# ISB LTMS 2nd Edition Example

Art Andrews

May 2010
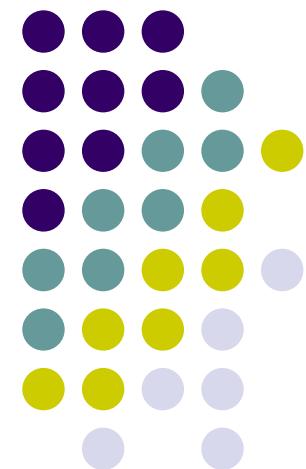
LTMS 2nd Edition Choices

1. Choose primary parameters
2. Choose acceptance criteria for new stand
   - # of initial calibration tests (currently=2 for new lab, =1 for subsequent stands)
   - Use severity EWMA fast start?
3. Choose Severity EWMA (Z) limits
   - Intent is to set these at point where oil discrimination is lost, or unit conversion between physical units and standard deviation units breaks down (Chadwick Plots)
4. Choose reference entity: lab or stand
   - In this example, entity = lab
5. Other choices
   - SA's? lambda?

Primary Parameters

- ACSW - Average Cam Shaft Wear
- ATWL - Average Tappet Weight Loss

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

| Chart Level | Limit Type | EWMA Chart | | | | Shewhart Chart | |
| | | LAMBDA | | K | | K | |
		Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.3	2.10	2.36	2.10	1.96
Industry	Warning	0.2	0.2	2.10	2.36	--	--
	Action	0.2	0.2	2.80	3.00	--	--

API CJ-4 Pass/Fail Limits

Cummins ISB

Tappet Wear, max	mg	100
Cam Wear, max	microns	55
Crosshead Weight Loss	mg	Rate & Report
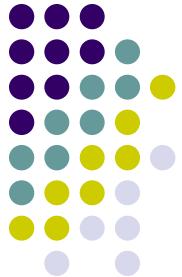
Alarms and Severity Adjustments

Current LTMS 1st Ed.

- Shewhart severity alarm is the only alarm that triggers additional reference test

- No severity adjustments are in place

- lambda = 0.3

2nd Ed.

- Includes no Shewhart severity alarm

- Relies on *e* alarms

- Option to include EWMA severity alarm

- Continuous severity adjustments

- lambda = 0.3
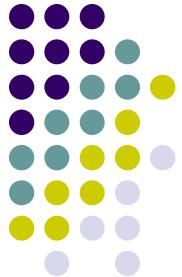
New Stand Acceptance Criteria

- LTMS 2nd Edition recommends 3 acceptable reference oil resuts for lab acceptance, and employs "fast start" principle for severity EWMA

  - Is this agreeable for ISB?

- This ISB LTMS 2nd edition example includes fast start for Z_0

TMC and ACC Reports

ISB – Report Period: APR 2010
Status Of Reported Tests

STATUS	COUNT	PERCENT
Aborted	2	12.50
Invalid	1	6.25
Valid	13	81.25
Total Reported Tests	16	100.00
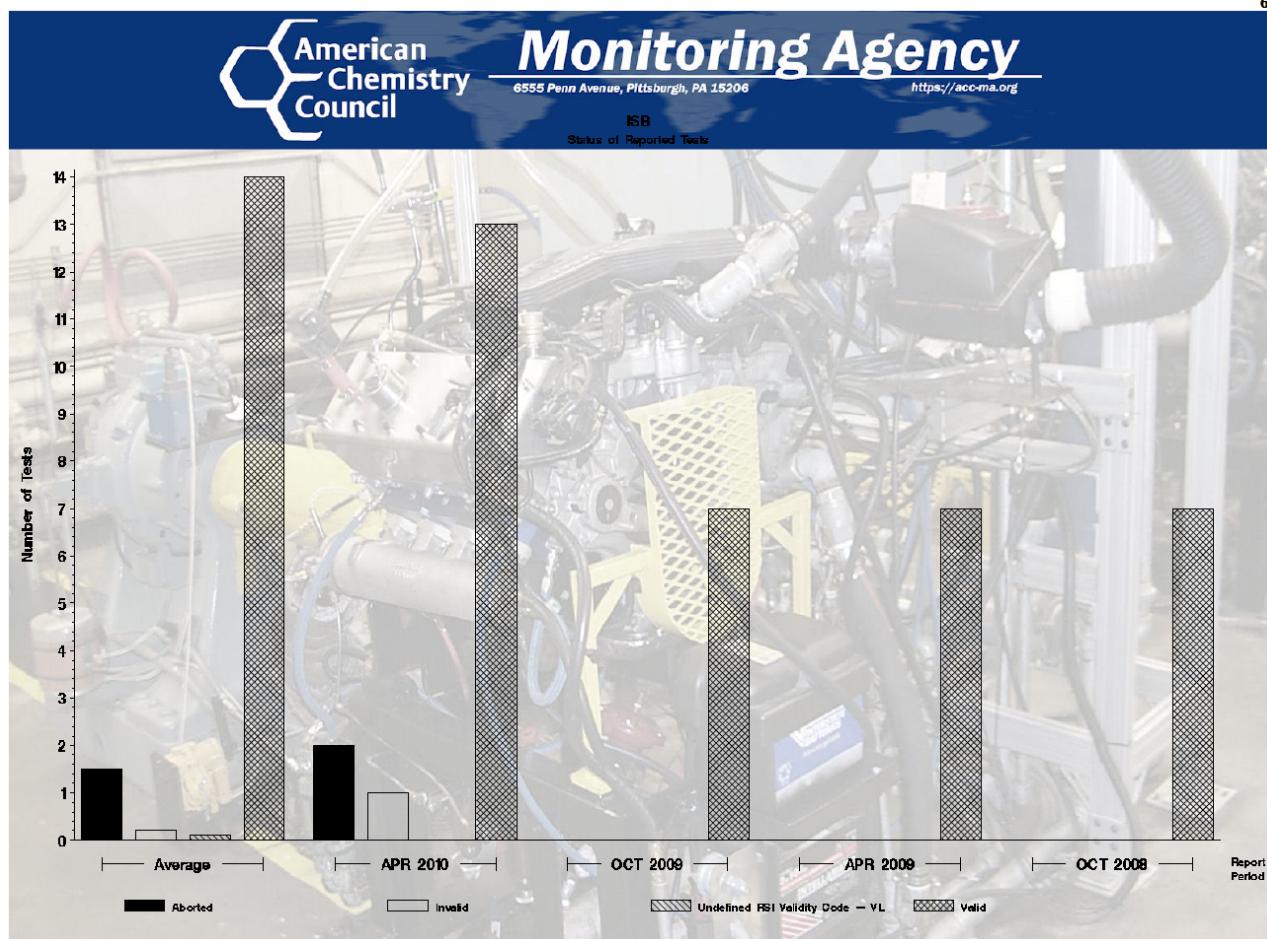
Severity Charts

ACSW

ATWL

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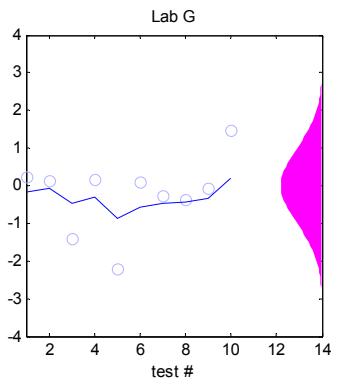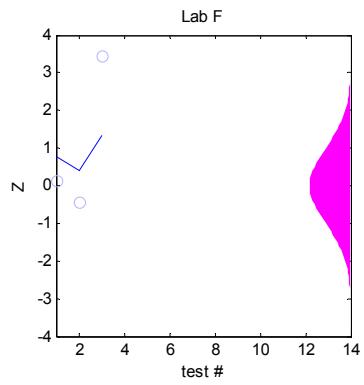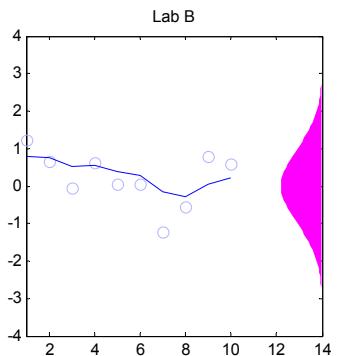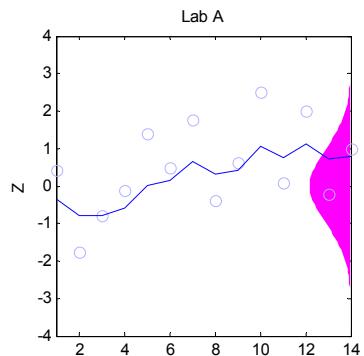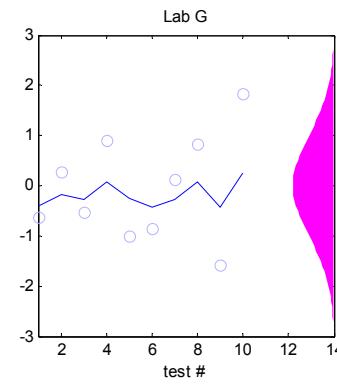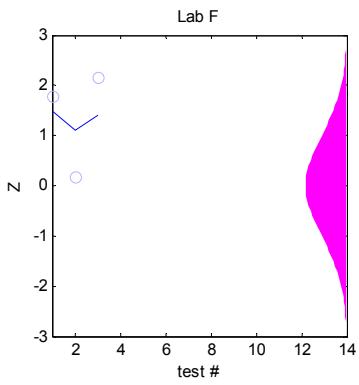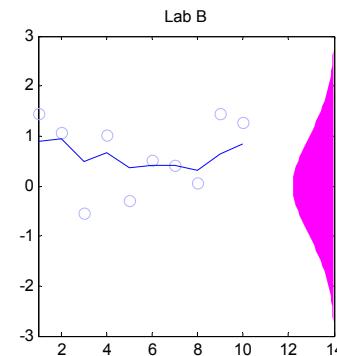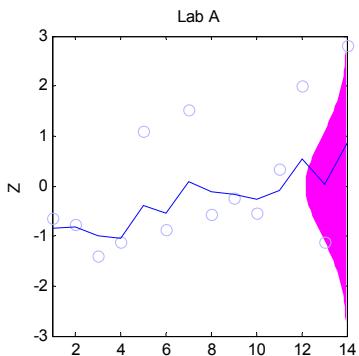
Severity Charts with Undue Influence
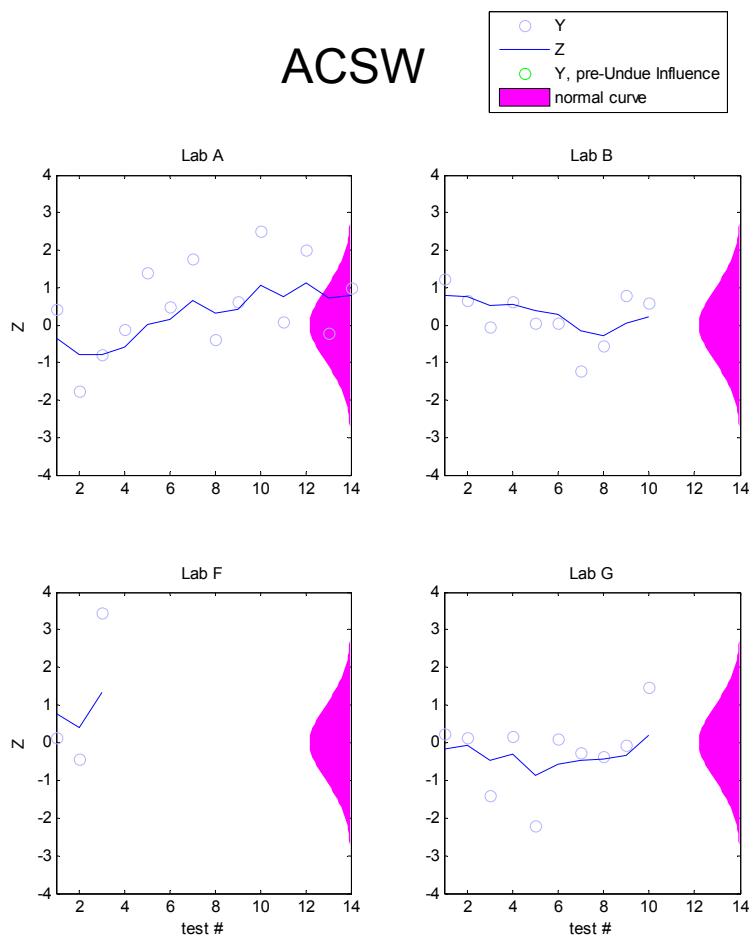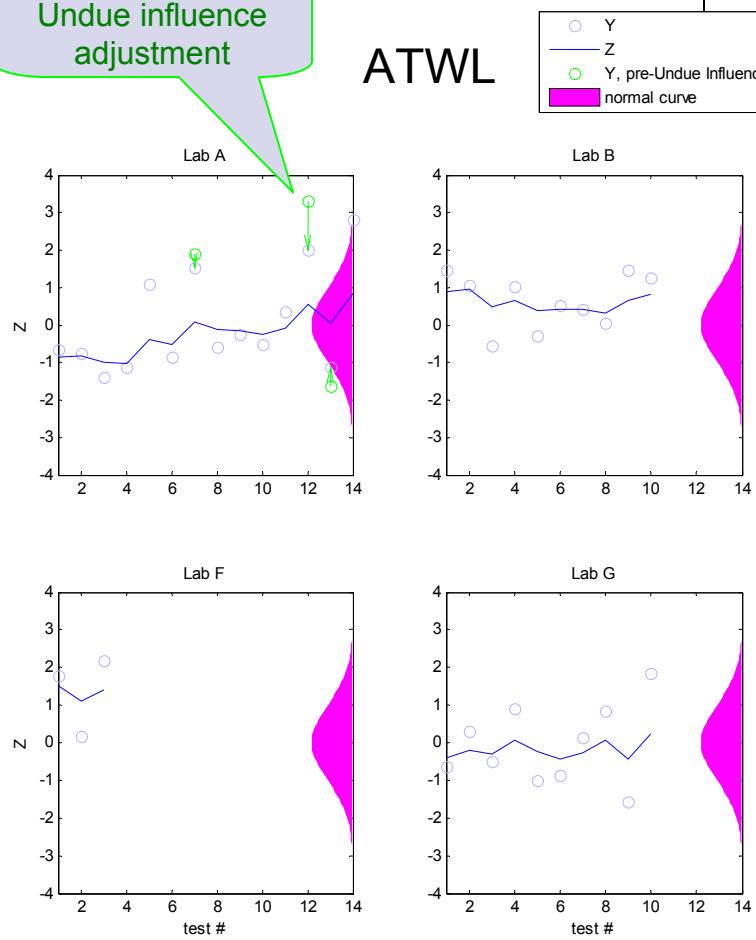
Effective Pass/Fail Limits
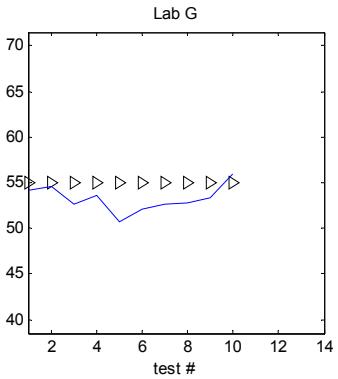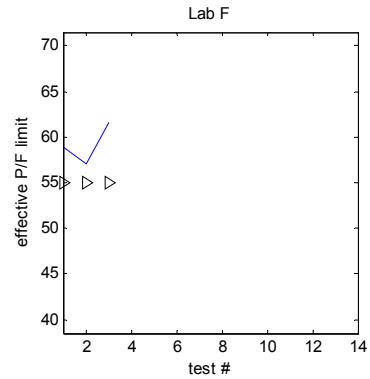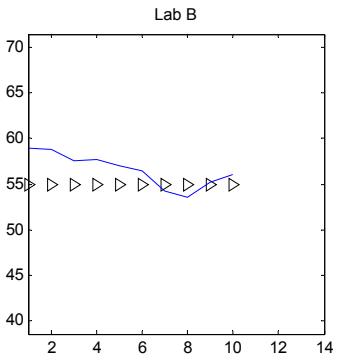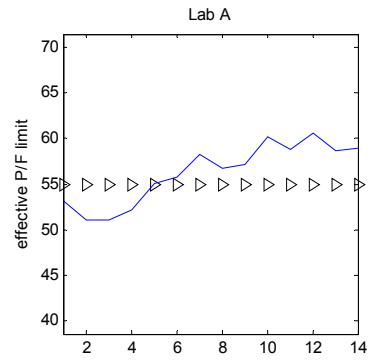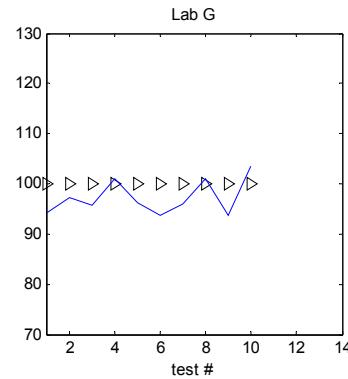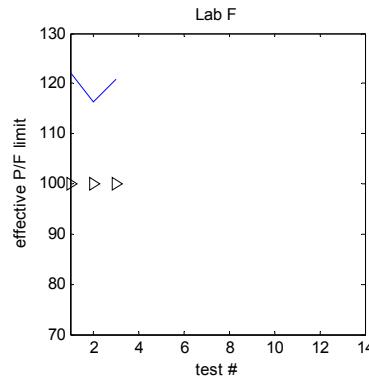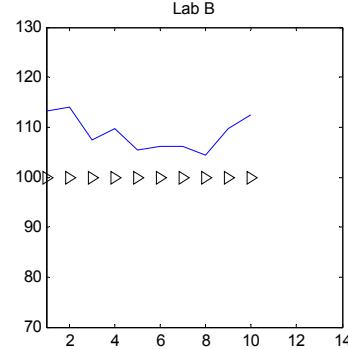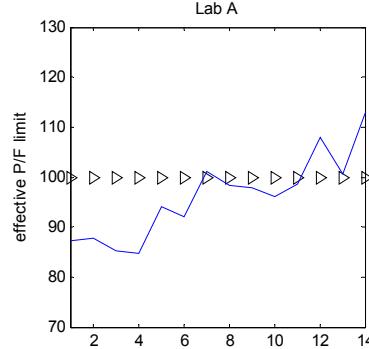
Alarms – All Engine Stands
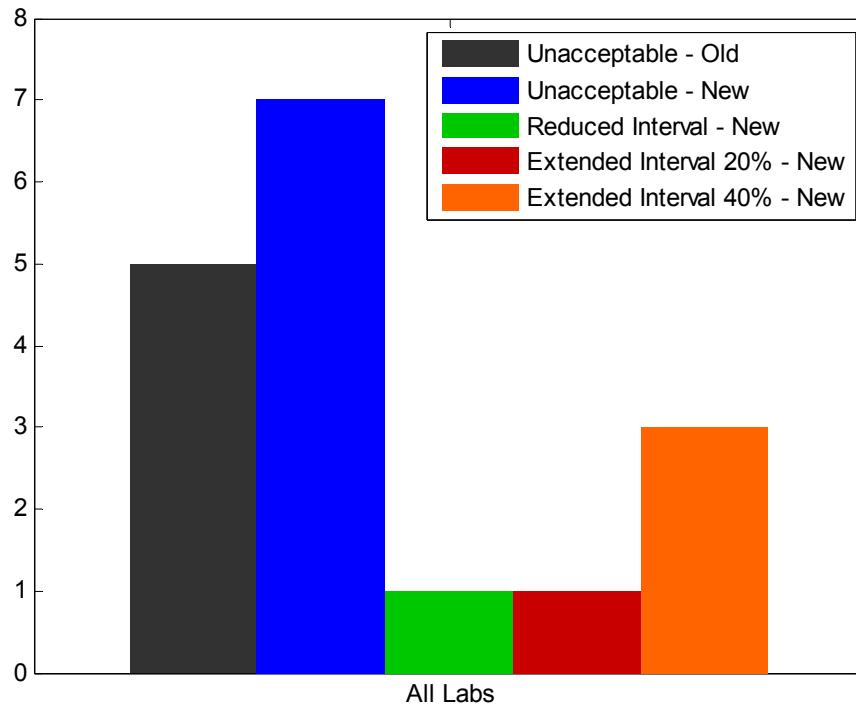
* using LTMS 2nd Edition default limits

Alarms by Lab

rotated view
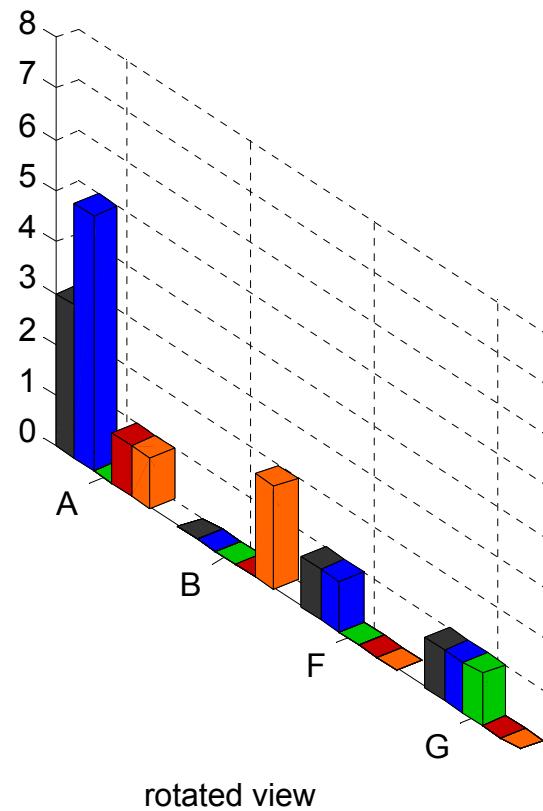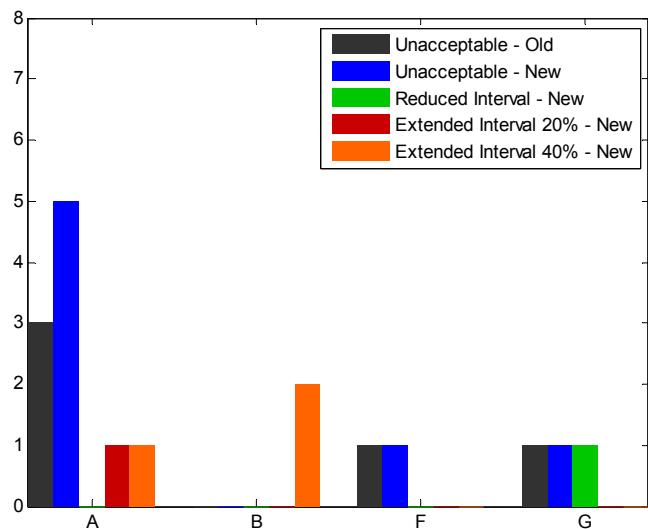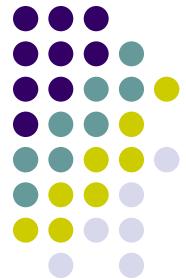
Prediction Error - All Labs
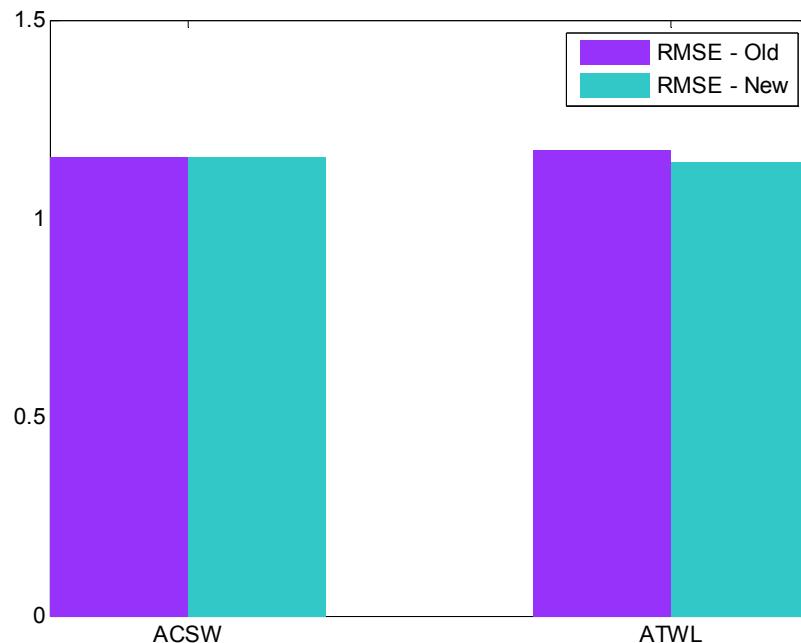
LTMS 2nd Edition can account for engine bias. However, historical ISB stands showed little bias ($Z \approx 0$).

Therefore 1st and 2nd edition systems produce similar prediction error.

Prediction Error by Lab
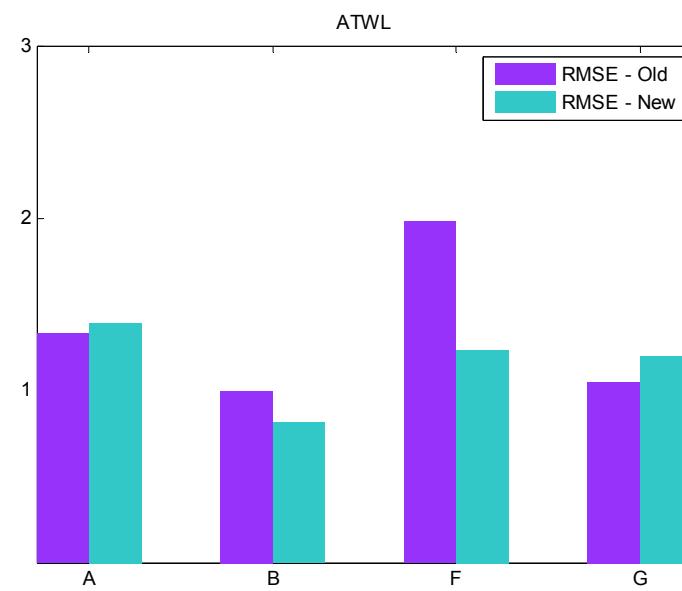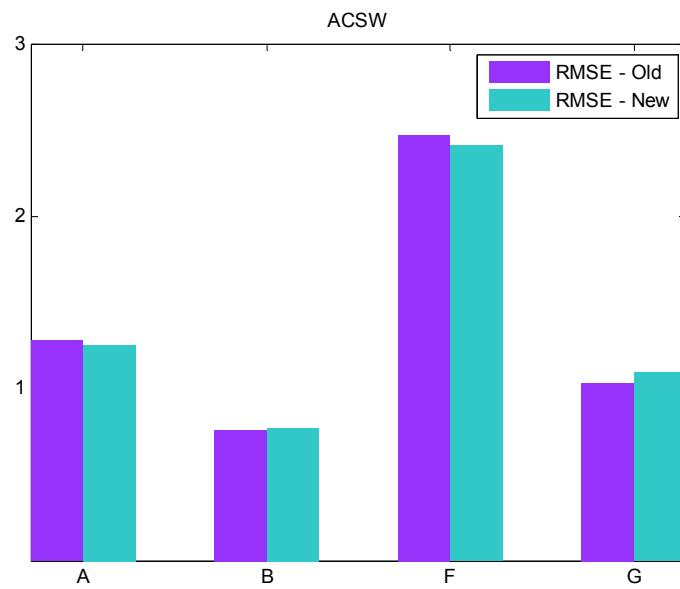
# Backup Slides
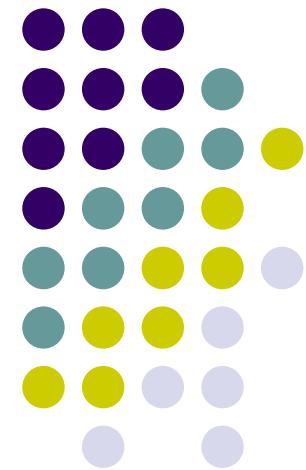
Residual (*e*) Charts


ACSW

ATWL

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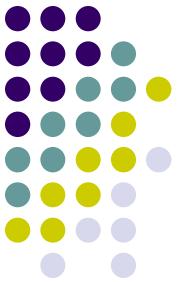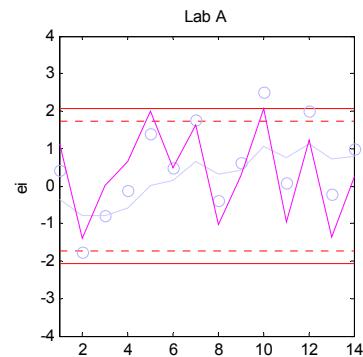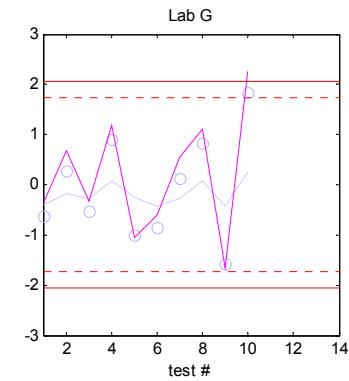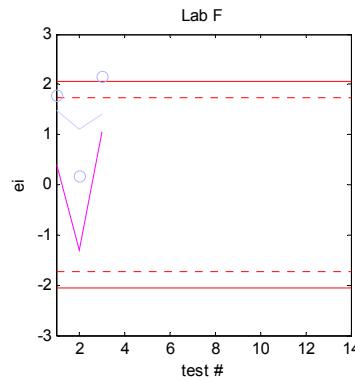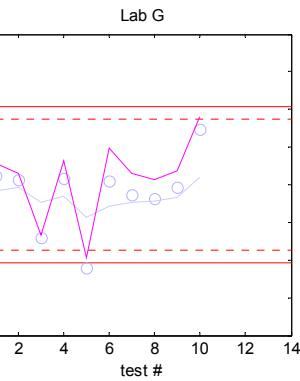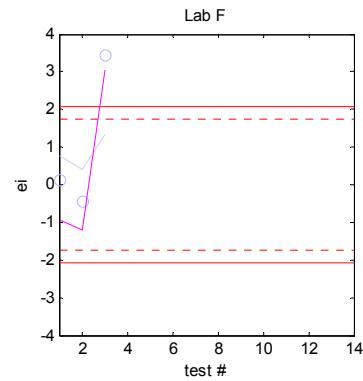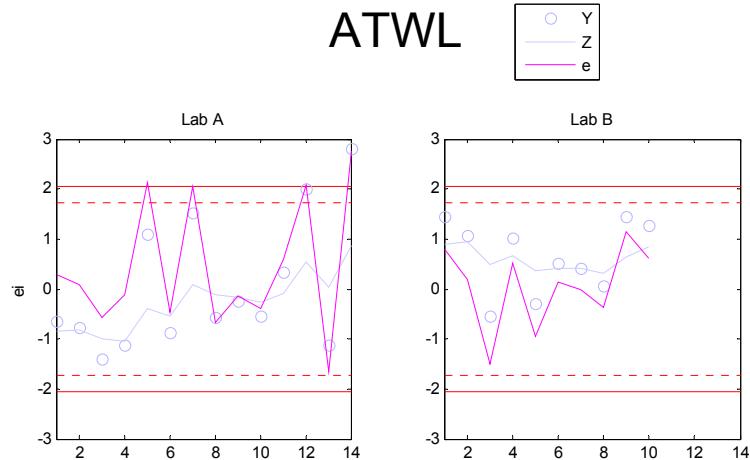
# Residuals- with and without UI
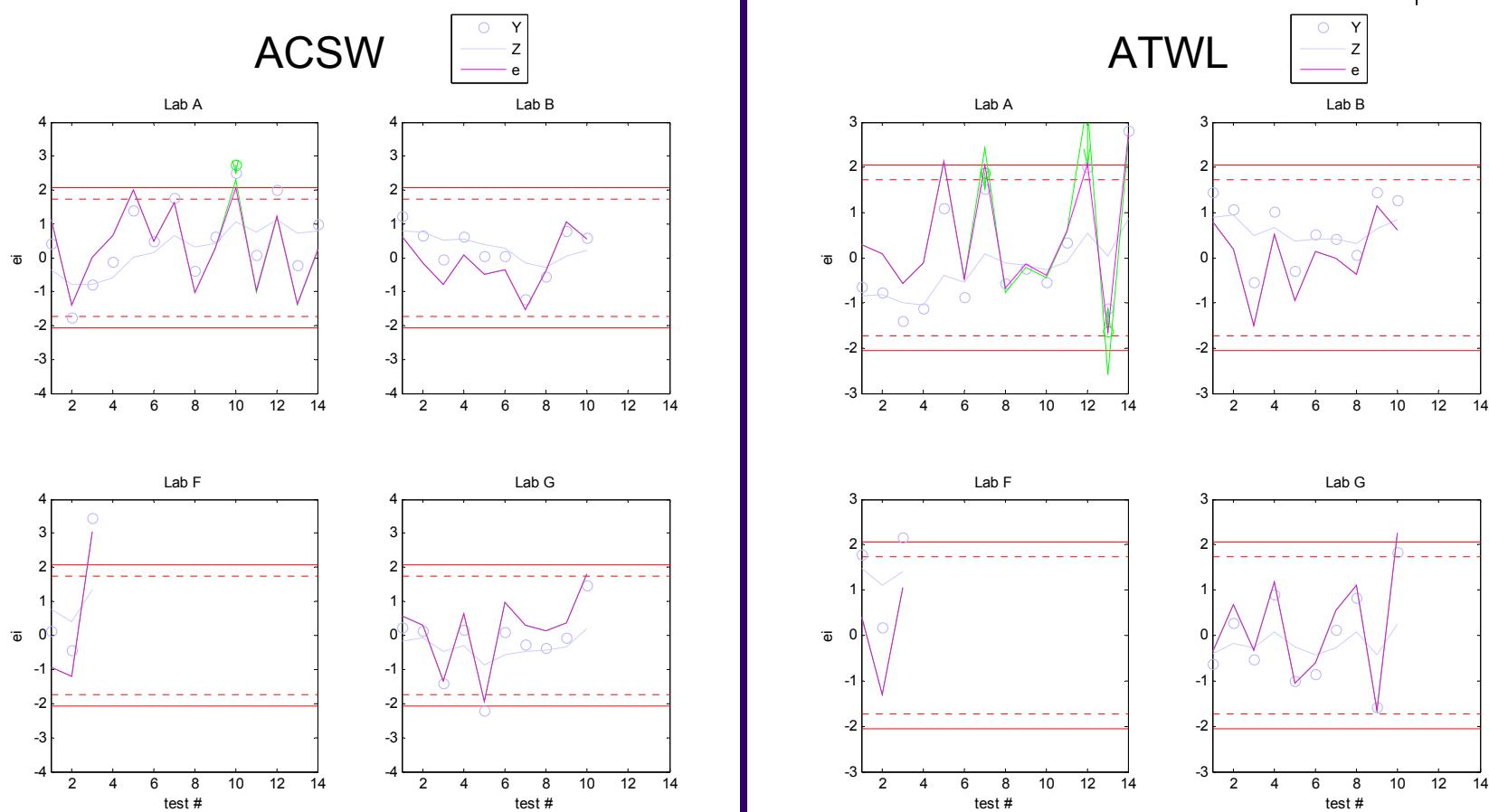
ACSW

ATWL

Tests for *e* Normality
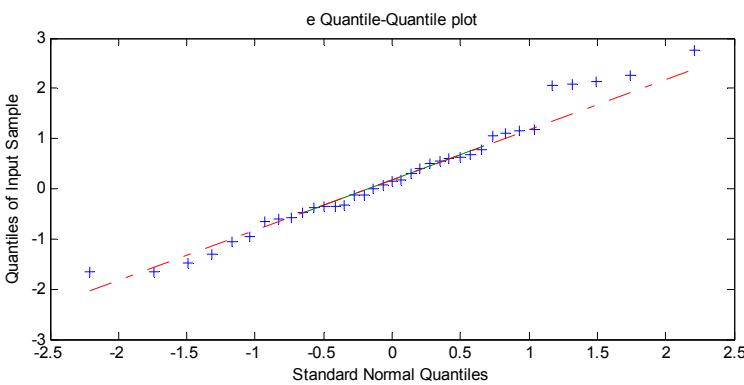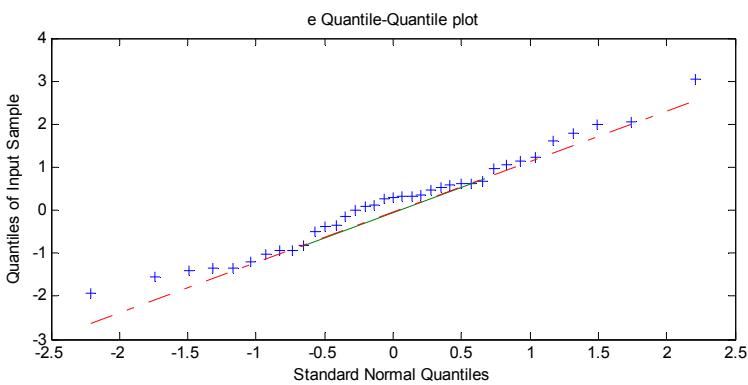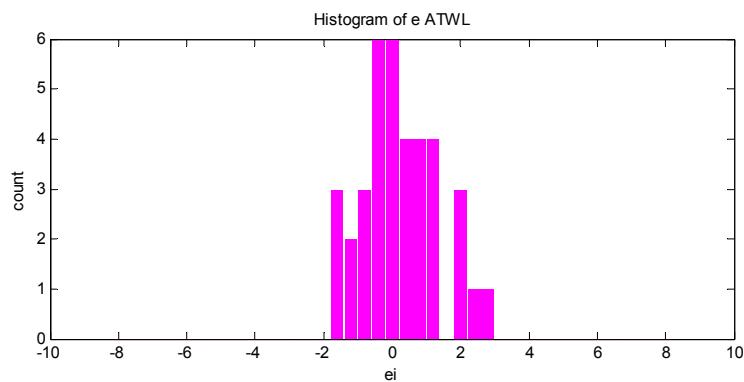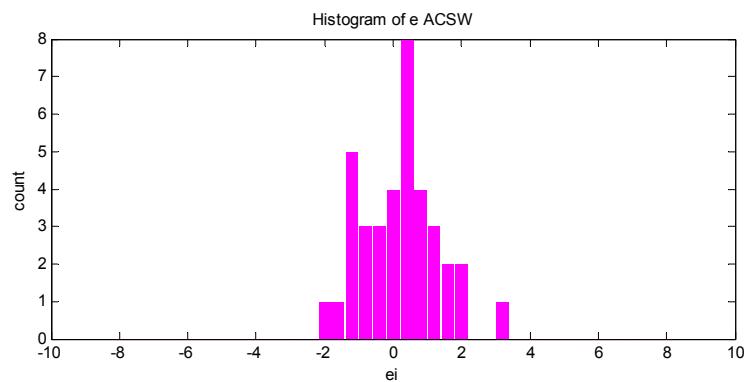
Lambda Optimization
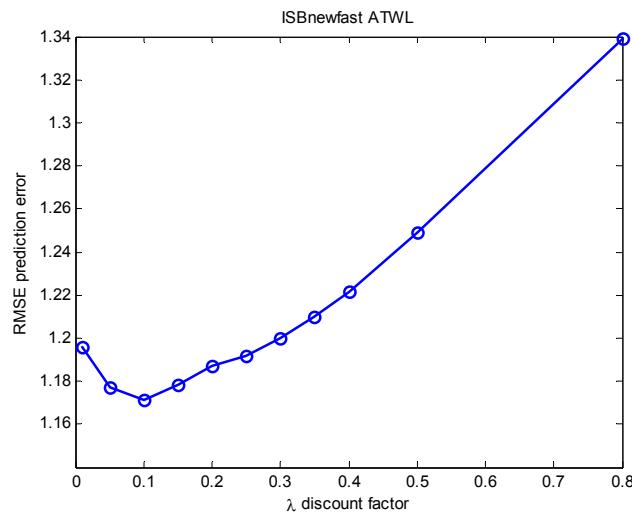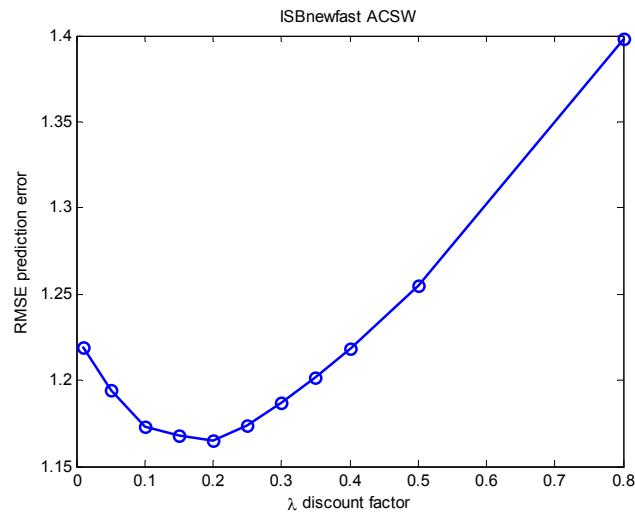
- LTMS 2nd Edition default λ = 0.2
- ISB LTMS 1st Edition λ = 0.3
- These plots indicate optimal $\lambda \approx$ 0.2 , however this is subject to some uncertainty

Reference Intervals
+40%, +20%, -20%, -100% (immediate re-reference)
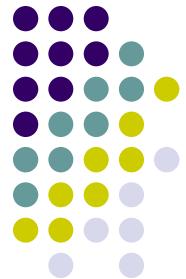
ACSW
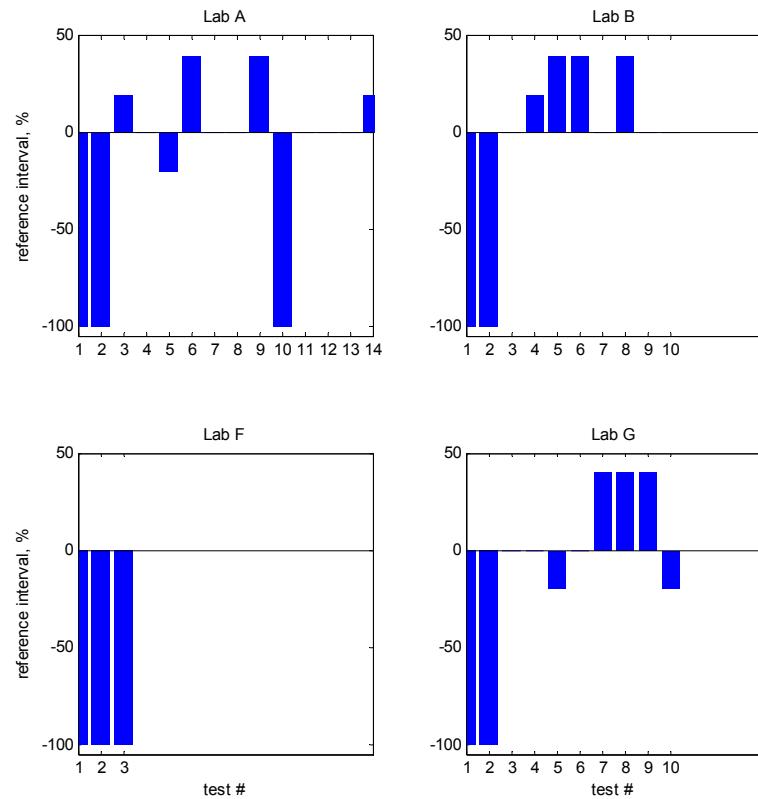
ATWL
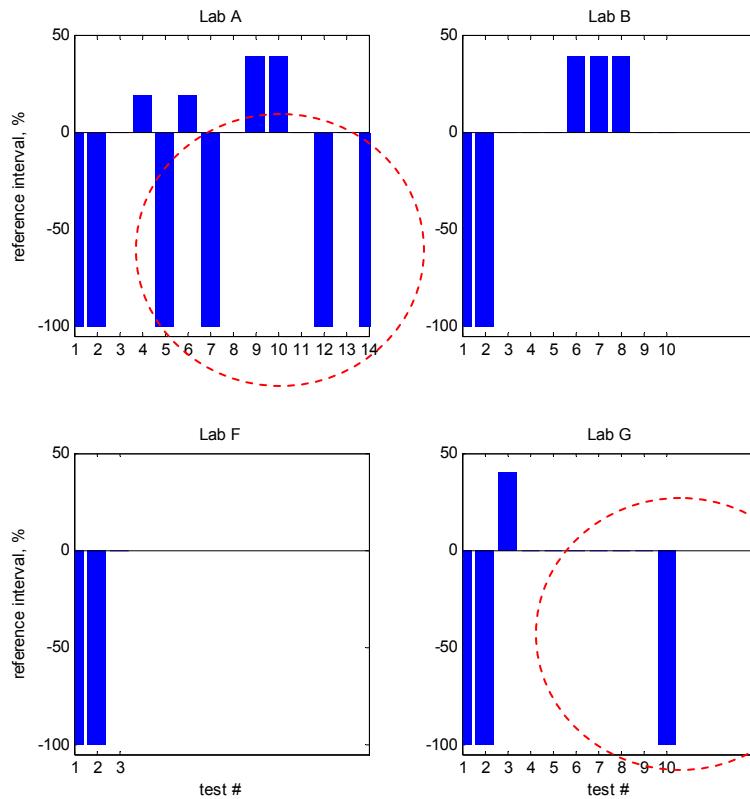
ATWL produced more alarms than ACSW

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