

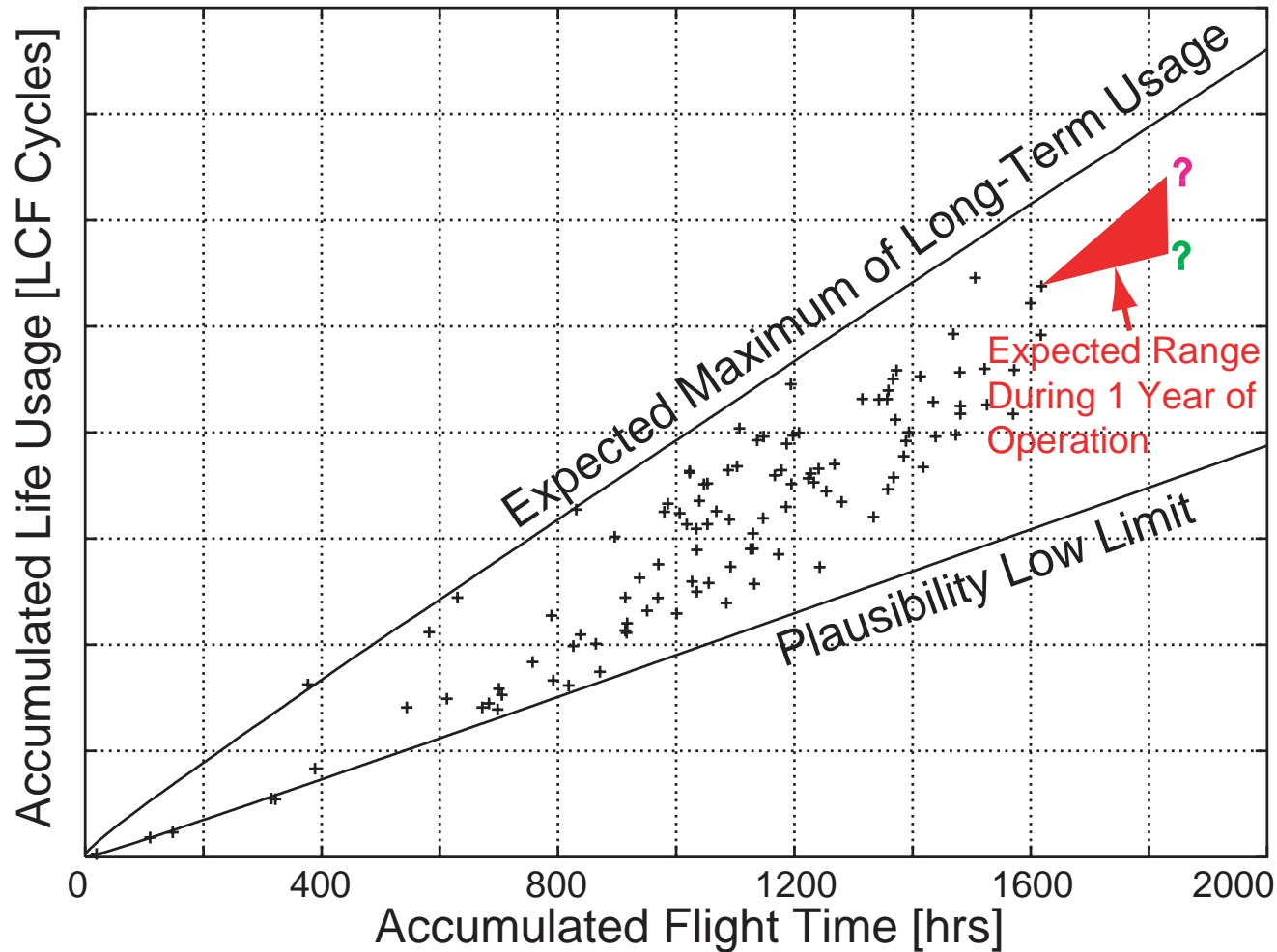
The Information Content of Turbine Engine Data - A Chance for Recording-Based Life Usage Monitoring

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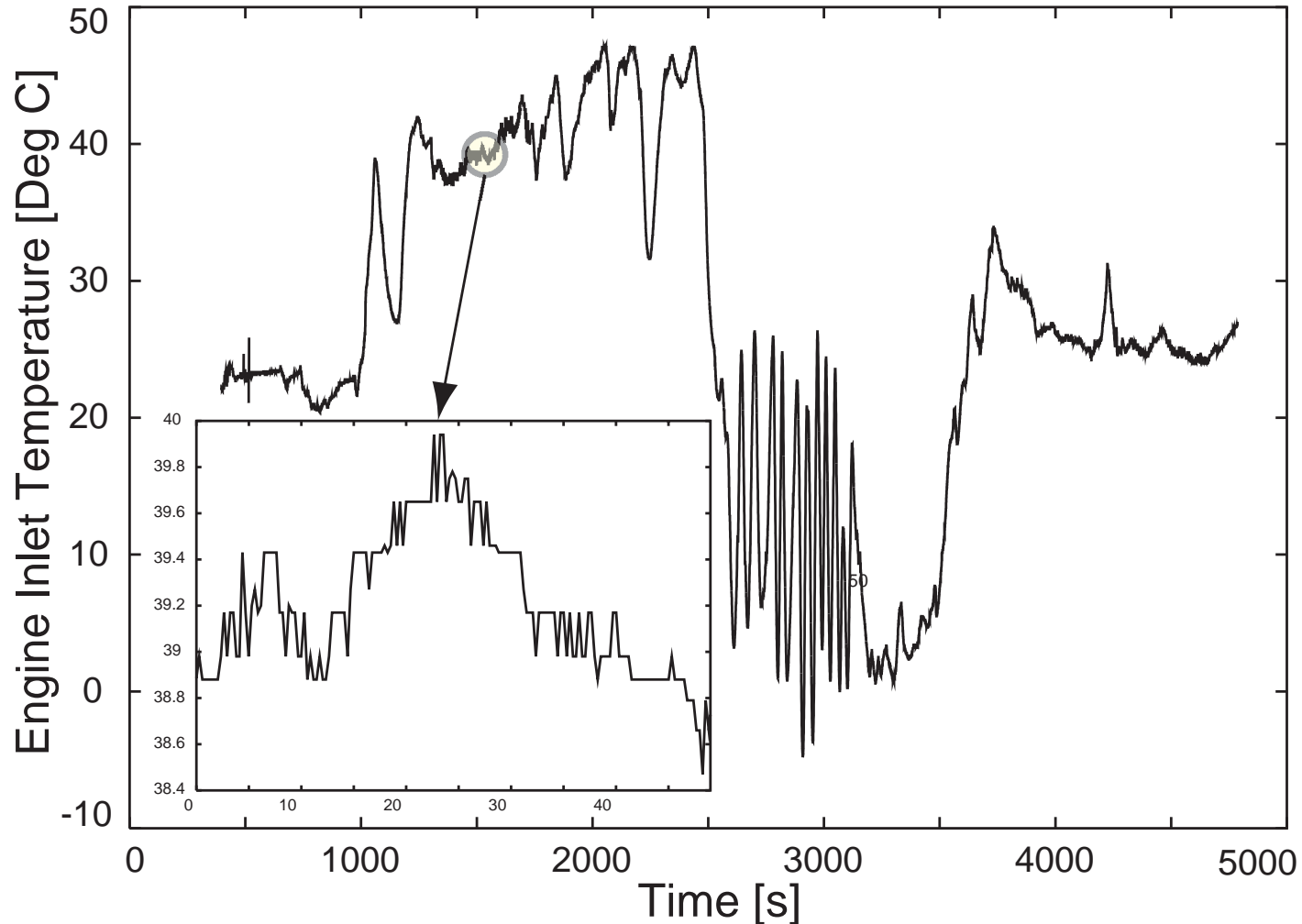
Introduction

- Principles of Life Usage Monitoring
- On-Board Monitoring or Recording
- Advantages of Data Recording

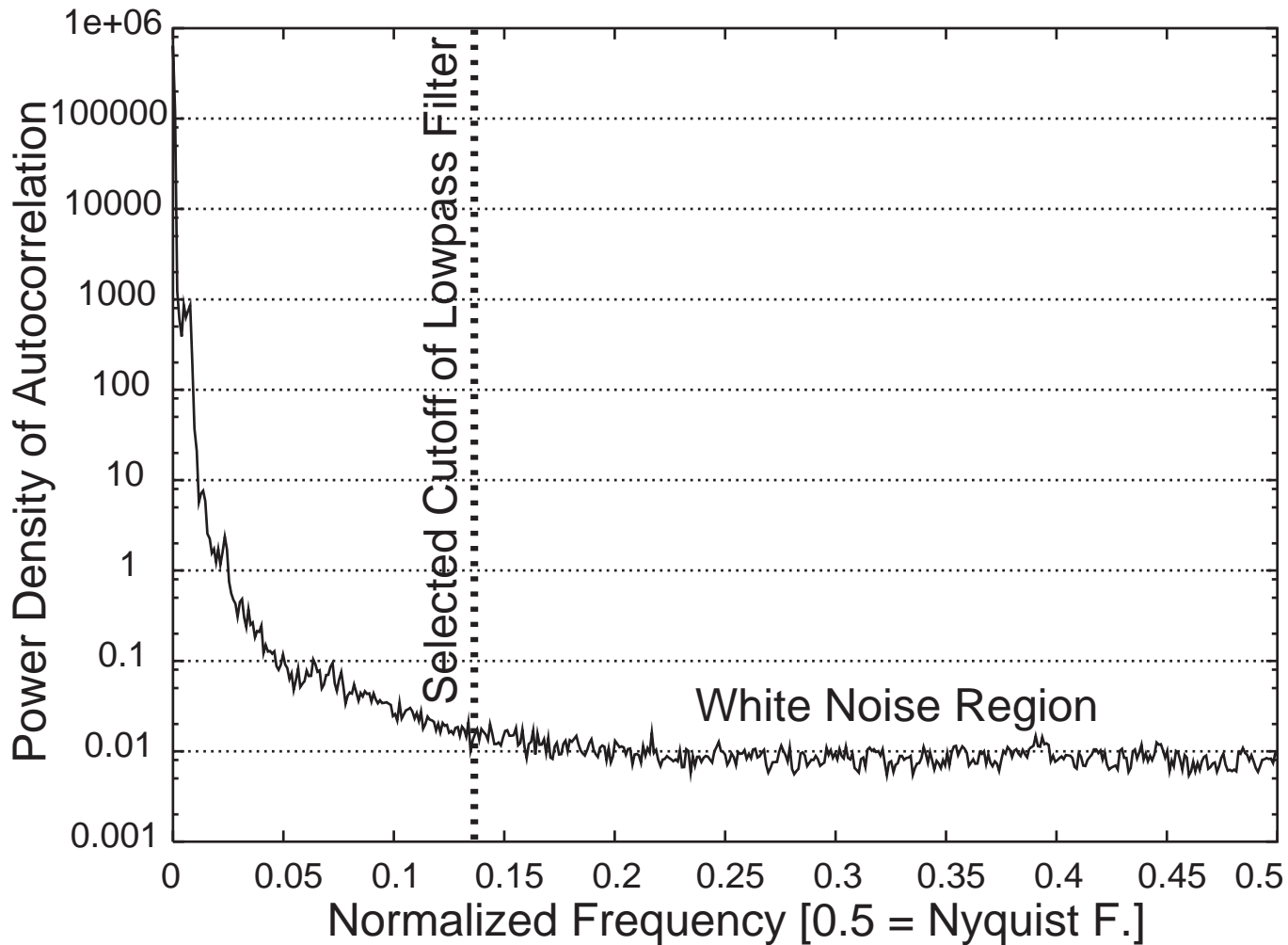
Observed Scatter of LCF Life Usage



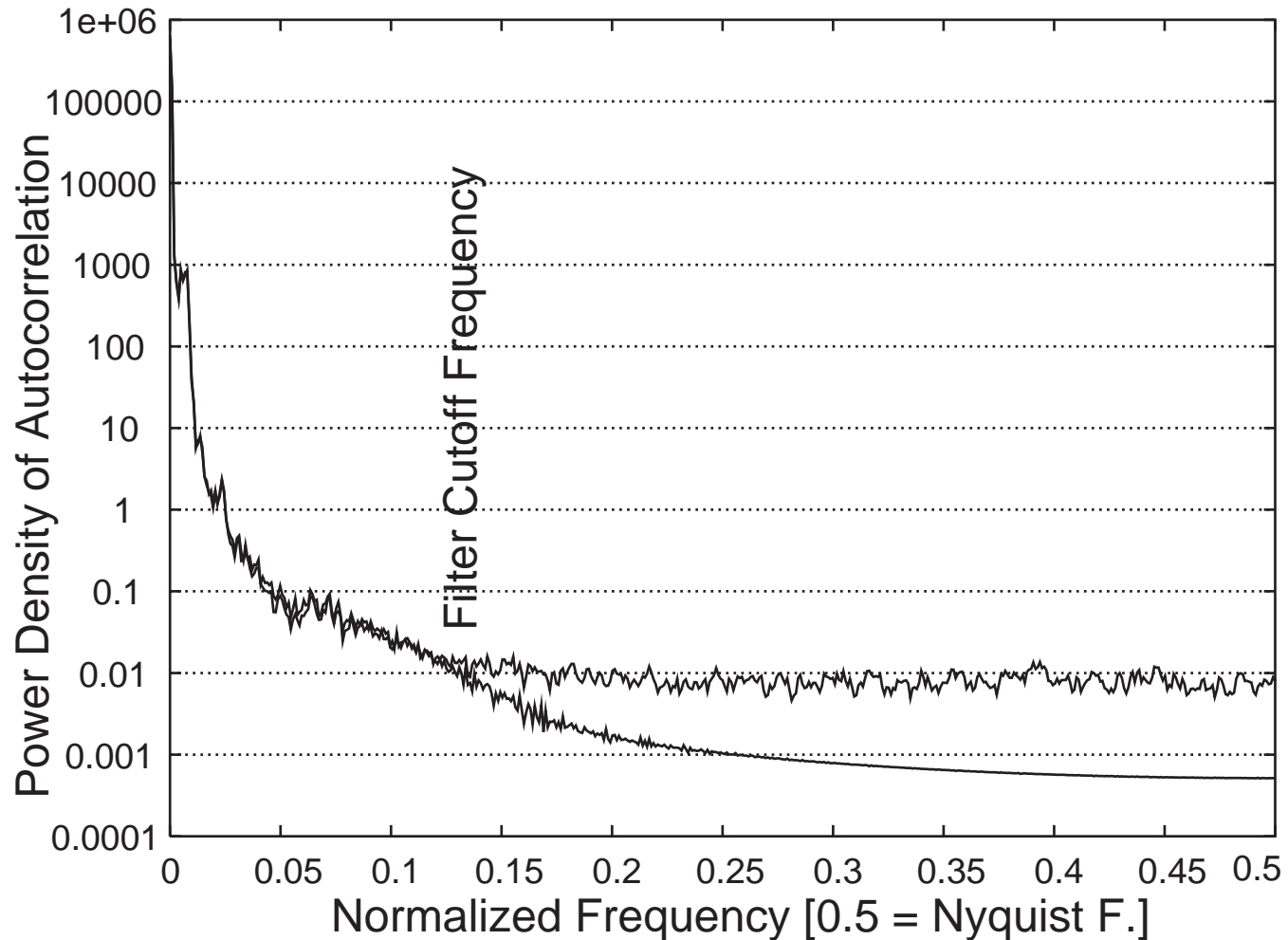
Total Inlet Temperatures for Trainer Mission



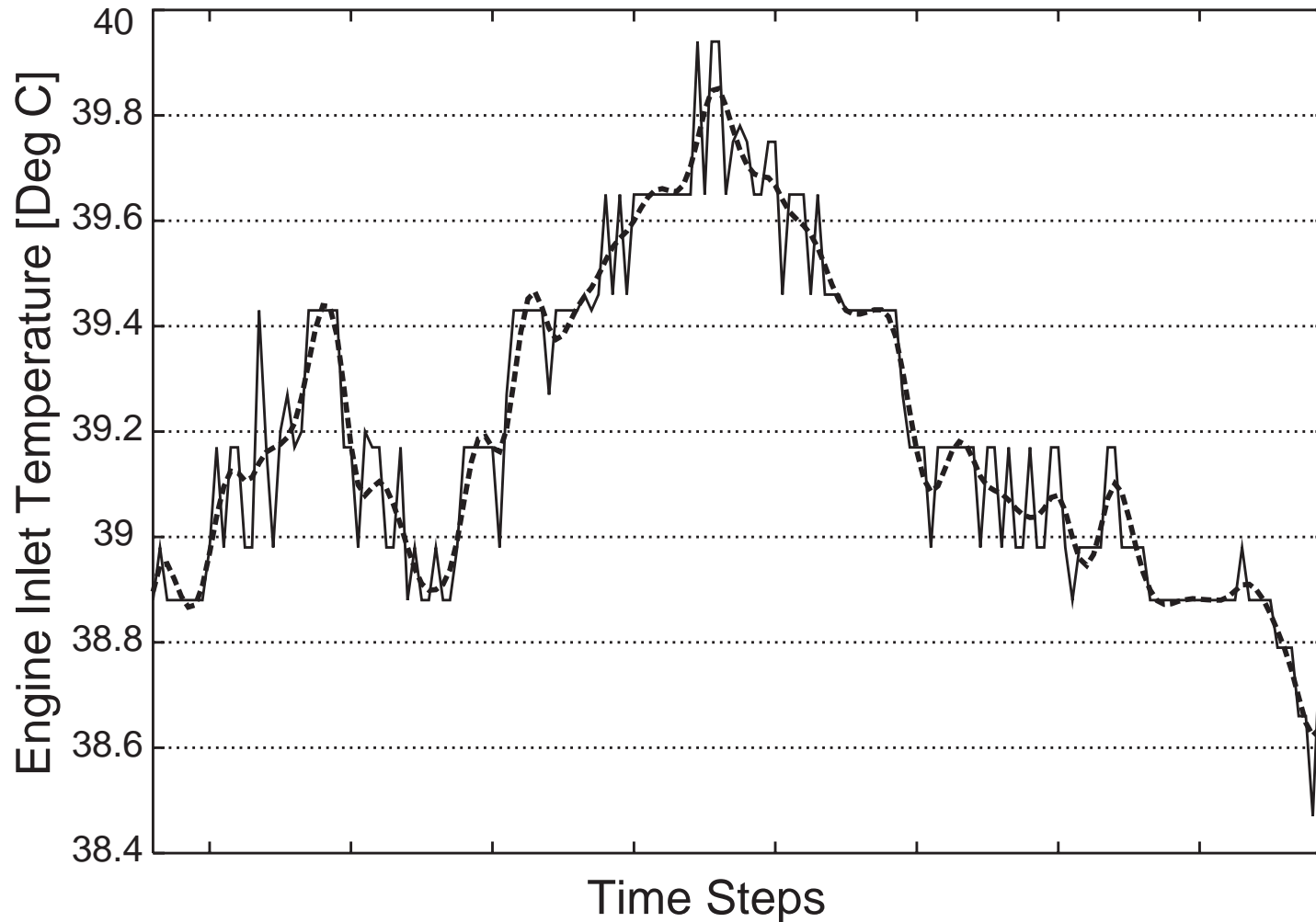
Autocorrelation Spectrum of T1 Signal



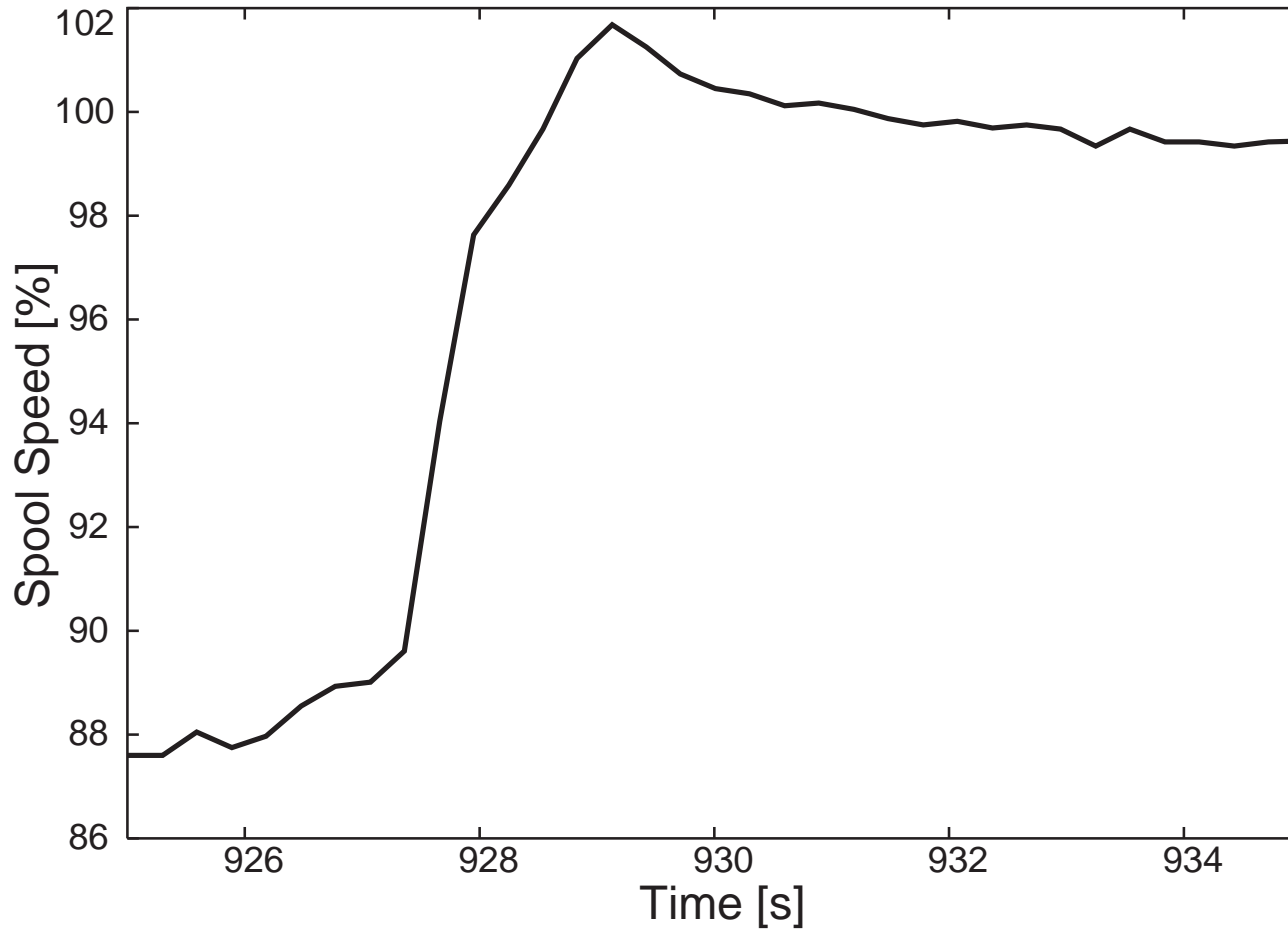
Influence of Butterworth Low Pass Filter



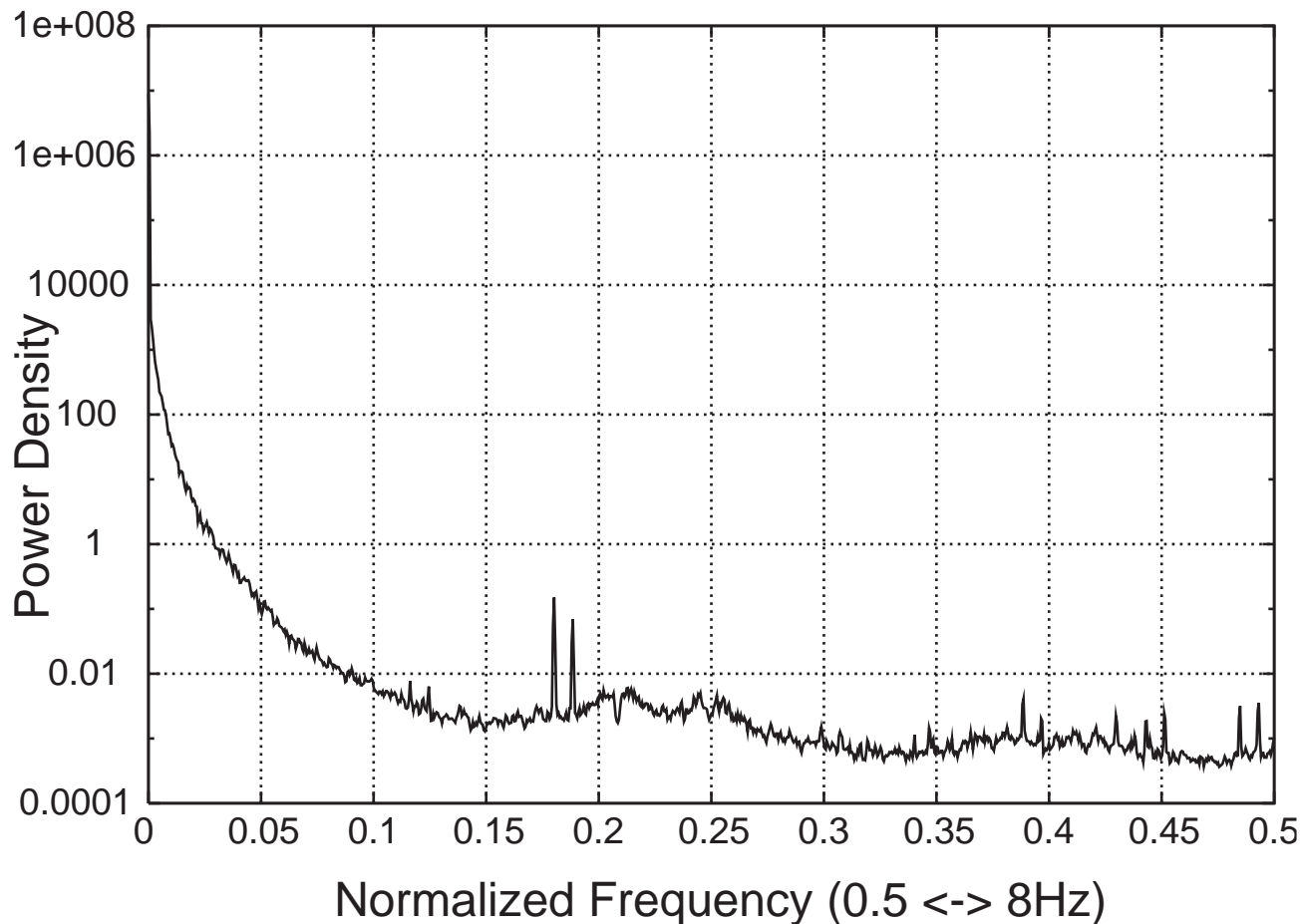
Order 4 Butterworth Filter Applied to T1 Signal



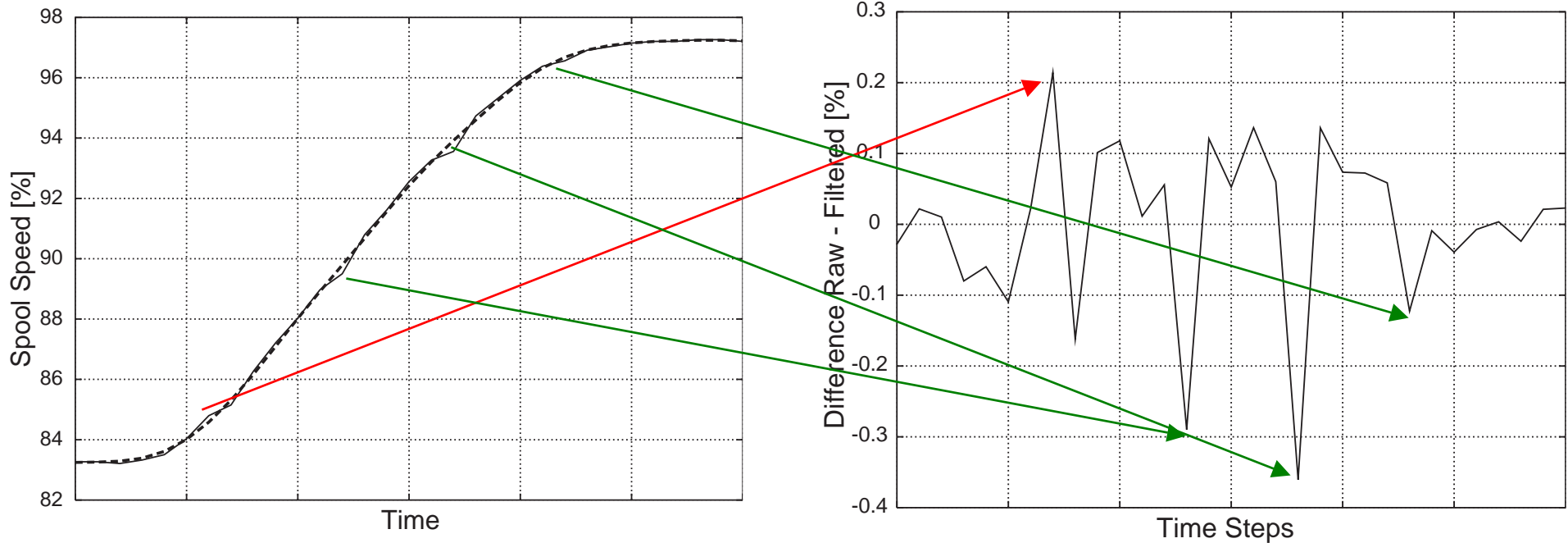
Overshoot of Spool Speed



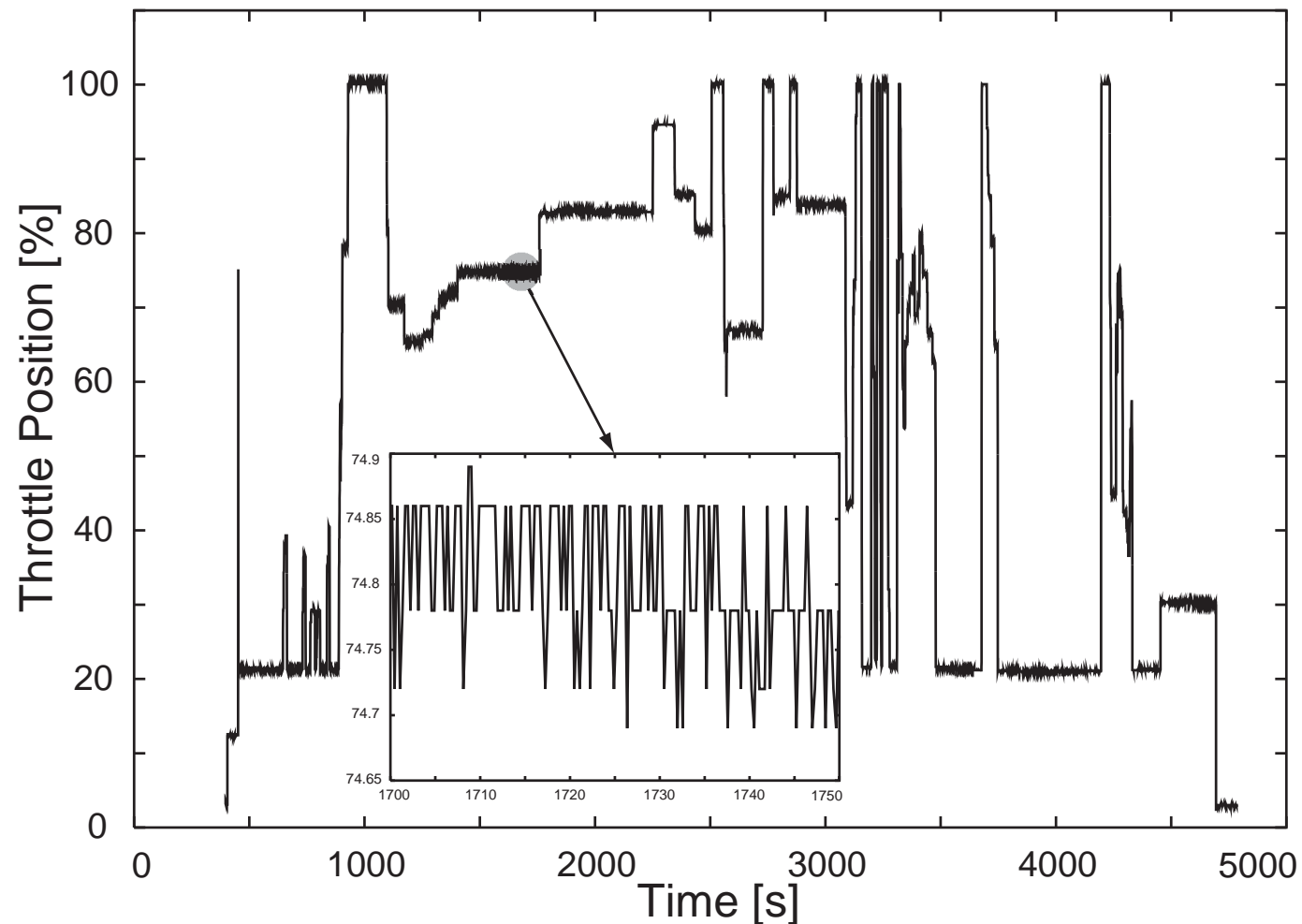
Mixing Harmonics in Autocorrelation Spectrum Caused by Incompatible Rates of Data Acquisition and Recording



Difference between Raw and Filtered Signal



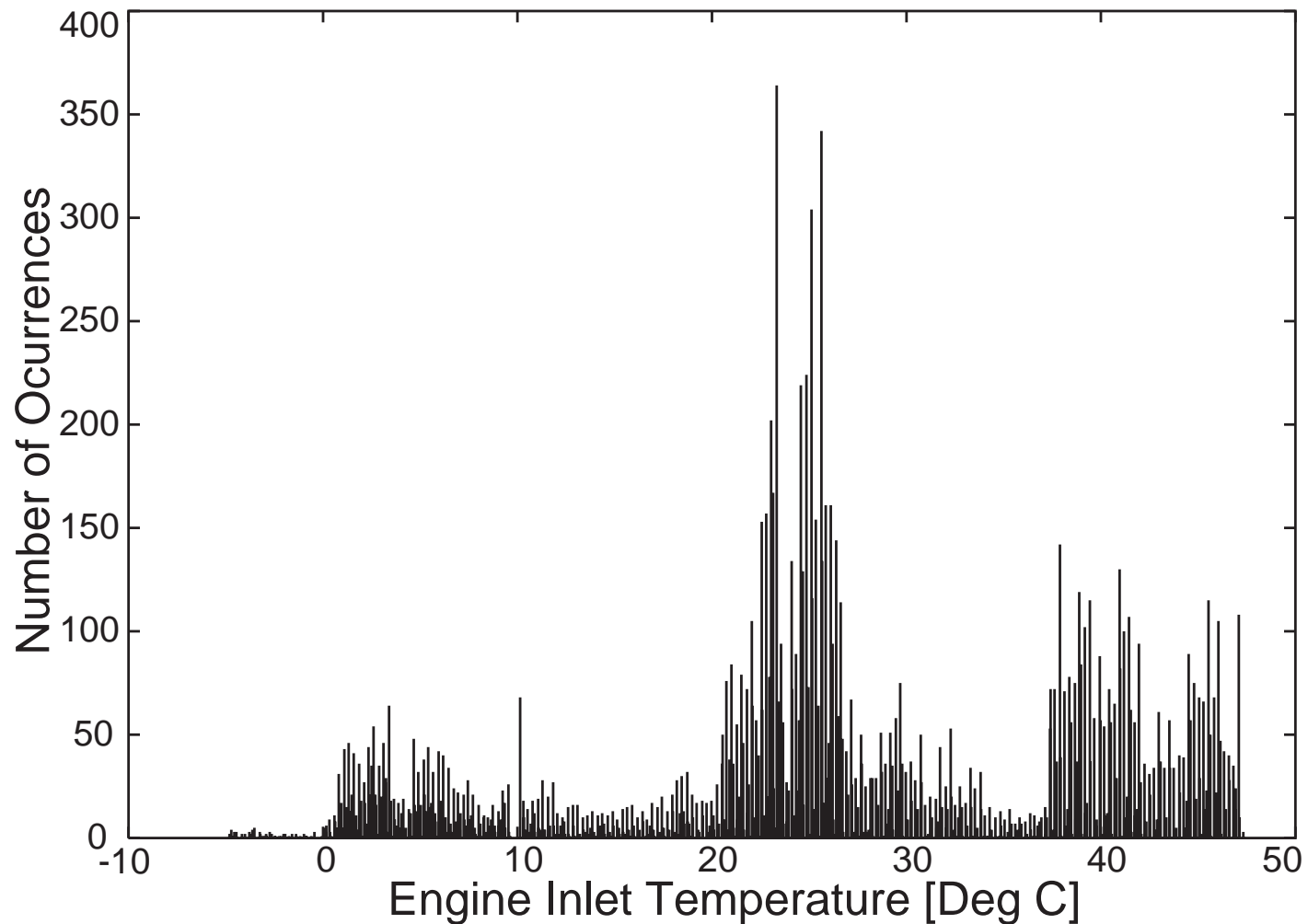
Suppress Recording of Small Signal Changes ?



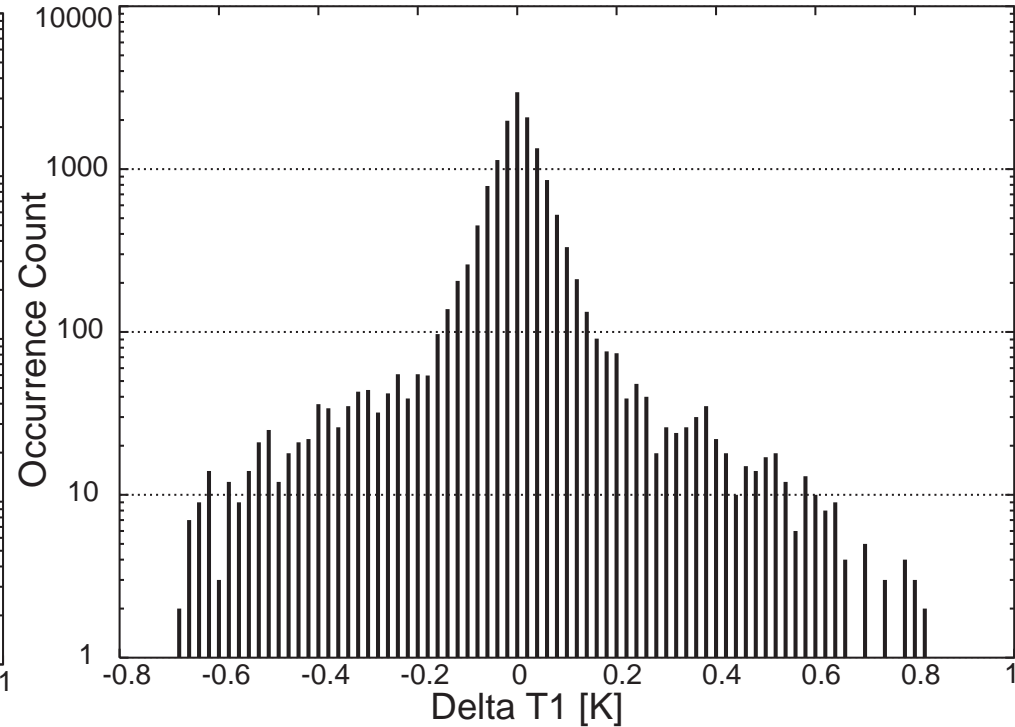
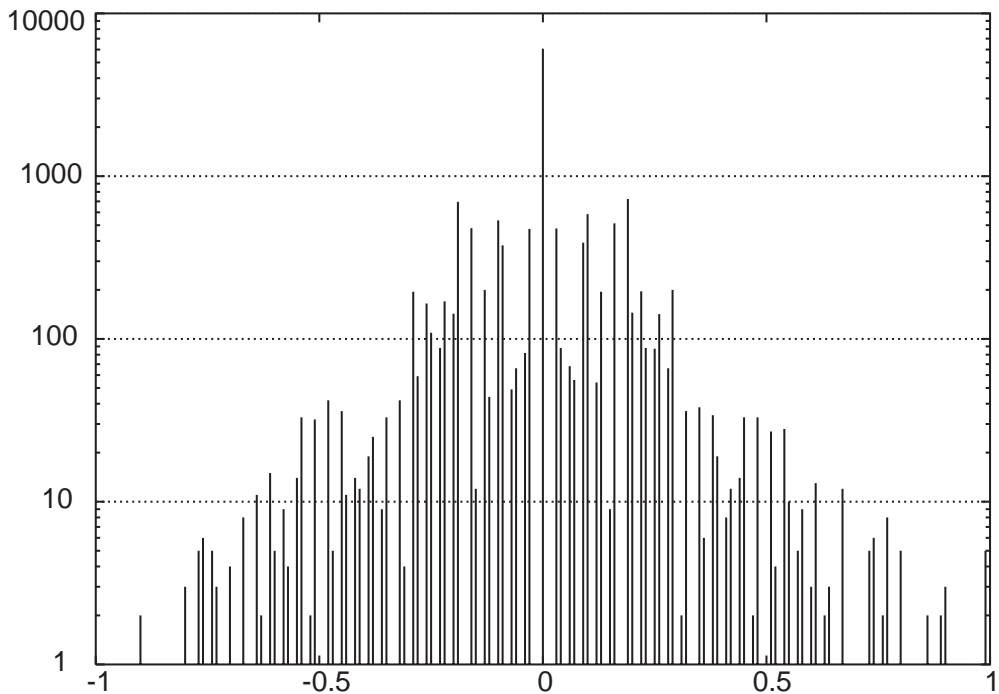
Dedicated Processing for Each Signal

- Rate conversion from the sampling rate of the data source with application of anti-alias filters
- Sampling with the minimum required rate
- Removing noise with a low pass filter or discarding low amplitude changes
- Application of a suitable data compression technique

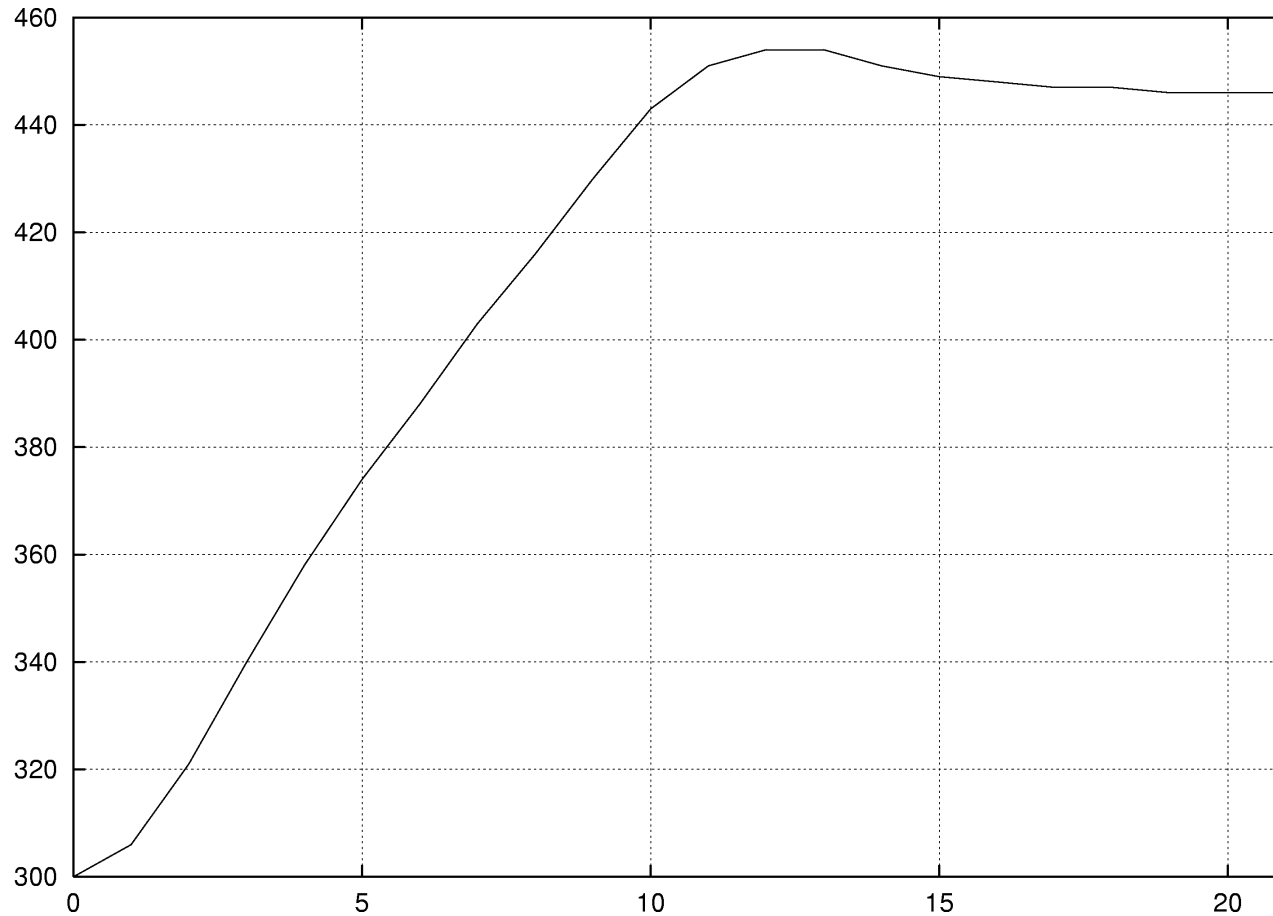
Histogram of Engine Inlet Temperature T1



Influence of Filtering on Histogram of Delta T1



Delta Coding with Letters



_ = 0
 A = 1
 a = -1
 B = 2
 b = -2

F O S R P N O M N M H C _ c b a a _ a _ _

“Letter-Coded” Spool Speed Delta Values (Take-Off and Climb)

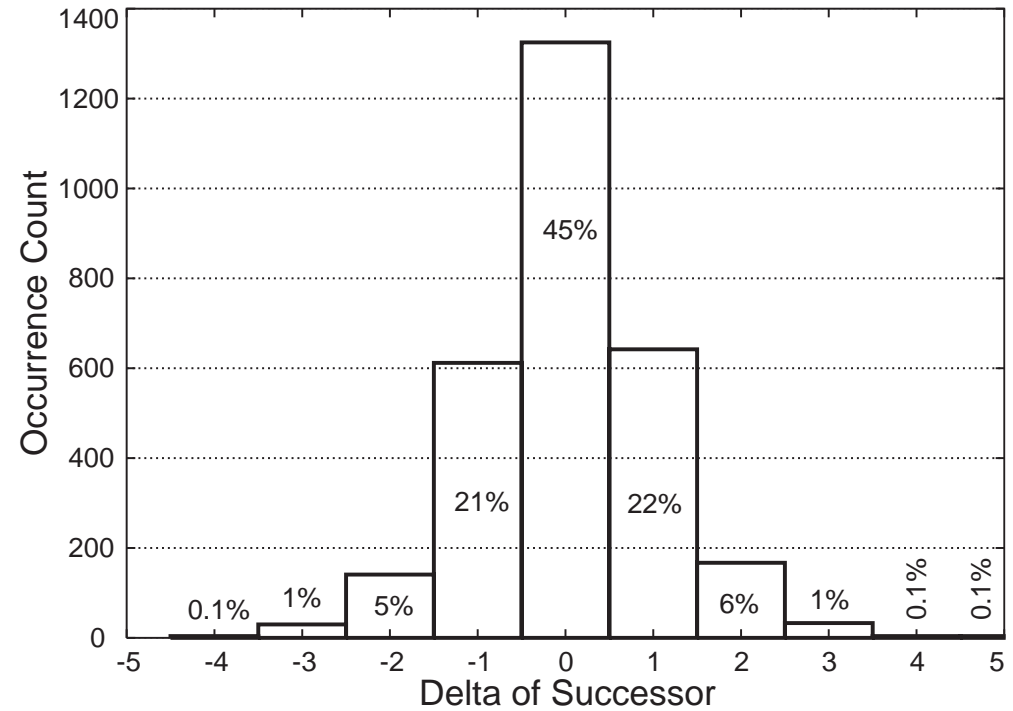
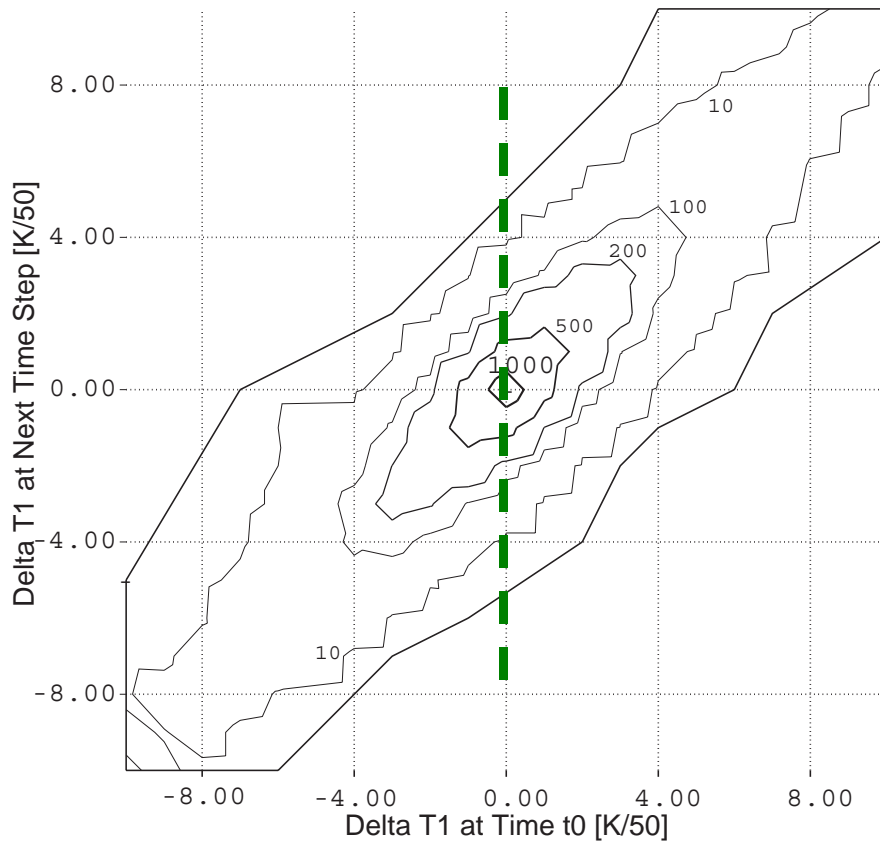
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A_a_A_a_A_aA_a_A_a_A_a_A_a_A_a_A_a_A_a_A_a_A_a_A_a
a_Aa_A_aA_a_A_aA_aA_a_A_aAaA_a_A_aA_aA_aA_aA_aA_a
A_a_A_aA_aA_aA_aA_aA_aA_aA_aAaA_aA_aA_aA_aA_a
A_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_a
ALPLGB_A_a_ckda_a_dfigba_a_a_A_aA_a
A_a_FOSRPNOMNMHC_cbaa_a_a_aA_b_b_A_DA_a_a_a_A_a_A_a_a_A
a_Aa_aA_aA_a_A_a_a_A_AaA_a_a_AccAA_A_AA_hfHHA_b_b_BA
a_Aelgba_a_A_a_A_a_A_EICA_a_jdaa_a_A_a_A_a_A_a_a_aic_a
A_a_aA_A_a_a_d_a_a_A_c_cca_A_aBaa_A_a_A_A_abcda_a_a_A_A_a_A_a_Aa
A_aA_aA_aDMPPGA_ab_a_gkebaada_a_A_a_A_a_a_A_a_a_a_A_a_a
fb_a_A_a_A_a_A_a_A_a_A_a_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A
AA_b_Aa_A_a_A_aAa_A_aA_a_A_a_A_a_A_aA_A_A_A_A_A_A_A_A
a_A_a_ca_a_eca_a_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A_A
A_aA_ca_je_a_a_A_aA_aA_a_A_a_A_A_A_A_A_A_A_A_A_A_A_A_A
babdbcbba_BAAAAABABCBAABBBAAAA_A_AAAAA_cbbba_aa_b_AB_ba
AA_aa_aaba_A_A_BB_ba_a_AABAAABBB_A_b_ba_aa_aaab_a_a_a_a_a
b_a_B_AA_AAAAA_AAAA_aabbabaa_AA_aaababaa_bba_AB_AAAAA
BAAA_AA_A_A_B_a_aaaa_A_A_A_aA_ab_BAB_a_a_B_aa_aa
A_abbgmmia_A_aA_aAa_A_A_a_A_CCAa_aA_a_A_aA_aA_aA_aA_a
a_A_a_A_aAa_A_aA_aA_a_A_a_A_aA_aA_aA_aA_aA_aA_aA_a
A_aA_a_A_a_A_a_A_a_A_aAa_A_a_A_aA_aA_aA_aA_aA_aA_a
A_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_a
A_aA_aAa_A_a_A_a_a_A_aA_aA_aA_aA_aA_aA_aA_aA_aA_aA_a
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A_a_A_a

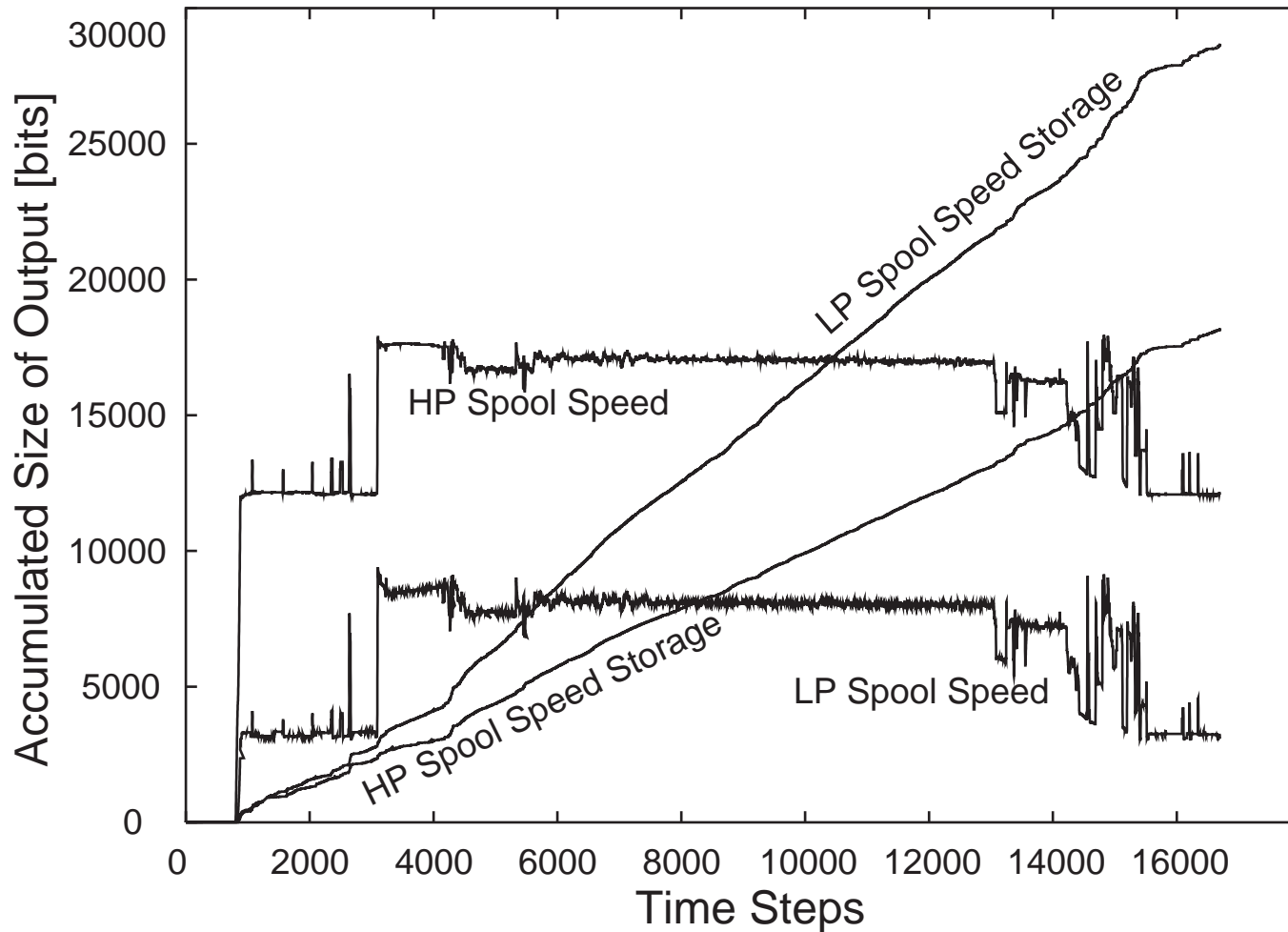
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Engine Acceleration Signature: [FOSRPNOMNMHC_cbaa_a_a](#)

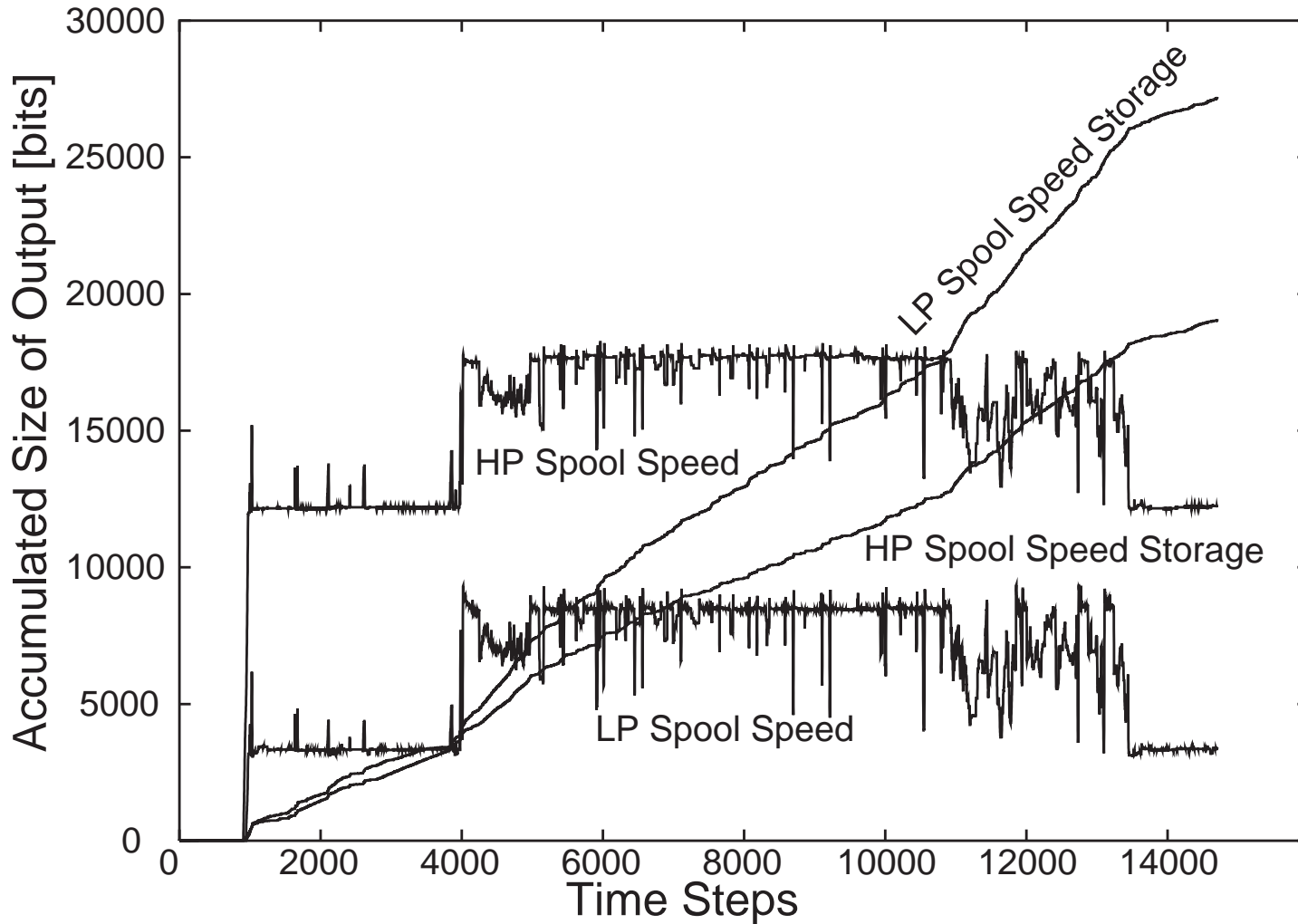
Occurrence Counts of Delta Combinations



Data Storage for Ferry Flight



Data Storage for Patrol Flight



Perform Your Own Data Compression Experiment

- Determine a scaling of the signal that limits the maximum delta per time step to the range ± 127
- Apply low-pass filters to cut off noise or periodic components, if necessary
- Write sequence of delta values to a binary file. Due to the range limitation one byte per time step will be sufficient
- Apply the standard “ZIP” compression with the “maximum compression” switch to this file
- The expected size with an optimal statistical adaptive arithmetic coder will be $\approx 75\%$ of the size of the ZIP file.