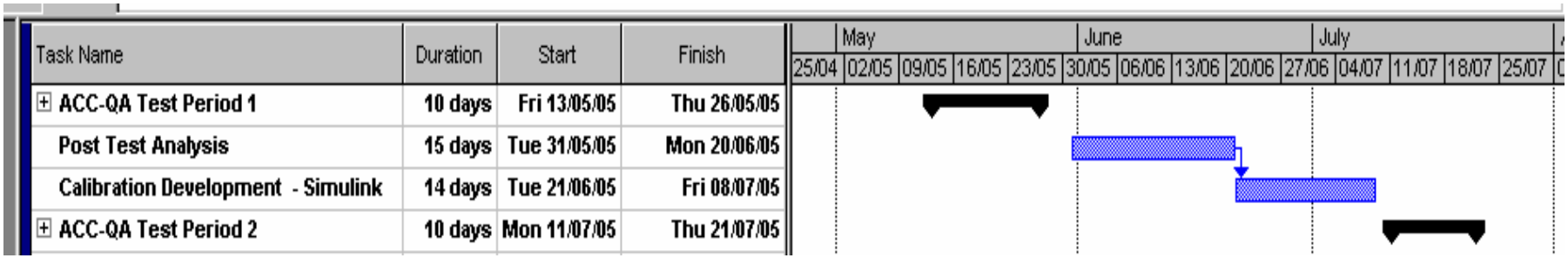
TEST & DEVELOPMENT

- In reality major development was required
- Second test period was for validation NOT development
- Tight timescales & challenging vehicle allocation



Task Name	Duration	Start	Finish
ACC-QA Test Period 1	10 days	Fri 13/05/05	Thu 26/05/05
Post Test Analysis	15 days	Tue 31/05/05	Mon 20/06/05
Calibration Development - Simulink	14 days	Tue 21/06/05	Fri 08/07/05
ACC-QA Test Period 2	10 days	Mon 11/07/05	Thu 21/07/05

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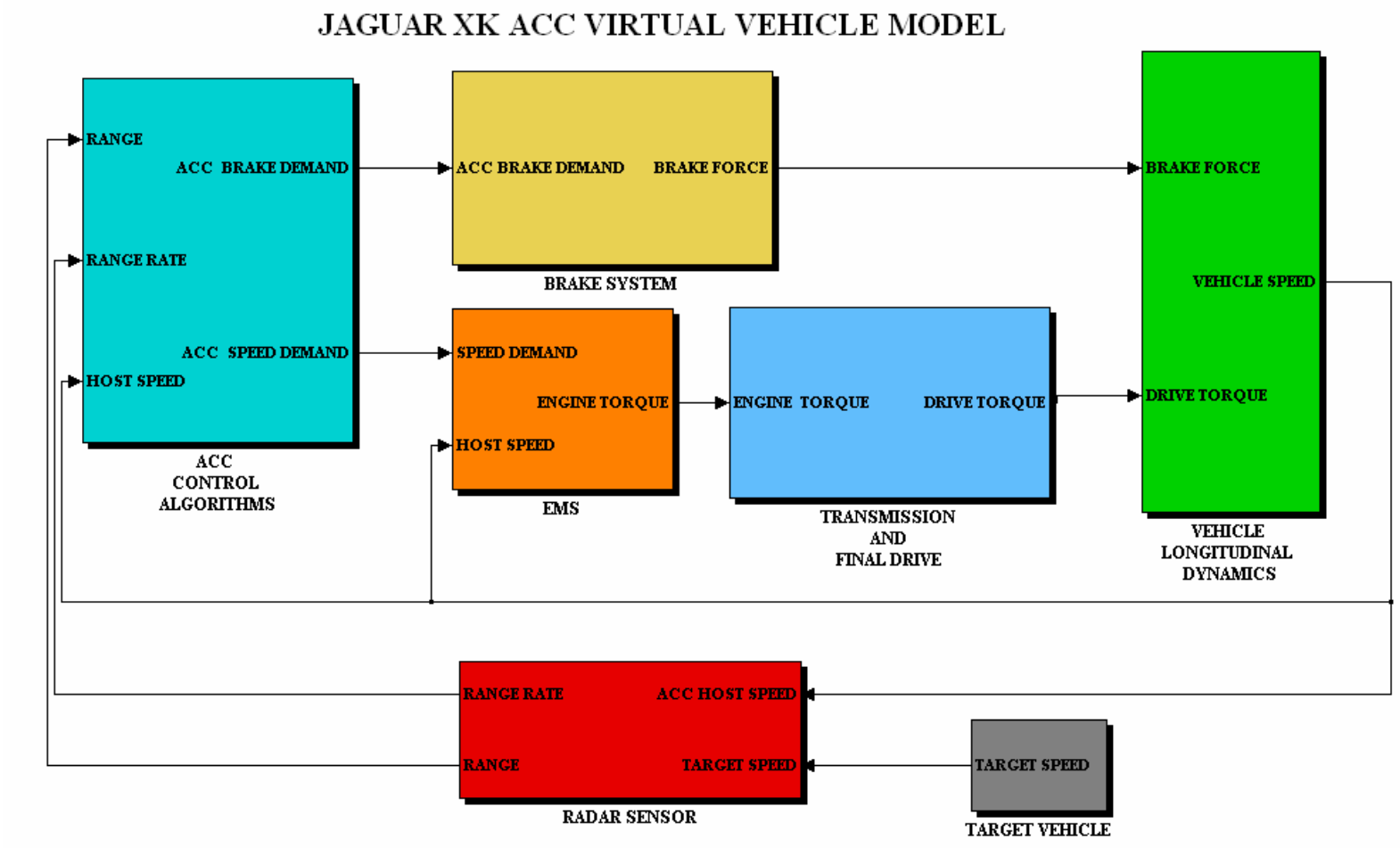
ADAPTIVE CRUISE CONTROL
VIRTUAL VEHICLE MODEL



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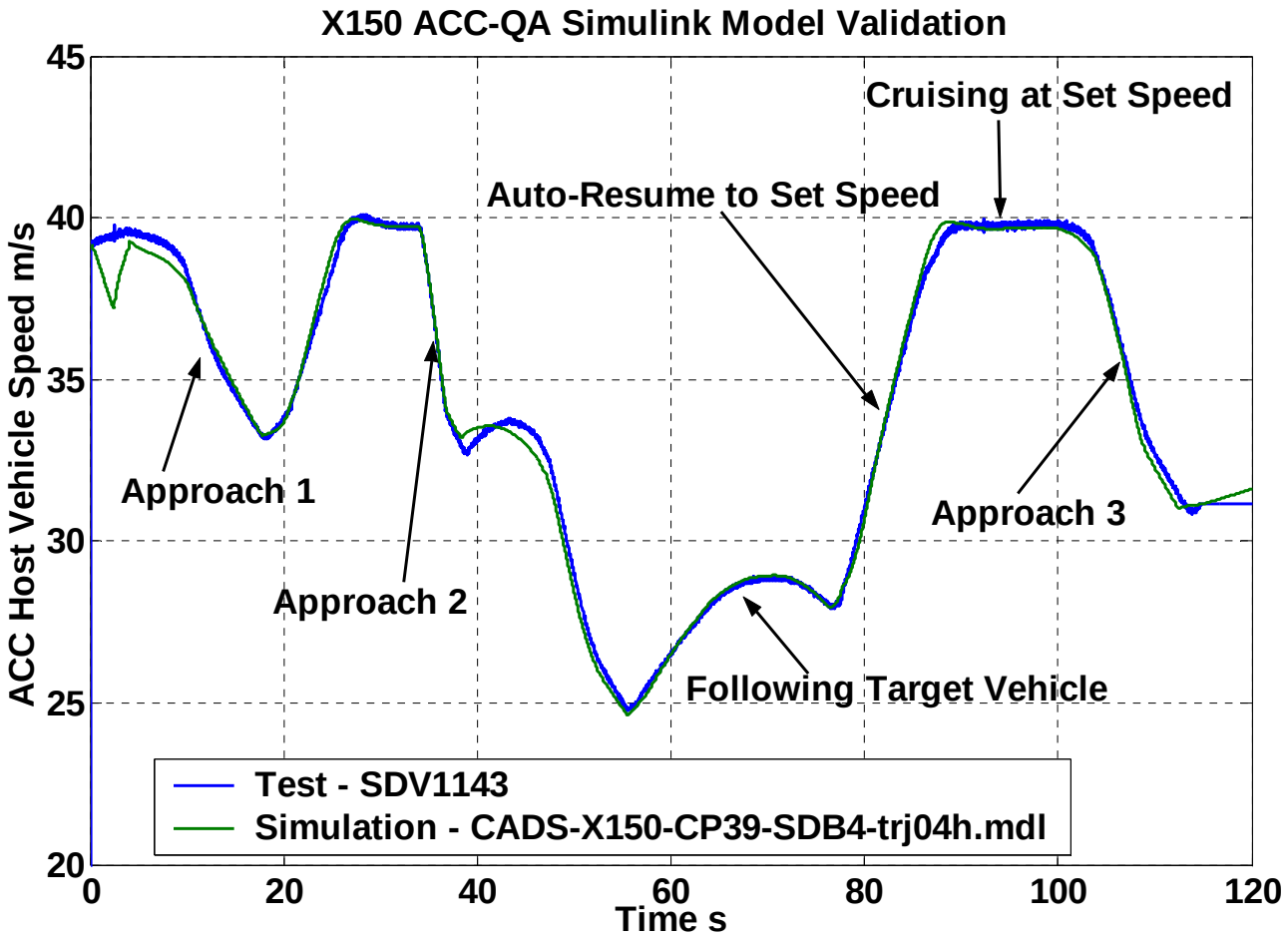
MODEL CORRELATION



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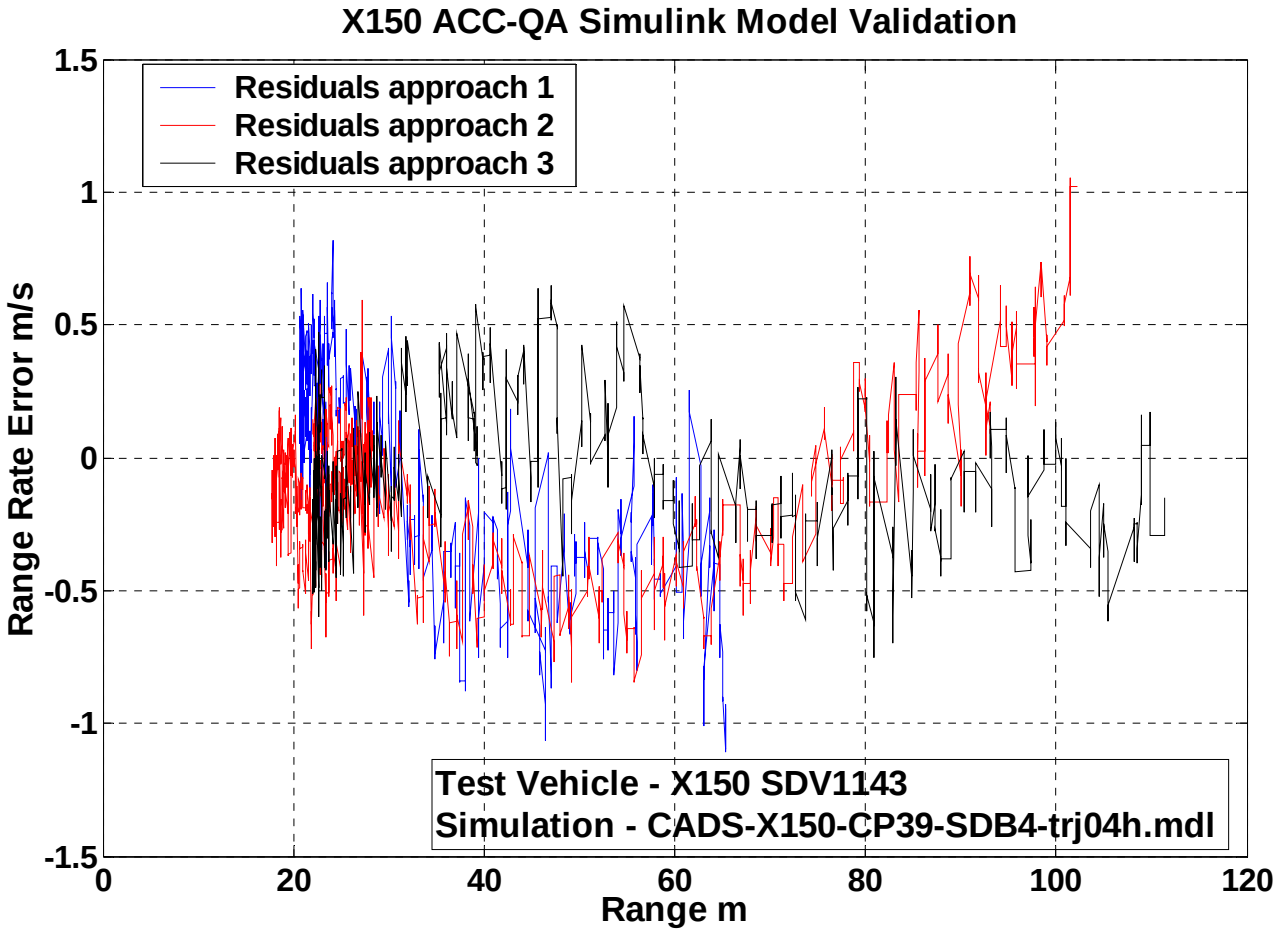
MODEL CORRELATION



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CALIBRATION DEVELOPMENT

- Test Results indicated seven parameters influenced ACC refinement
  - Lead Vehicle Acceleration Algorithm (LVA)
  - ACC brake gain
  - Brake demand slew rate
  - Time to collision gain
  - Residual Distance
  - Coast Deceleration Estimate
  - Headway Control Maps

CALIBRATION DEVELOPMENT

X150 ACC TEST MATRIX

Run No.	Headway Maps	LVA	Brake Slew Rate bar/s	Brake Pressure Gain bar/m/s^2	TTC Gain	Residual Distance	Coast Down Decel
1	X204 w/o RDB	ON	OFF	12	Default (R27)	Default (R27)	Default (R27)
2	X204 w/o RDB	OFF	RISING 12.0 FALLING 25	10.2	Default (R27)	Default (R27)	Default (R27)
3	x204 with RDB	ON	OFF	12	[0 0 0 0 0 0]	Default (R27)	Default (R27)
4	x204 with RDB	OFF	RISING 12.0 FALLING 25	10.2	Default (R27)	Default (R27)	Default (R27)
5	x204 with RDB	OFF	RISING 50.0 FALLING 50.0	12	Default (R27)	Default (R27)	Default (R27)
6	x204 with RDB	OFF	RISING 50.0 FALLING 50.0	12	Default (R27)	[20 0 0 0]	Default (R27)
7	x204 with RDB	OFF	RISING 50.0 FALLING 50.0	12	Default (R27)	Default (R27)	[0 0 0 0 0 0 0 0 0 0 0]
8	x204 with RDB	OFF	RISING 50.0 FALLING 50.0	12	Default (R27)	Default (R27)	5th gear coastdown curve X150

- Test Matrix of 8 possible ACC configurations
- 4 days per configuration to test on vehicle = 32 days vehicle testing
- Complete test matrix was evaluated by simulation in 10 days

➢ **ACC Vehicle Simulation was vital for calibration development**

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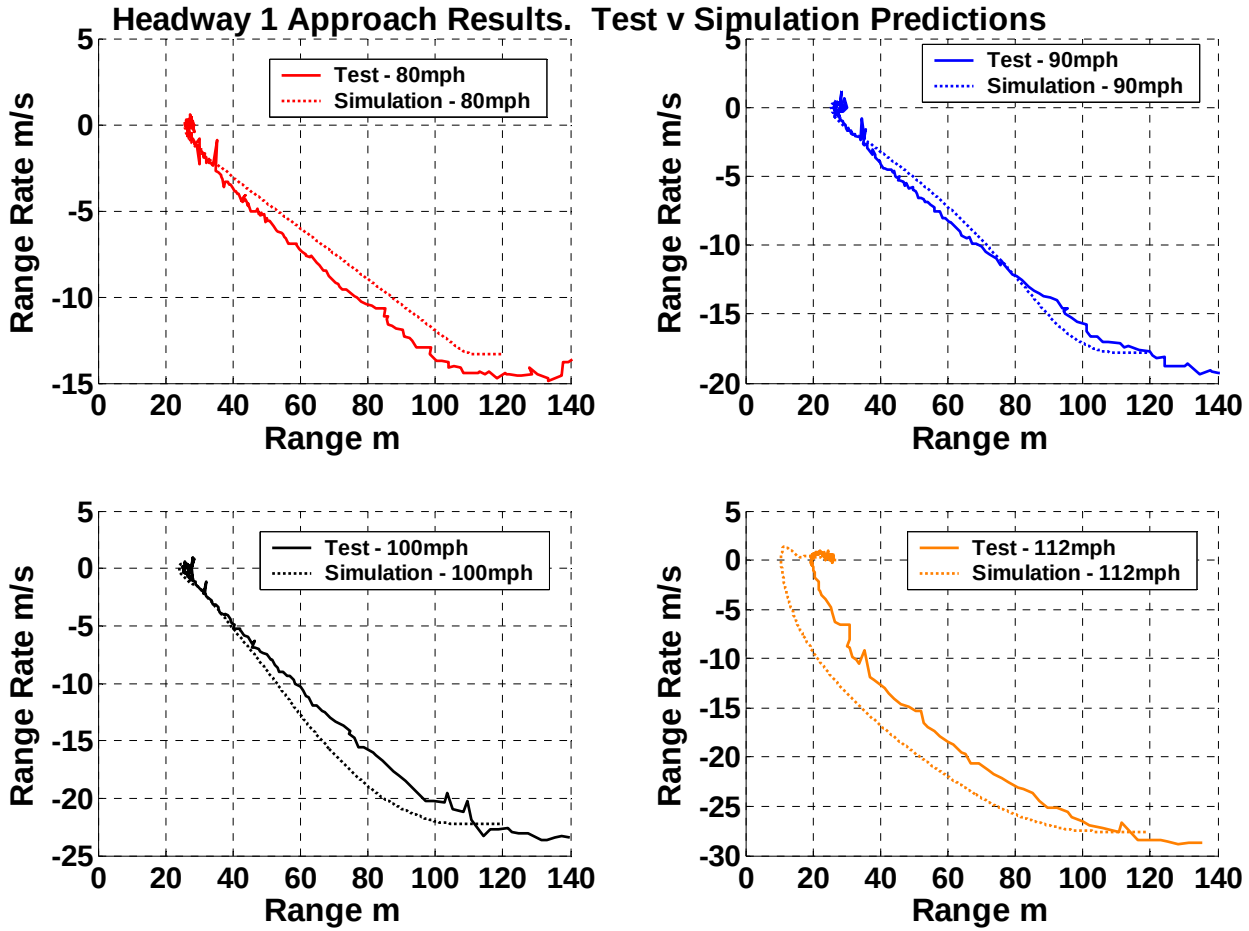
SIMULATION PREDICTIONS V TEST RESULTS



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COMPARISON OF SIMULATION PREDICTIONS WITH PRODUCTION CALIBRATIONS

X150 PREDICTED v PRODUCTION CALIBRATION

PARAMETER NAME	SIMULATION PREDICTED VALUE	X150 PRODUCTION VALUES
Headway Maps	X204 maps with range dependent braking	X204 with range dependent braking
k_select_dsd_accel_mode	1	1
k_decel_filter_enable	0	0
k_use_decel_rate	0	0
k_brake_demand_inc	**2.5**	**1.7**
k_brake_demand_dec	1	1
k_drag_decel_x	[0 8.2 19 22 25 30 35 40 45 50 55]	[0 8.2 19 22 25 30 35 40 45 50 55]
k_drag_decel_z	[0.0 0.0 0.47 0.5 0.54 0.61 0.69 0.78 0.89 1.0 1.1]	[0.0 0.0 0.47 0.5 0.54 0.61 0.69 0.78 0.89 1.0 1.1]
k_QA_residual_distance_x	[0 25 50 88]	[0 25 50 88]
k_QA_residual_distance_z	**[20 0 0 0]**	**[15 0 0 0]**
k_autobrakecancelthreshold	2.5	2.5

- Two calibrations changed from simulation to production
- Changes based on subjective driver assessment

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QUEUE ASSIST

- Extension of ACC operating range to 0mph
- Headway opened significantly at low speeds
- QA host vehicle unable to track target vehicle accelerating at a moderate rate
- Filtering of ACC Speed demand introduced significant lag

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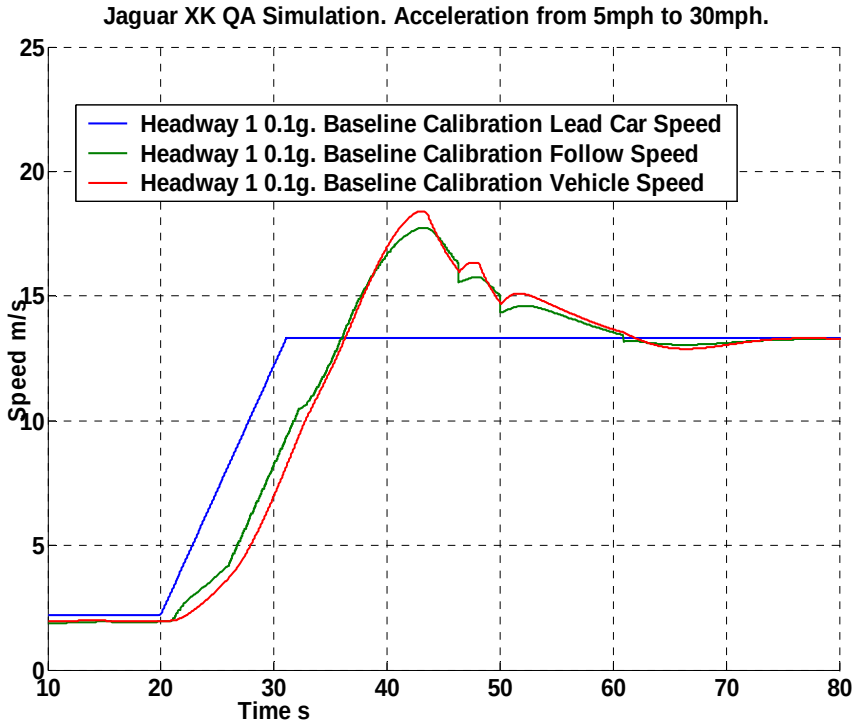
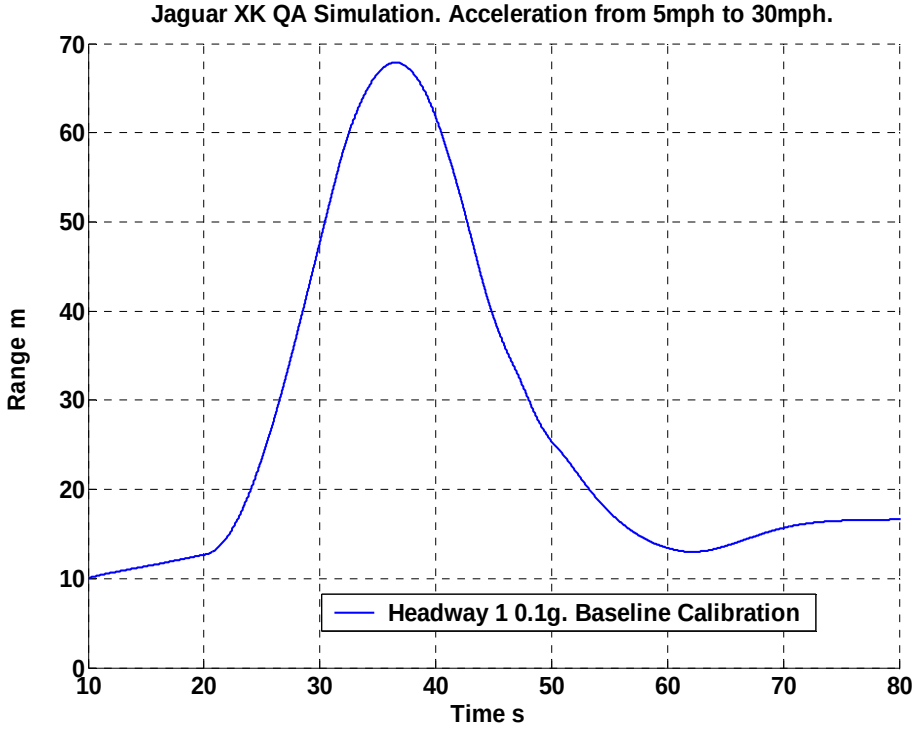
QUEUE ASSIST





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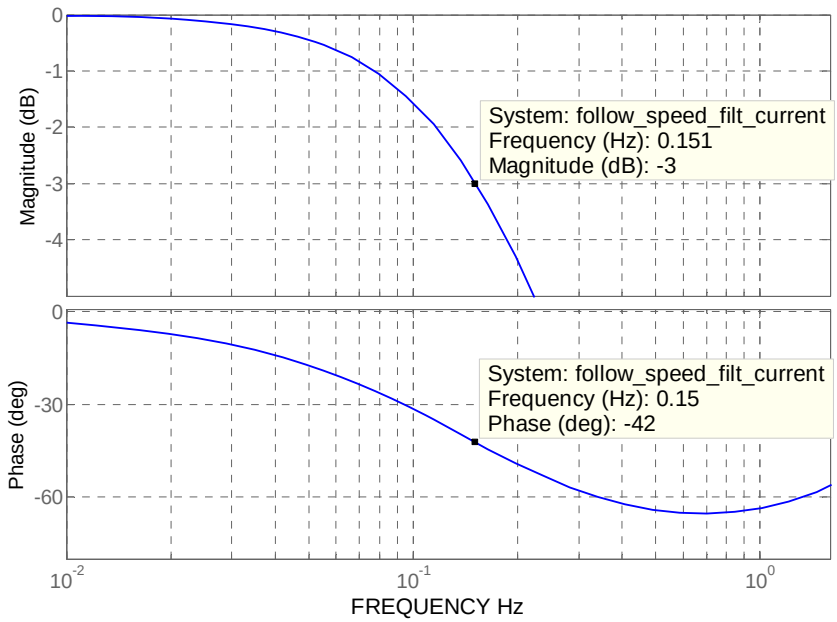
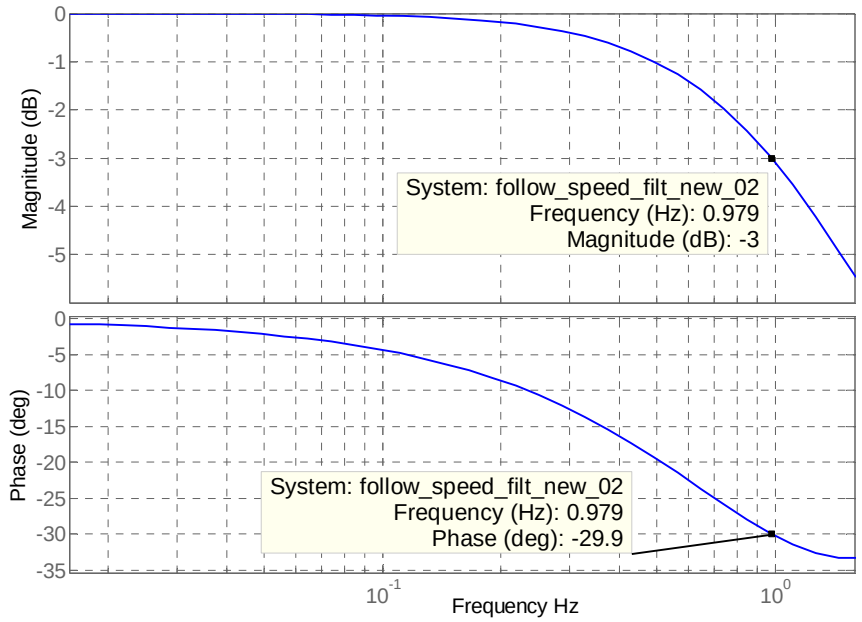
FILTER CUT-OFF FREQUENCY

- Use frequency response toolbox to re-calculate filter constant

FREQUENCY RESPONSE OF THE FOLLOW SPEED FILTER R44 CALIBRATION.



FREQUENCY RESPONSE OF FOLLOW SPEED FILTER - DESIGN 02.



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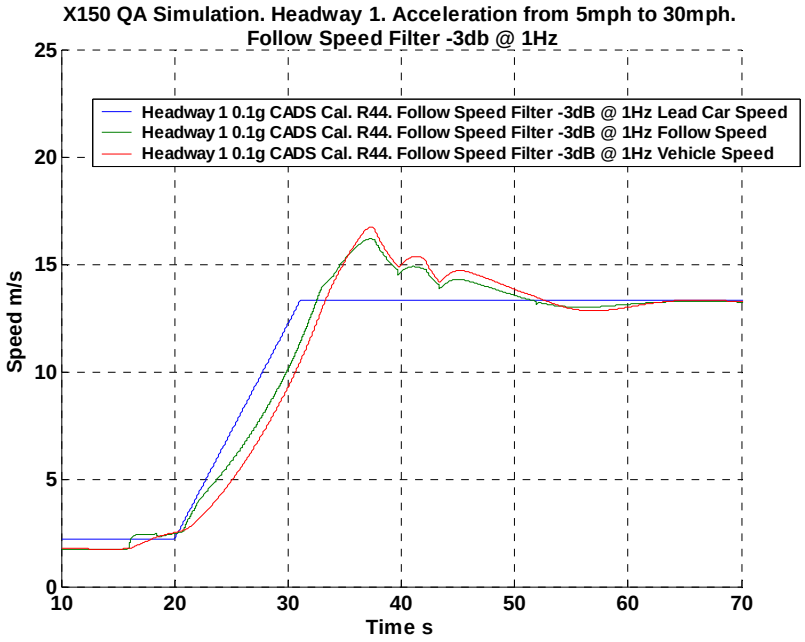
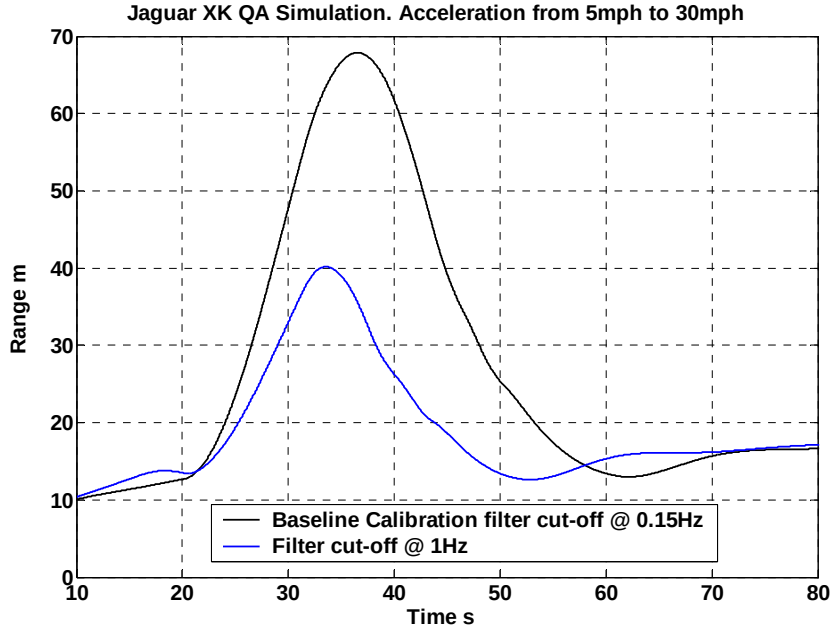
EFFECT OF NEW FILTER CONSTANT





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JAGUAR XK MODEL BASED DESIGN AND CALIBRATION

SUMMARY

- Jaguar XK ACC system modelled in simulink
- ACC Model shows good correlation with test results
- Model was used to develop Jaguar XK ACC Calibrations
- Development time per calibration loop reduced from 30 days to 10 days

  (Typically 3 - 4 calibration loops on a vehicle program)
- Vehicle test time now used for validation - not experimentation

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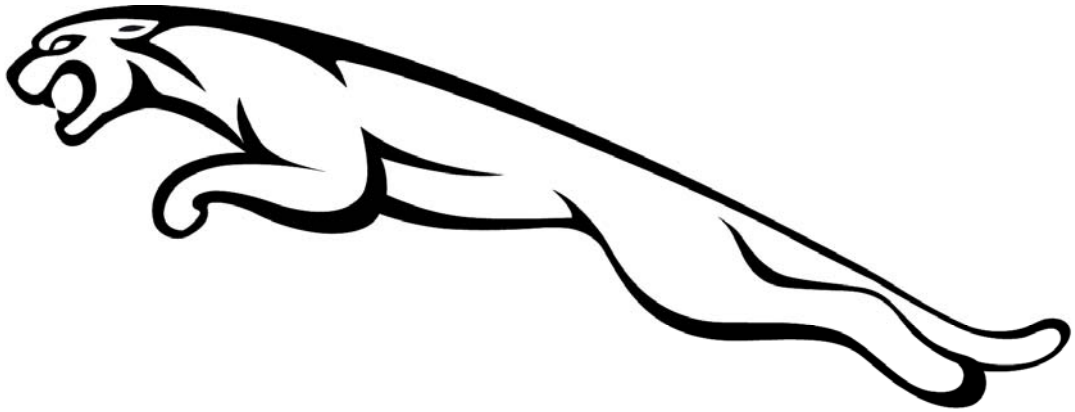

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