

Fleet Usage Spectrum Evaluation & Mission Classification



TOPICS

- Background
- Design Process
- C-130 Application
- Results
- Summary

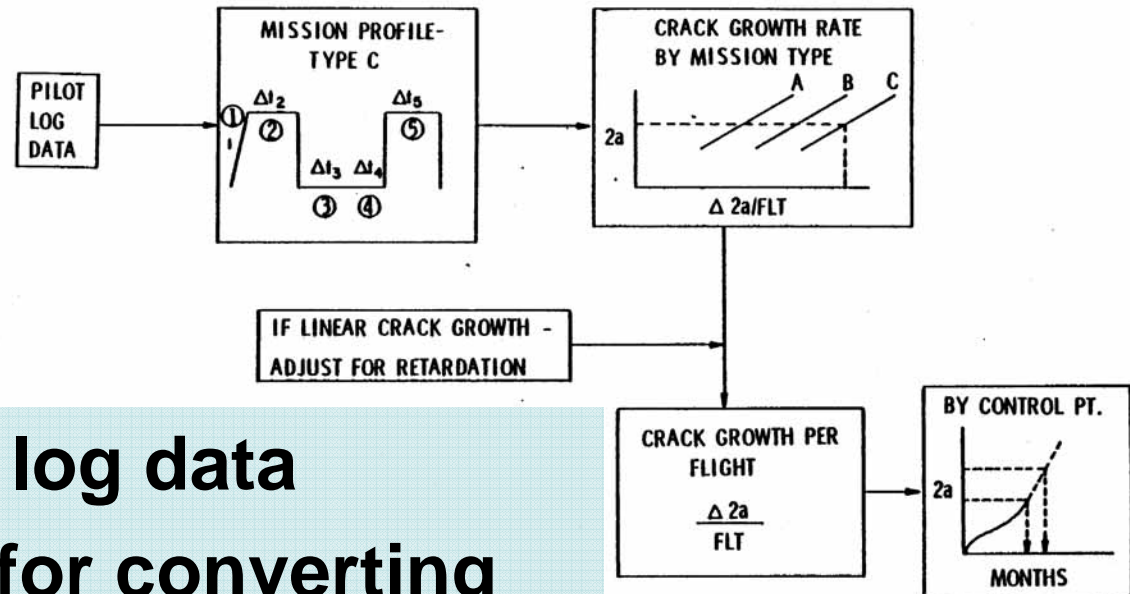
Background



Usage Description

- Measurement of parameters which are representative of the stress cycle and can be related to crack length.
- Usage Descriptions:
 - [Mission By Mission](#)
 - [Mission Segment By Mission segment](#)
 - [Time In Usage Category](#)
 - [Strain History](#)
 - [Damage Parameter](#)

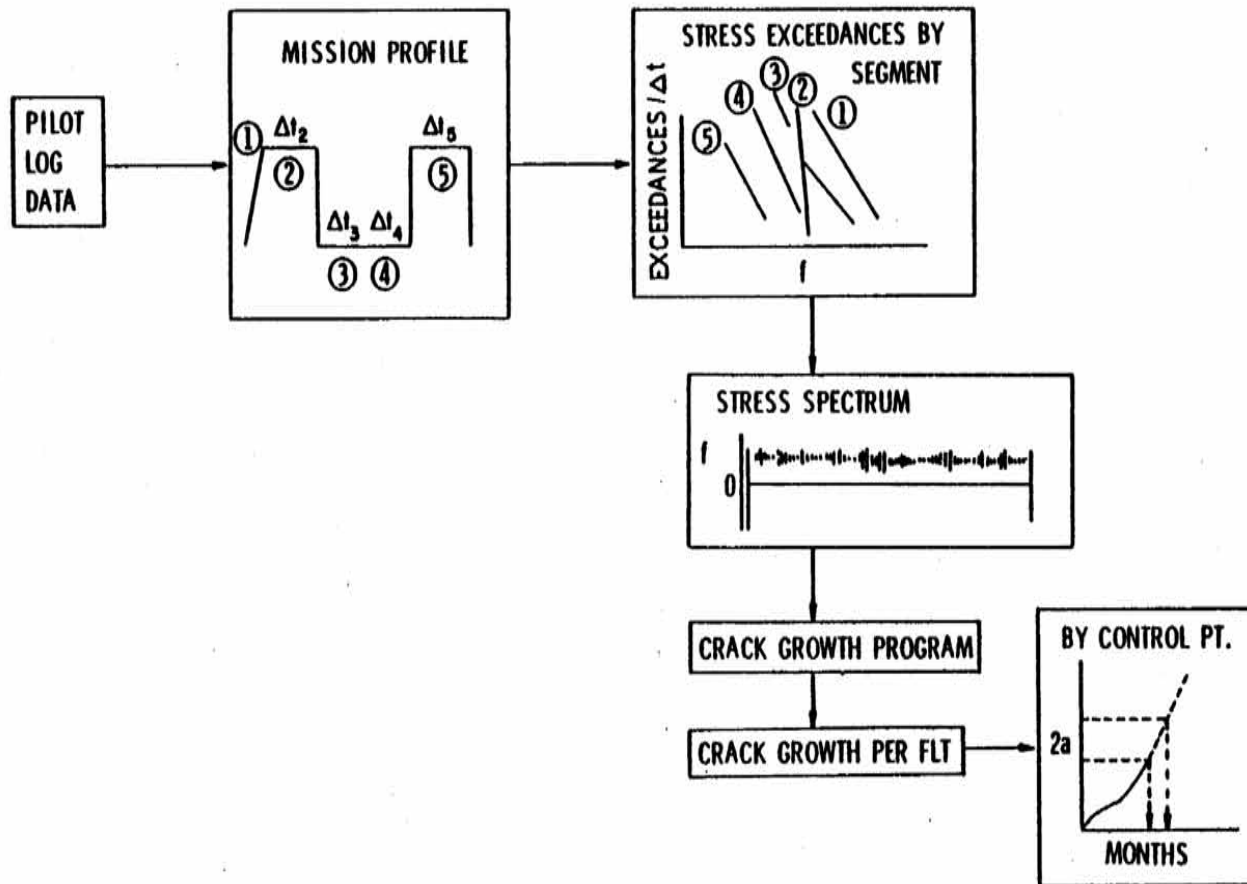
Mission By Mission



- Based on pilot log data
- Rapid method for converting usage data to damage.
- Most common on cargo fleets.

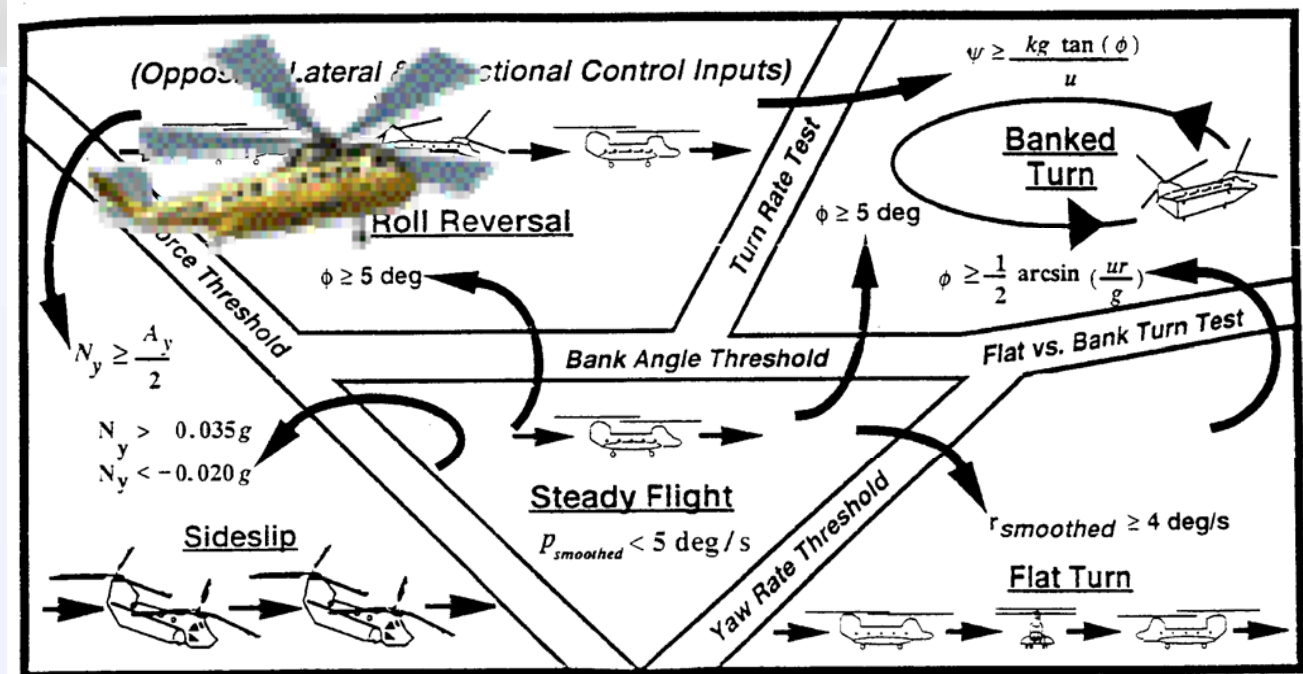


Mission Segment - Recognition

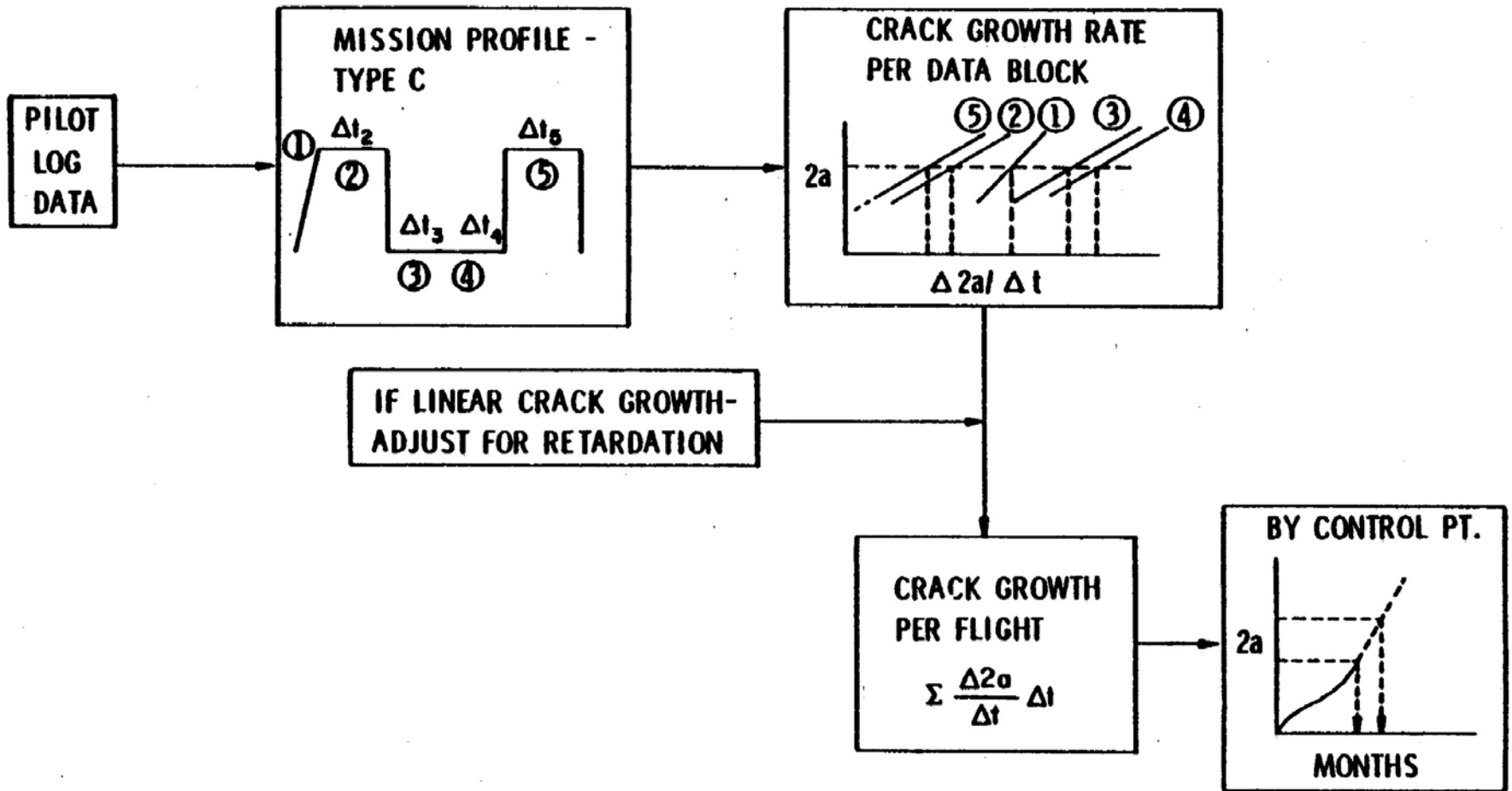


Mission Segment - Regime Recognition

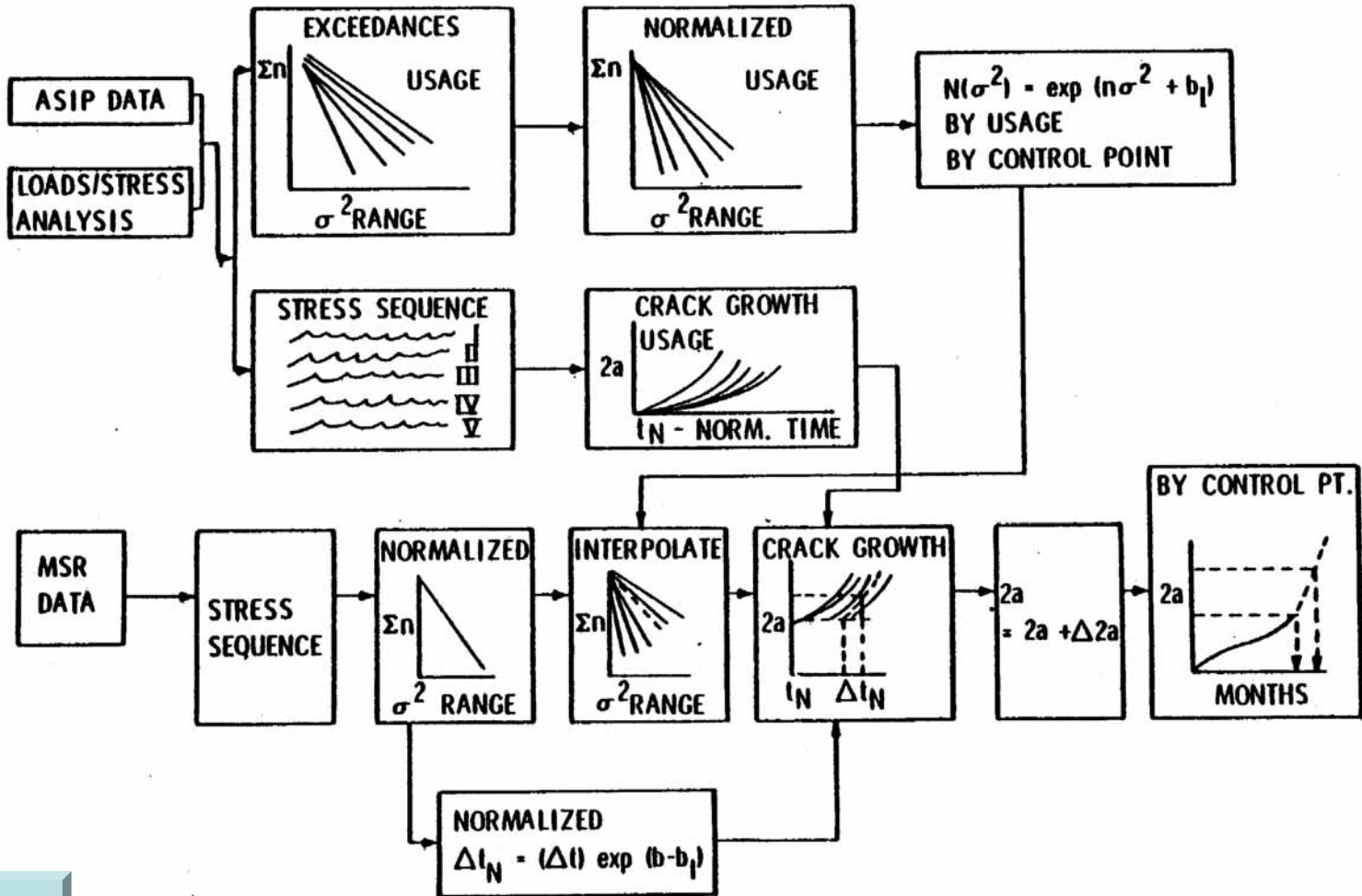
- Requires substantial amounts of calculation effort.



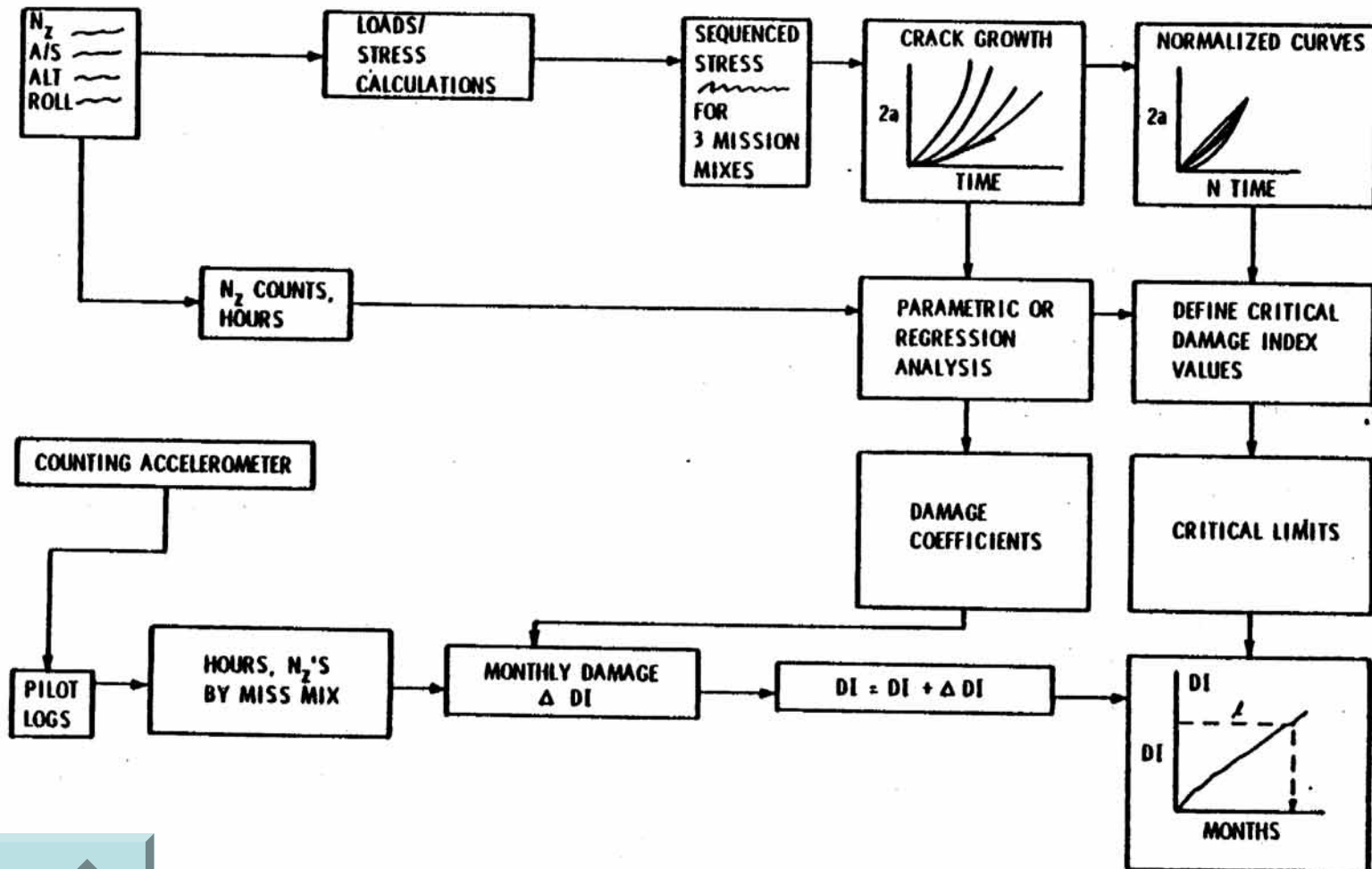
Time In Usage Category



Strain History



Damage Parameter



Goal

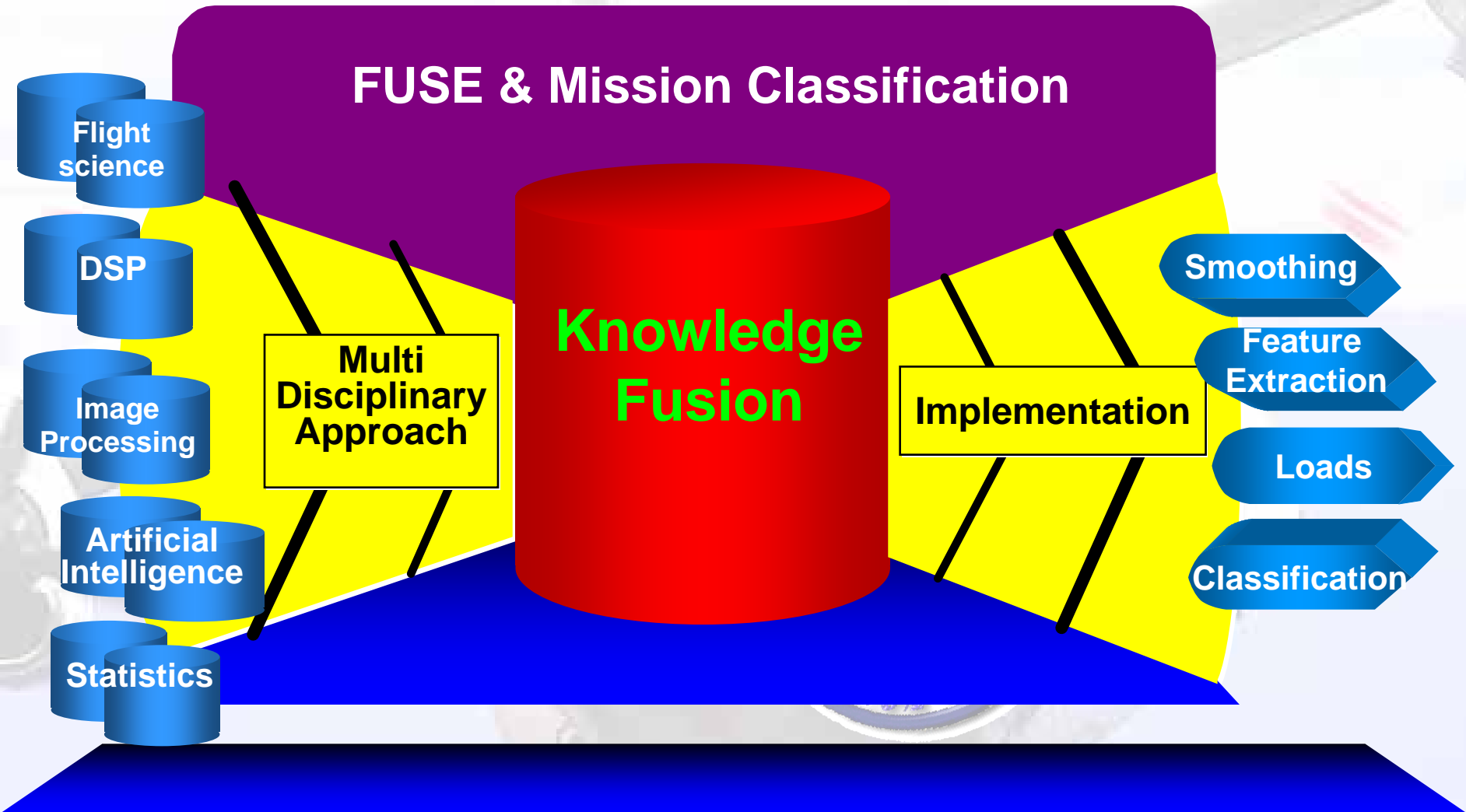
Proof of concept for
automated Fleet Usage
Spectrum Evaluation
(FUSE) and mission
classification



Design Process



Pattern Recognition Approach



**Operational
Data**

Segmentation

Smoothing

Integral

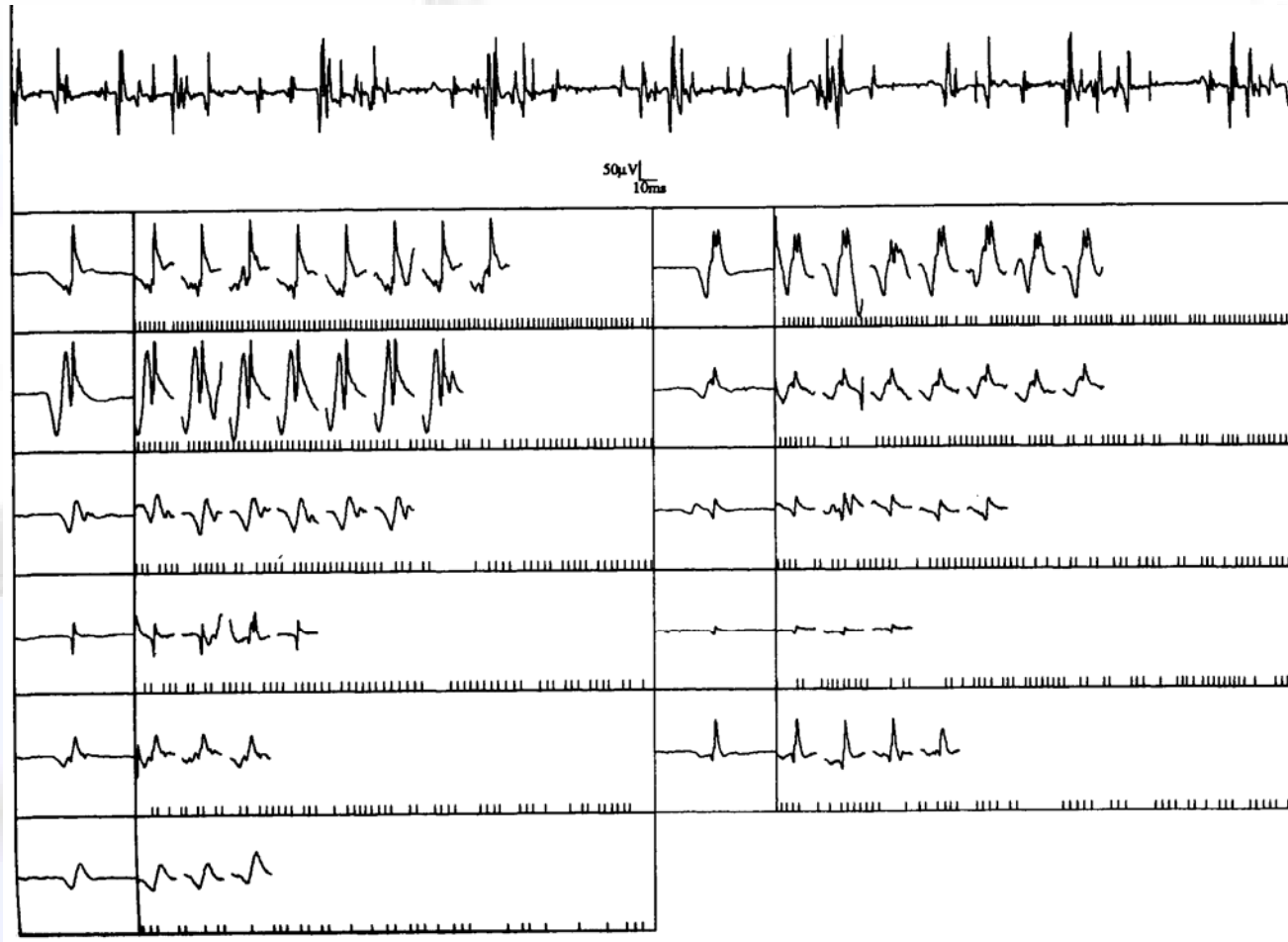
**Feature
Extraction**

Statistical

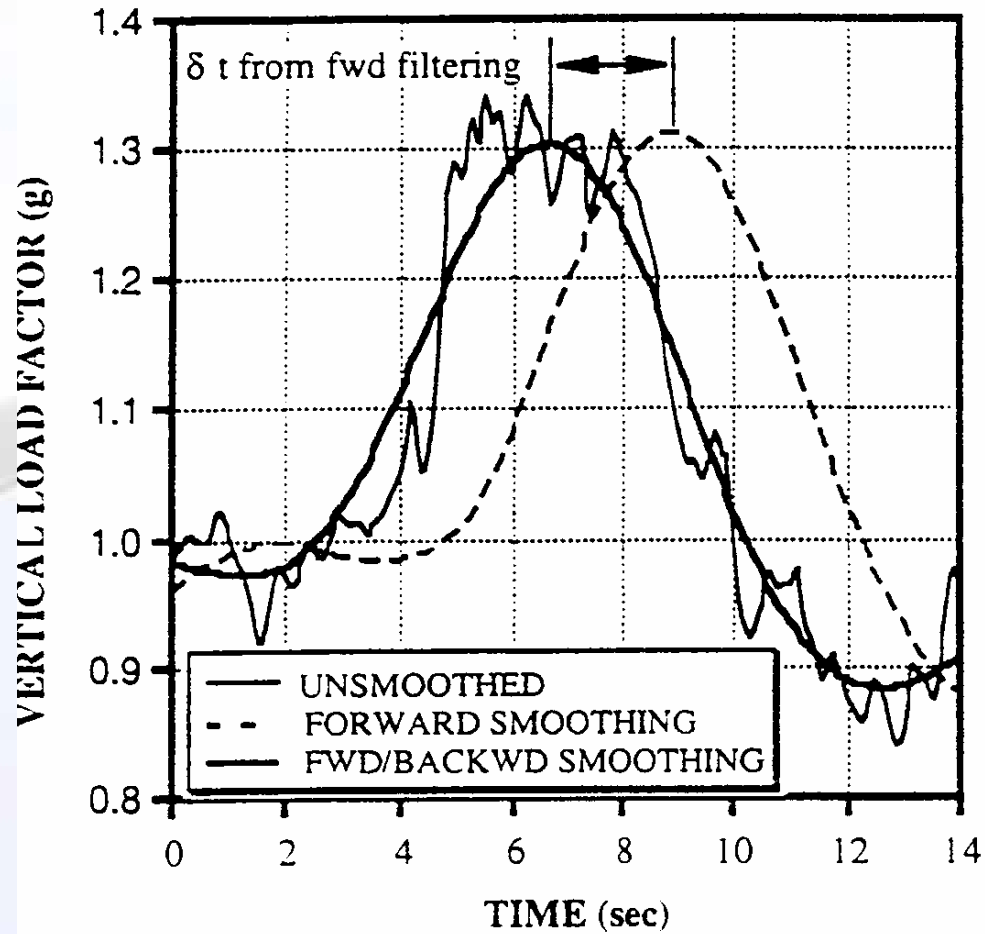
Mission Spectrum

**Mission
Classification**

Segmentation



Smoothing



Moment Invariants

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^\lambda}$$

$$\lambda = \frac{p+q}{2} + 1$$

$$\mu_{pq} = \iint f(x, y)(x - x')^p (y - y')^q dx dy$$

$$x' = \frac{\iint f(x, y)x dx dy}{\iint f(x, y) dx dy} \quad y' = \frac{\iint f(x, y)y dx dy}{\iint f(x, y) dx dy}$$



Moment Invariants

$$\phi_1 = \eta_{20} + \eta_{02}$$

$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2$$

$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$

$$\phi_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})\left\{(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right\} \\ + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})\left\{3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right\}$$

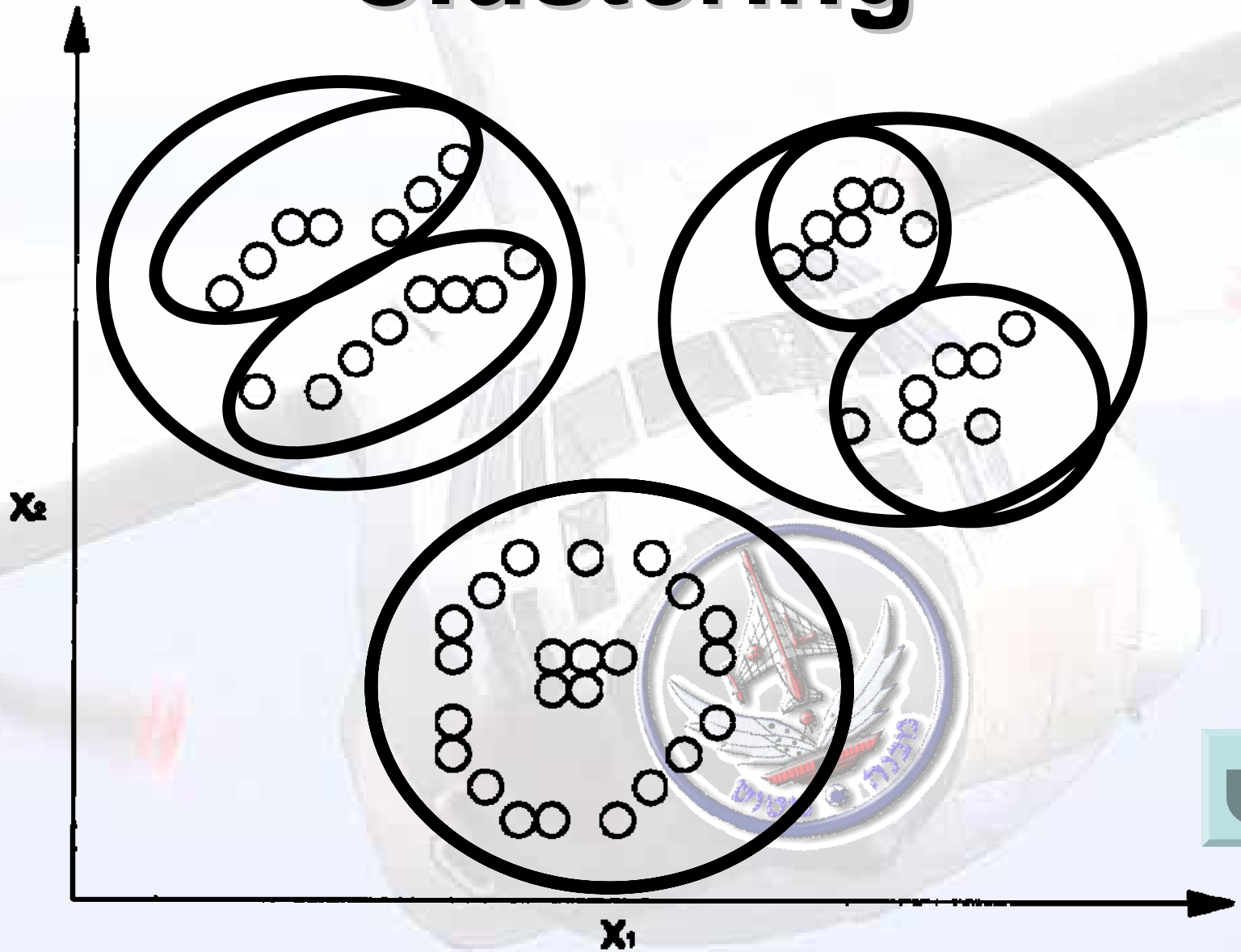
$$\phi_6 = (\eta_{20} - \eta_{02})\left\{(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right\} + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03})$$

$$\phi_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})\left\{(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right\} \\ - (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})\left\{3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right\}$$

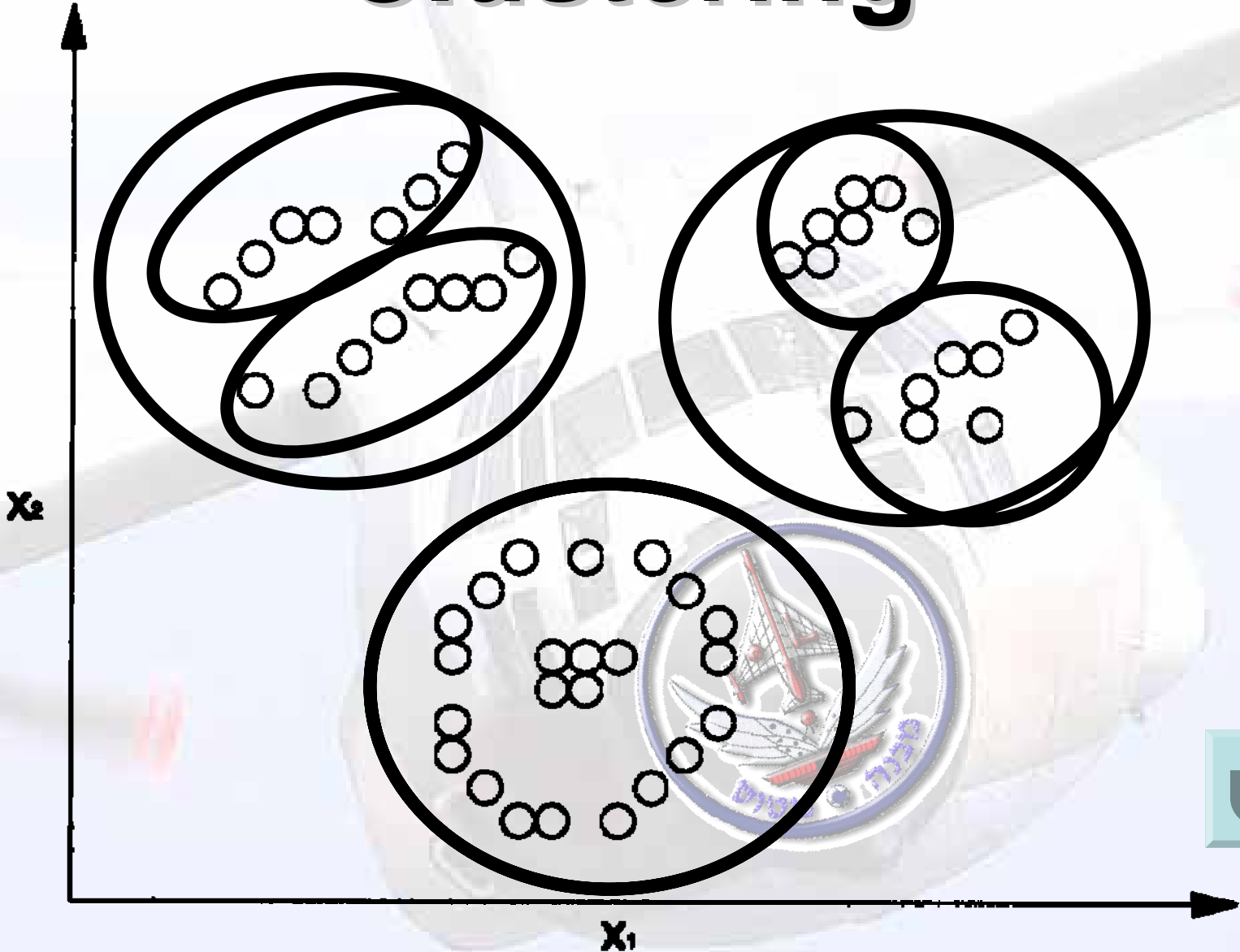
$$\phi_8 = \frac{\eta_{20}\eta_{02} - \eta_{11}^2}{\eta_{00}^4}$$



Clustering



Clustering



Classification

Nearest Cluster:

$$x = \langle a_1(x), a_2(x) \dots a_n(x) \rangle$$

$$x_i \in \text{Cluster}_k \Rightarrow \min(d_j)_{j=k}$$

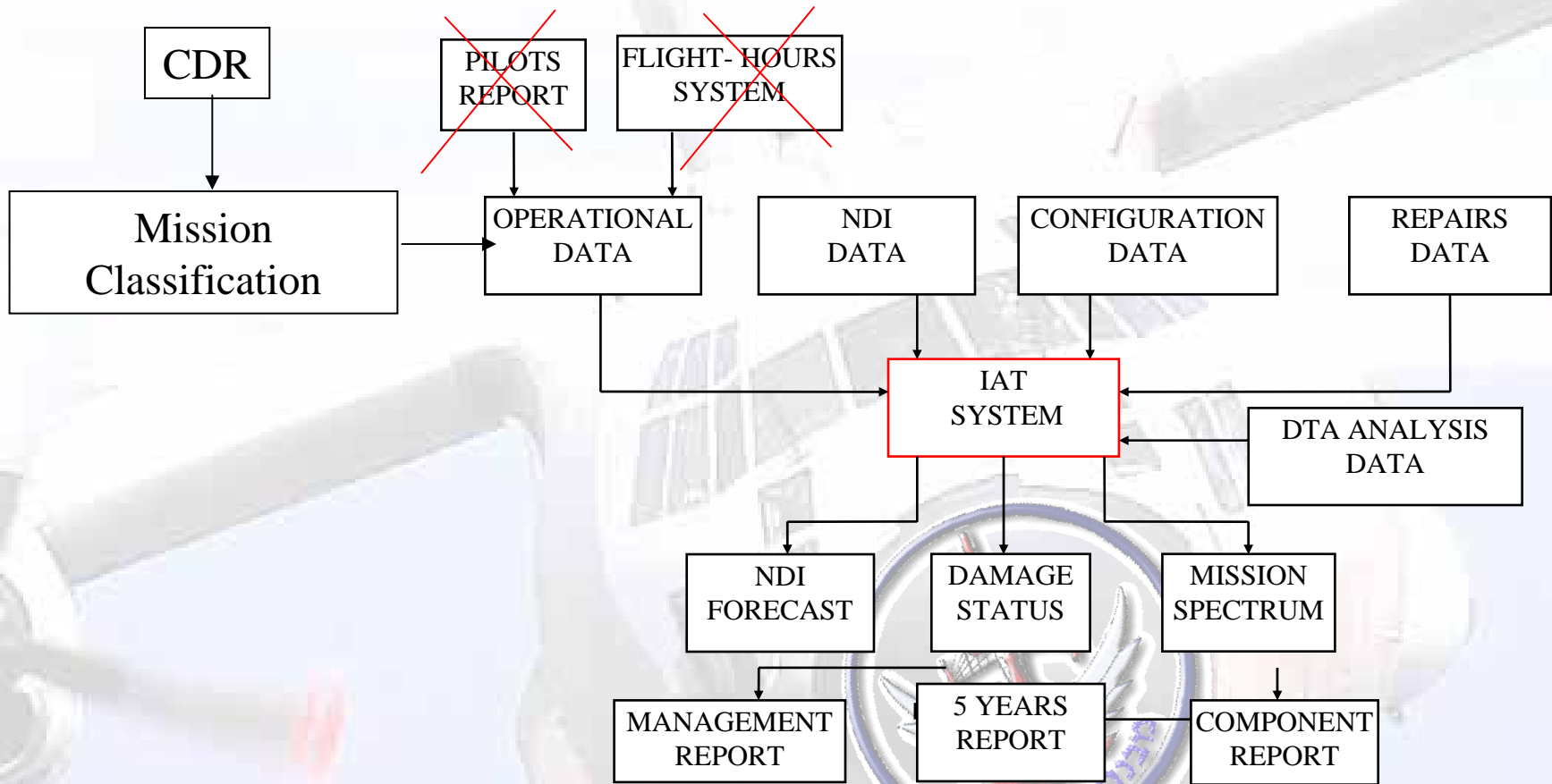
$$(d_j(x_i, \text{Cluster}_j)) = \sqrt{\sum_{r=1}^n (a_r(x_i) - a_r(x_j))^2}$$



C-130 Application



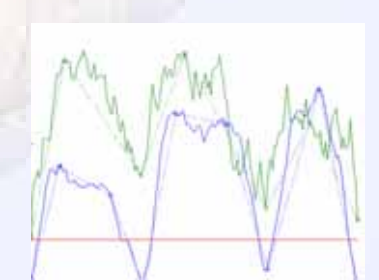
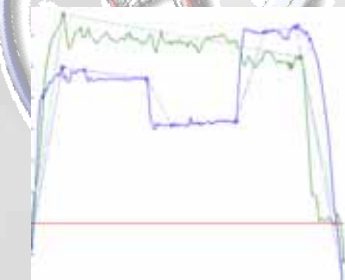
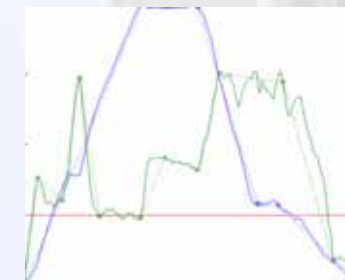
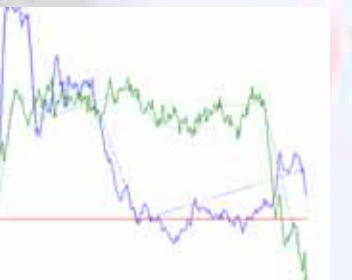
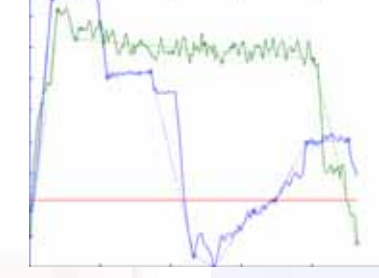
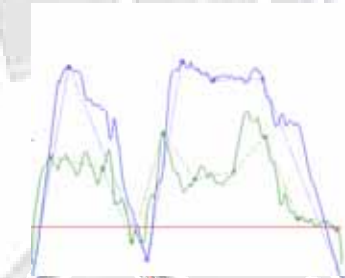
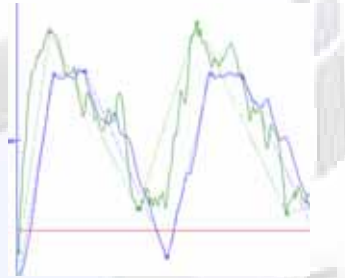
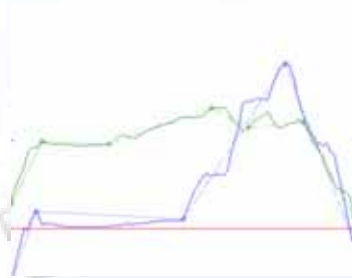
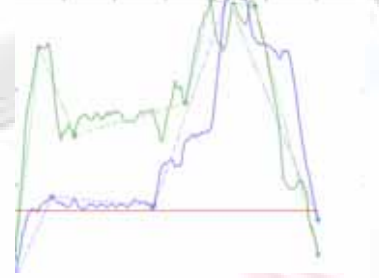
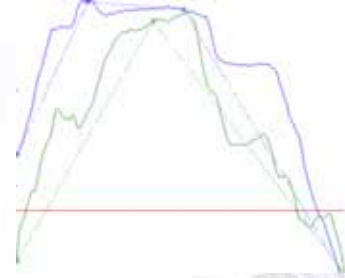
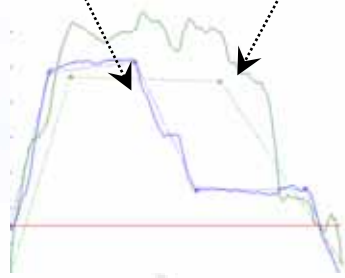
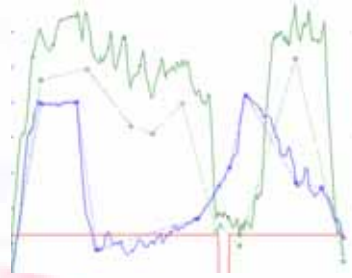
C-130 IAT Improvements



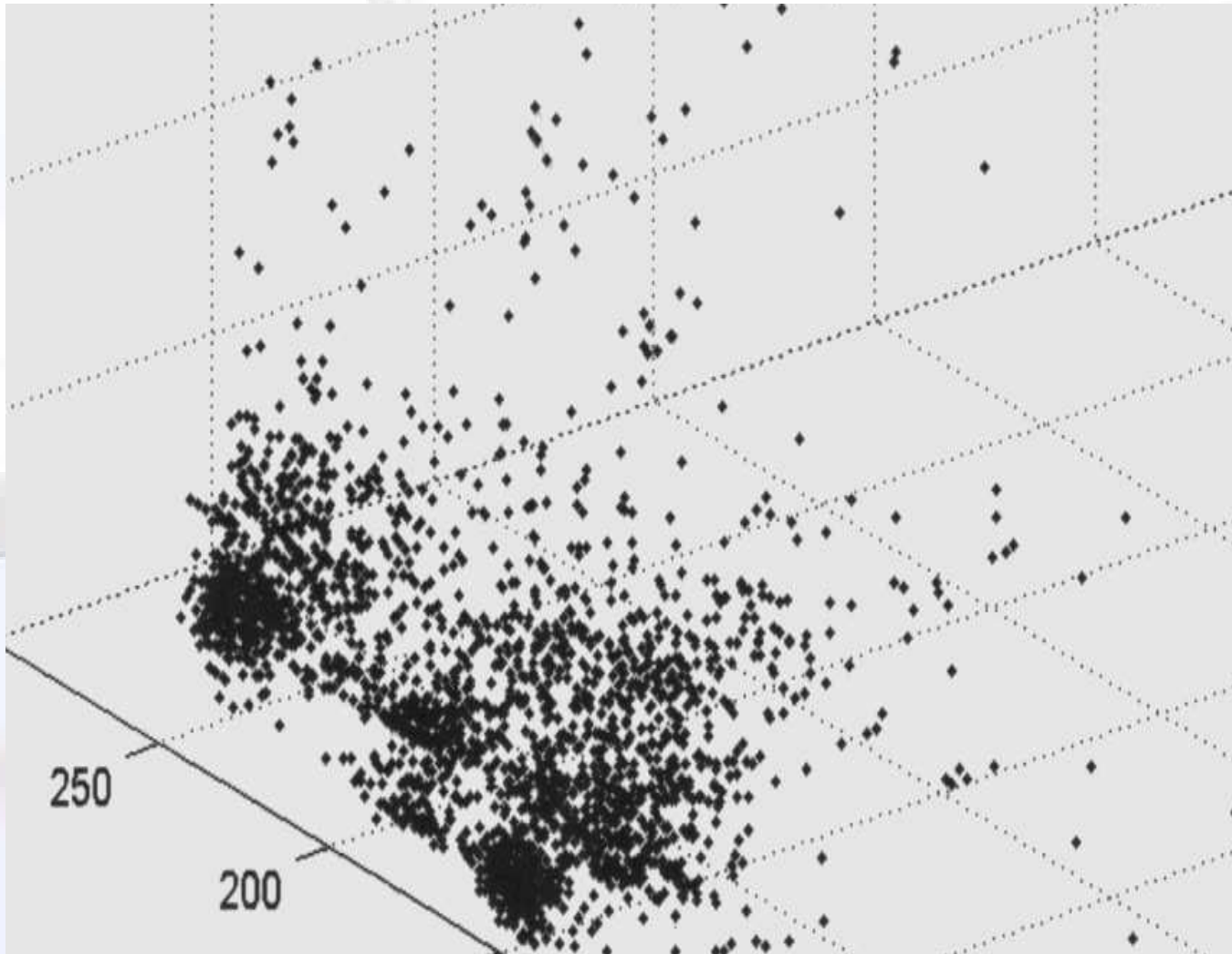
IAT upgrade current status

- Installation of CDR systems.
- Code development for transforming raw CDR data to a data base – Complete.
- Phase 1 – Cycle and Exceedance Counting algorithm – Completed.
- Phase 2 – Mission definition and categorization based on CDR data – Due 3/03.

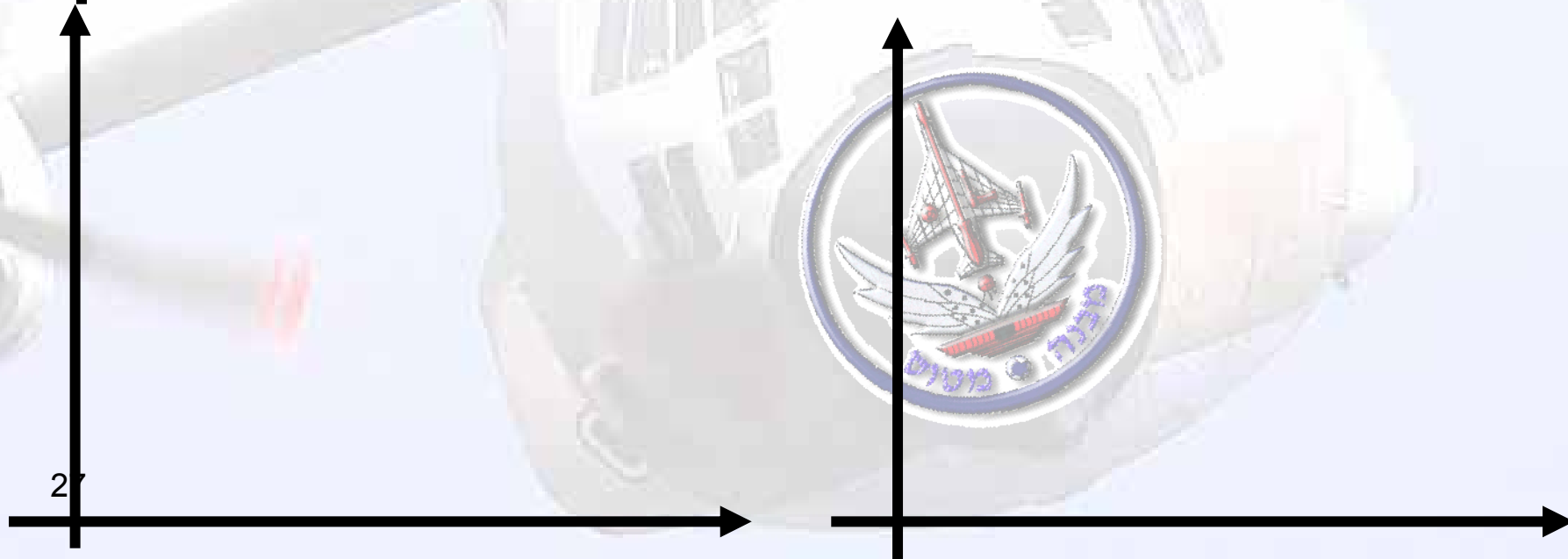
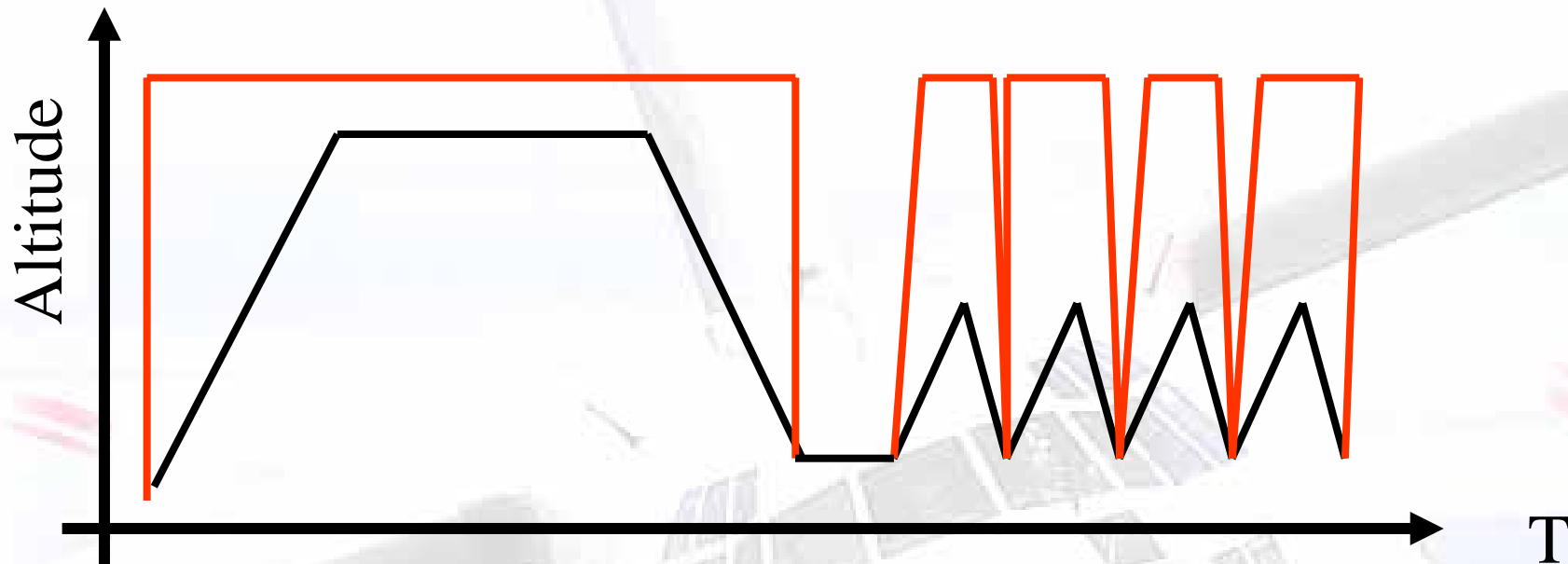
(Alt & Vel vs. Time)



Mission Scatter

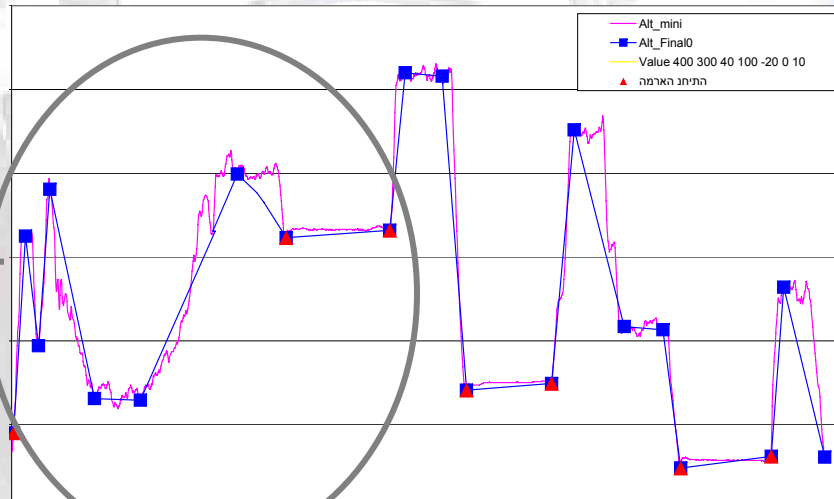
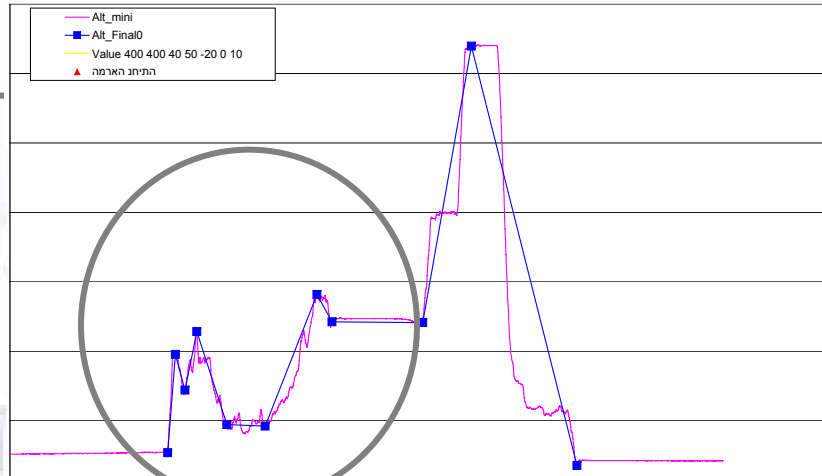


Global Mission Vs. Sub Mission

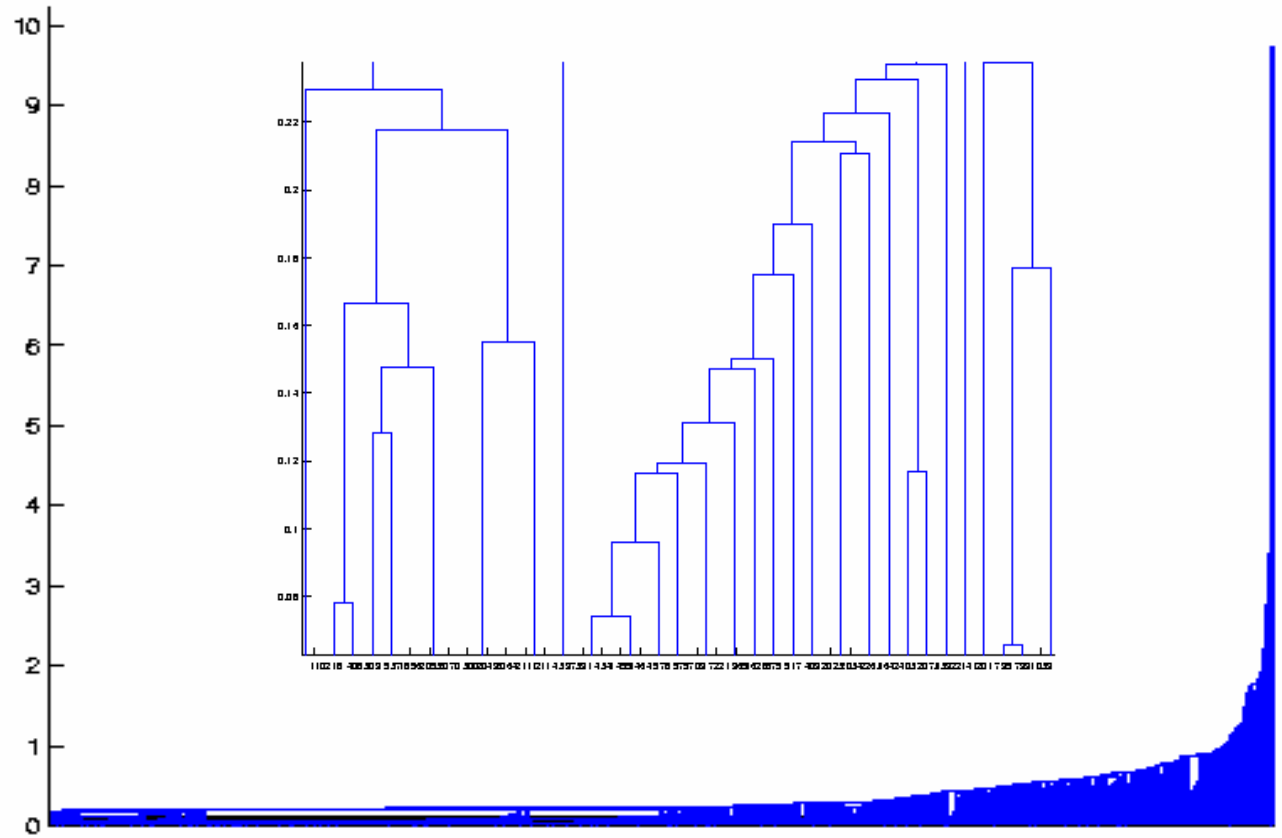


Sub Missions

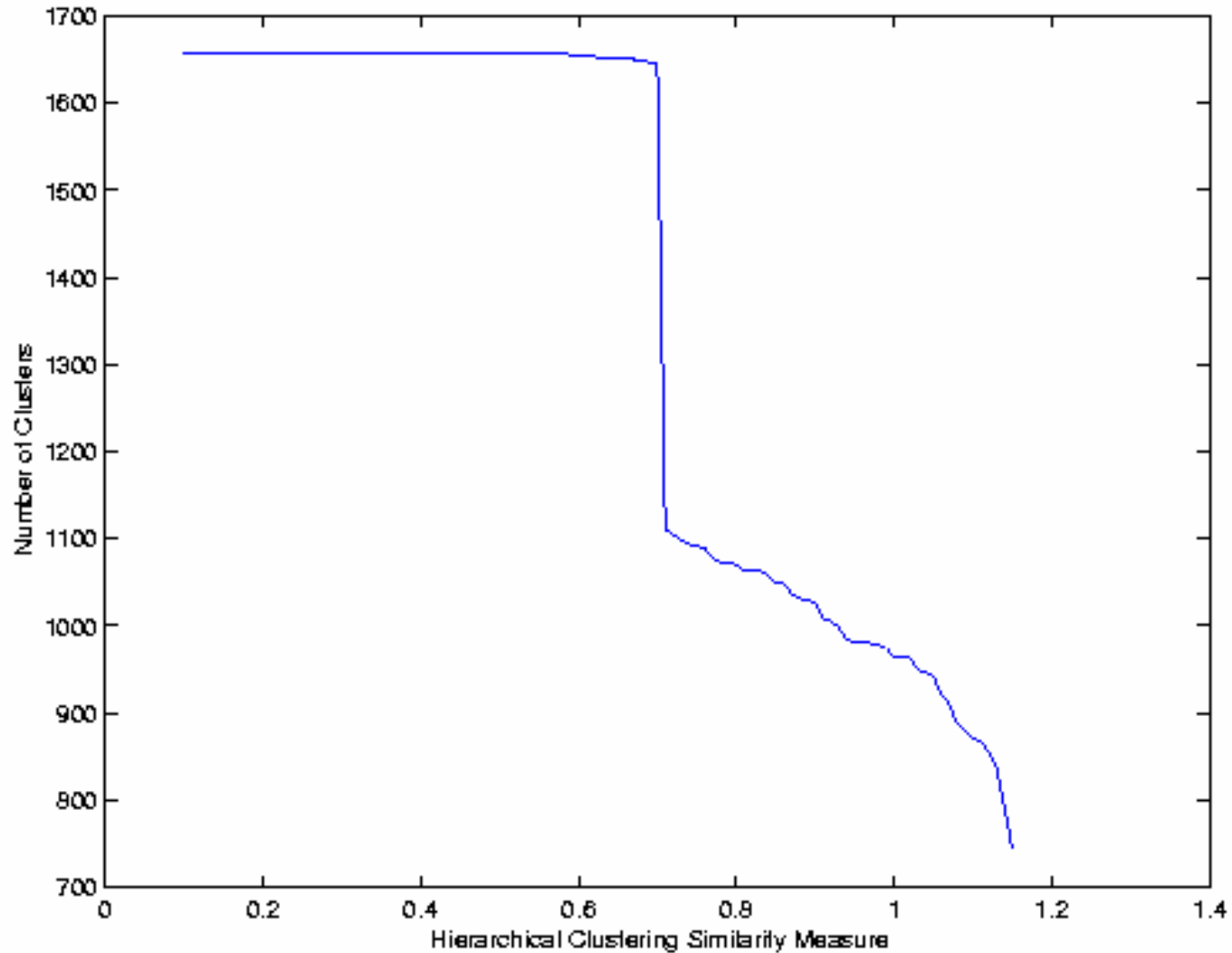
- Reduce number of basic mission
- Can effect on the inspection interval because it requires different Ground-Air – Ground cycle



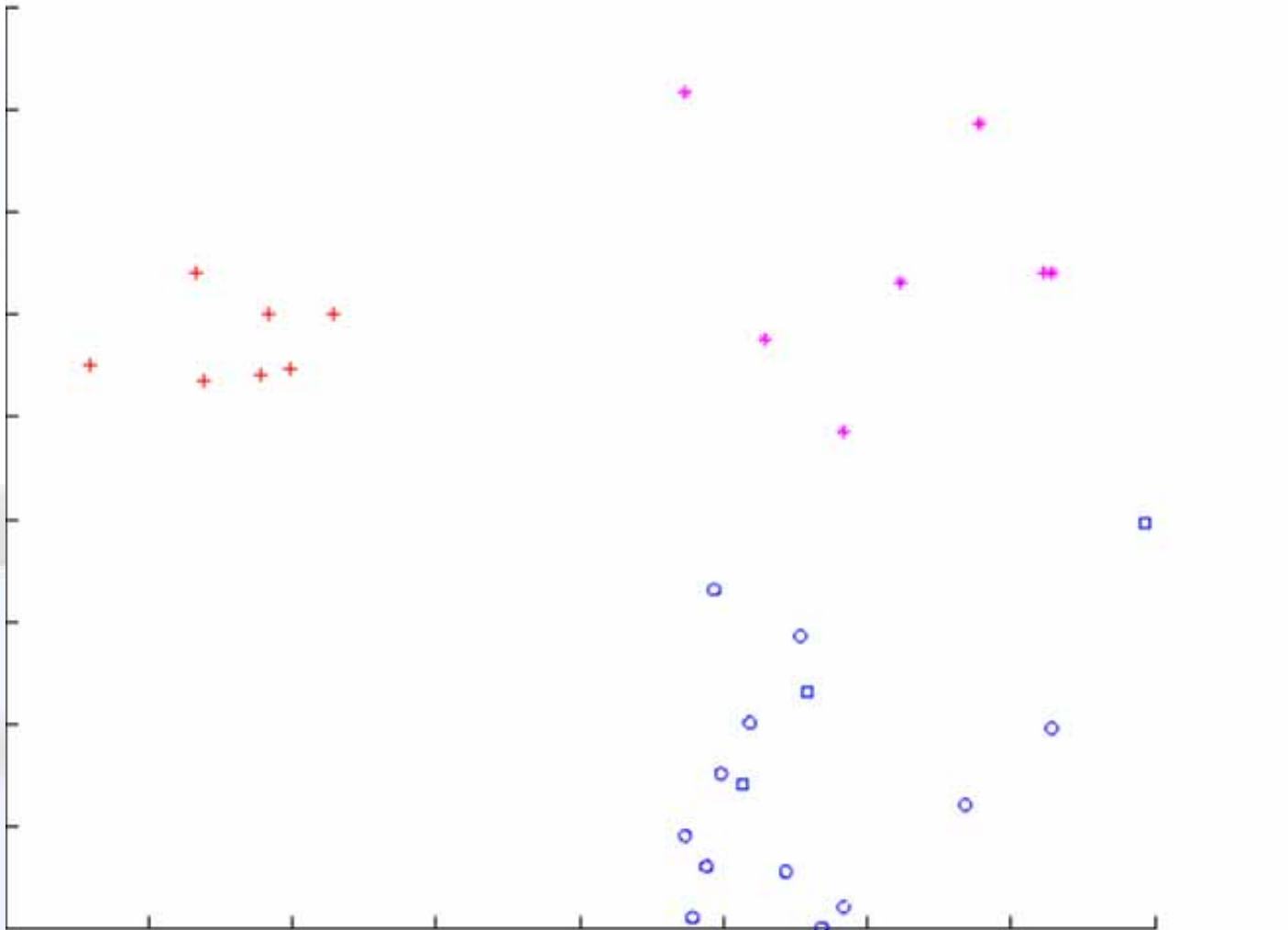
Hierarchical Clustering



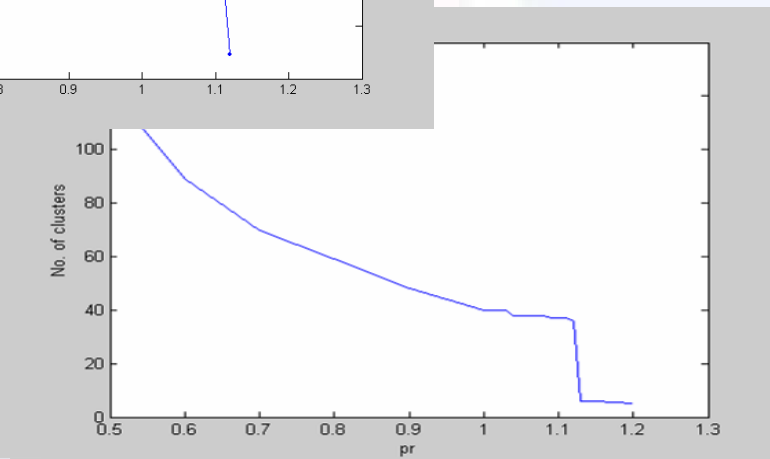
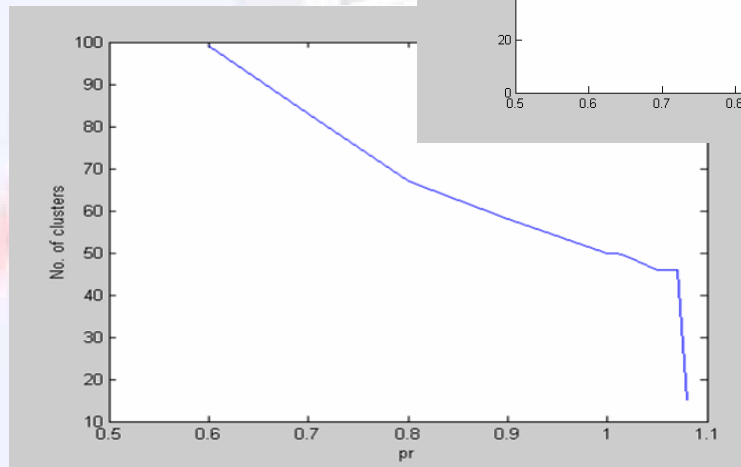
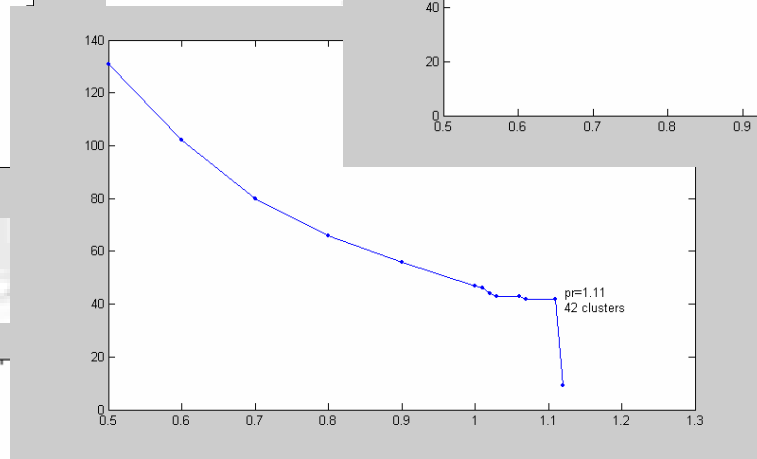
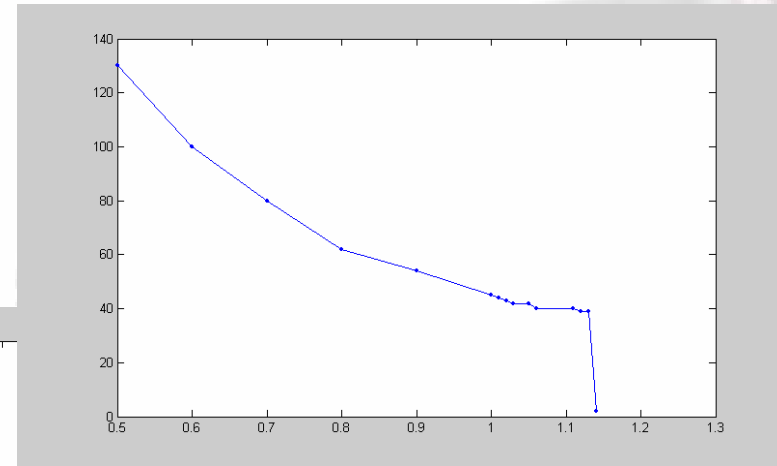
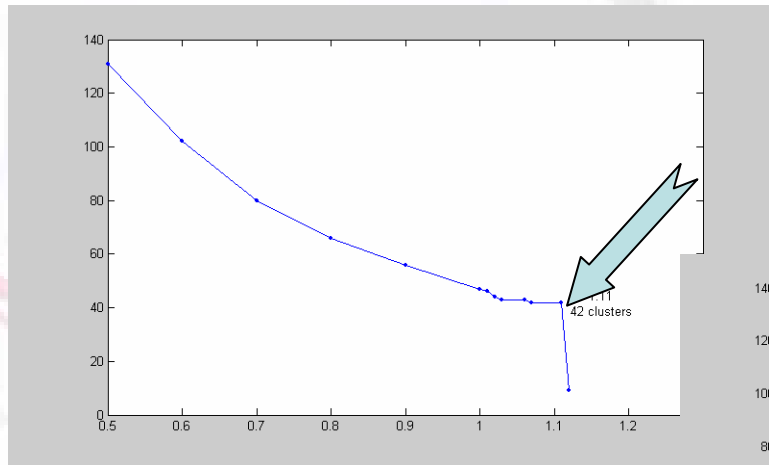
Traditional H.C. Divergence



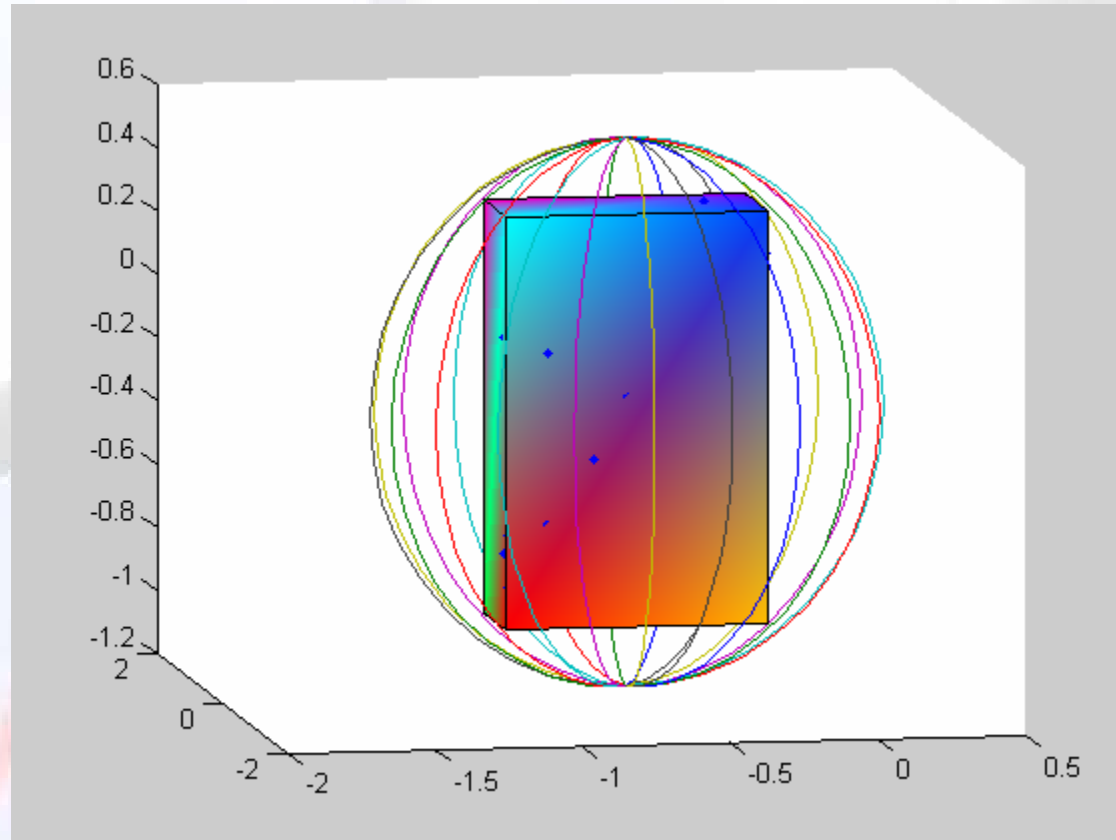
Clustering – nearest Cluster



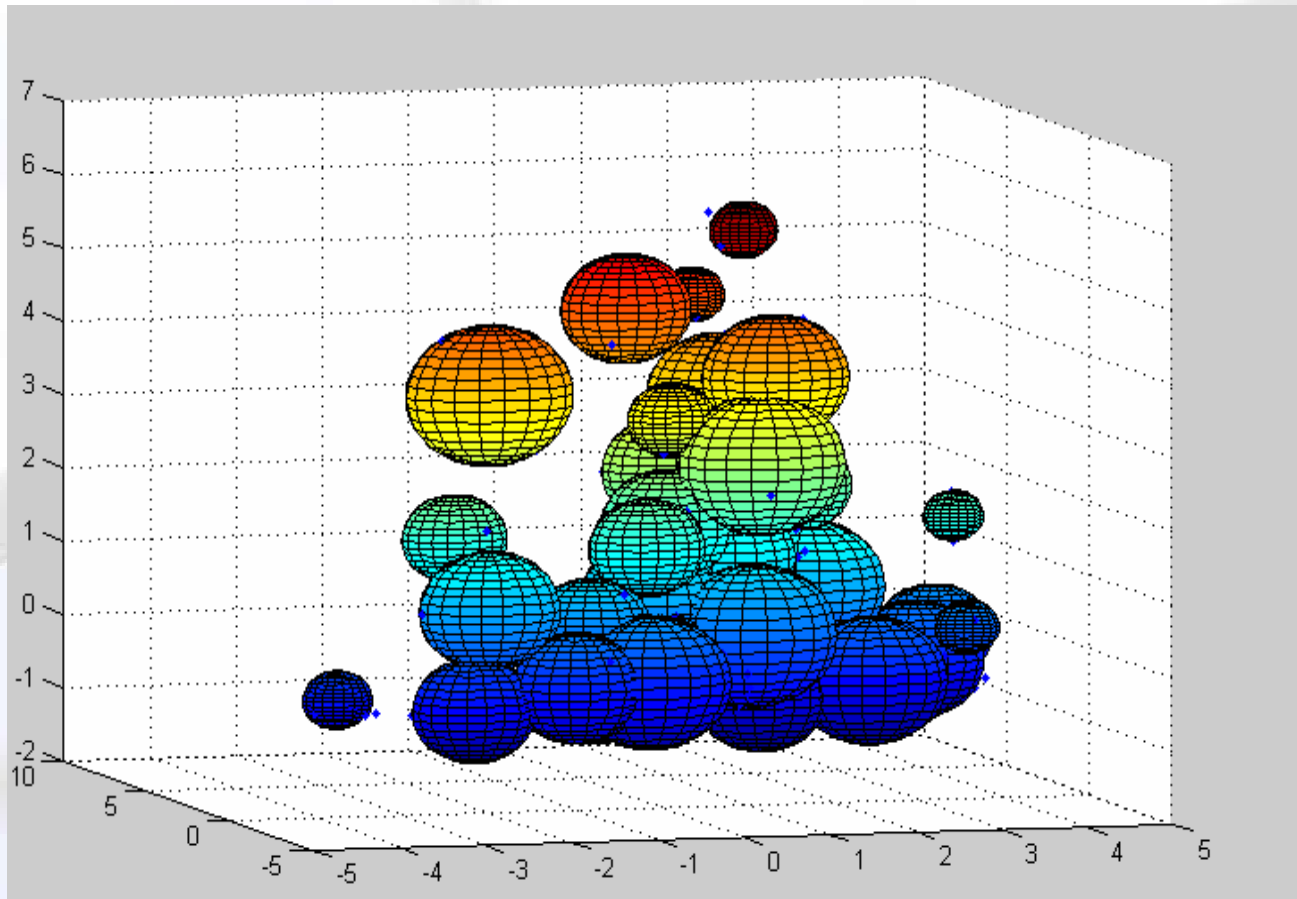
Natural Stopping Criteria



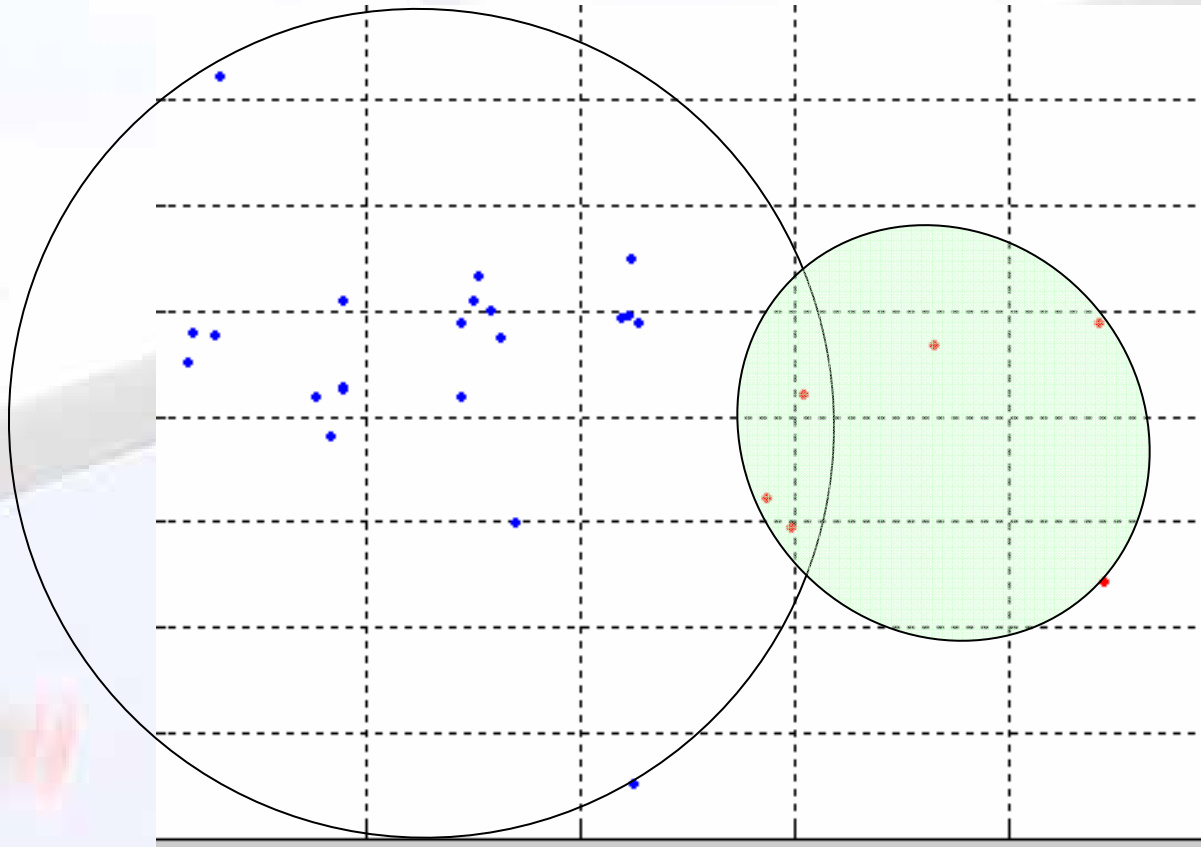
Cluster Representation



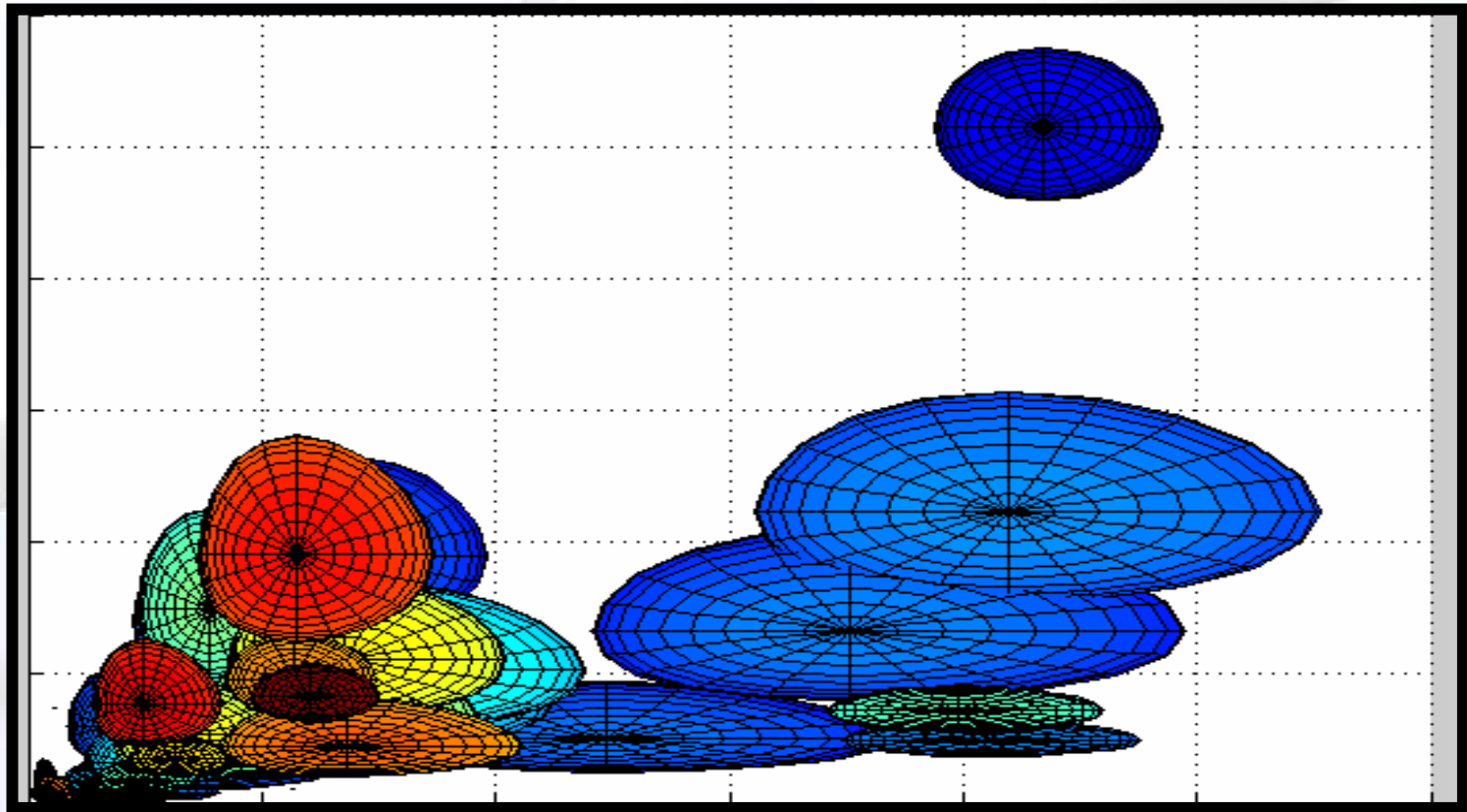
3D Classification spheres



Classification Decision Surface



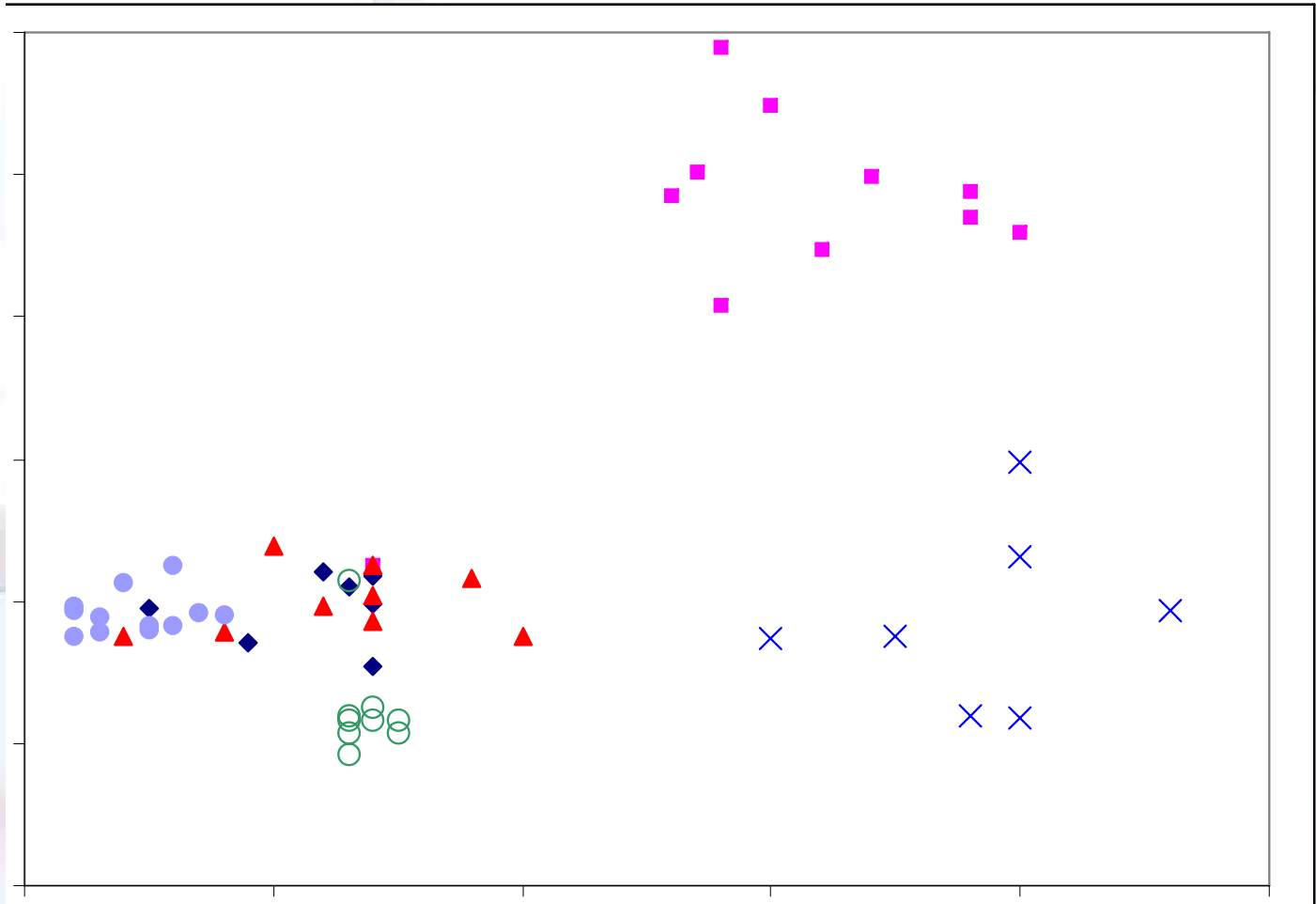
3D Distorted Classification spheres



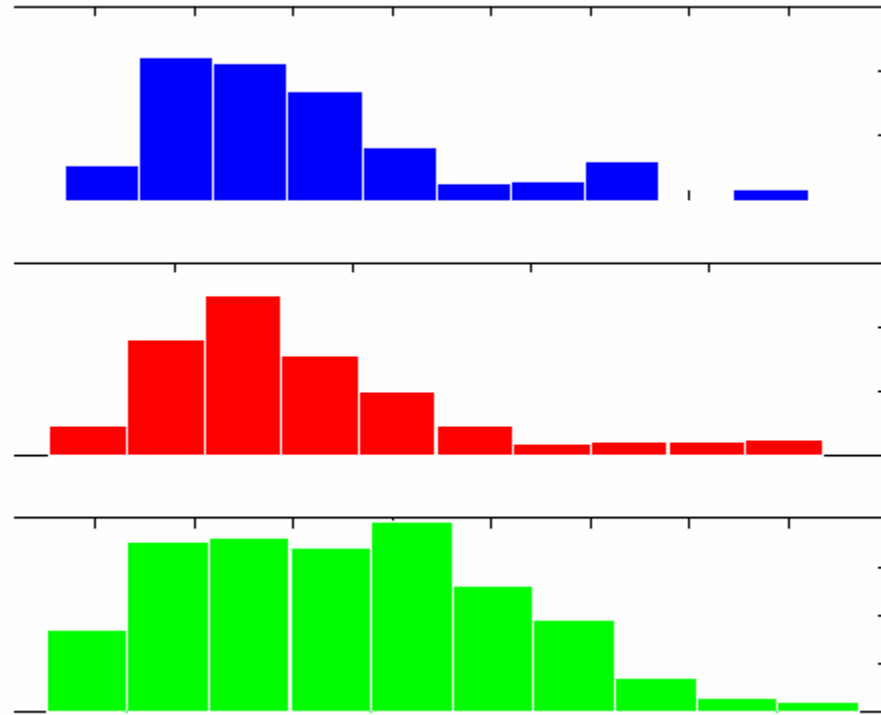
Results



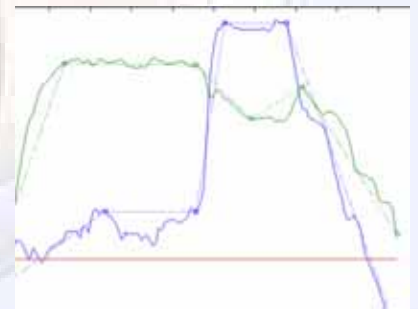
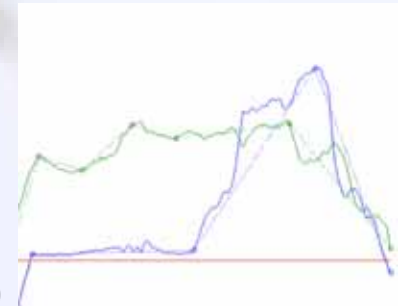
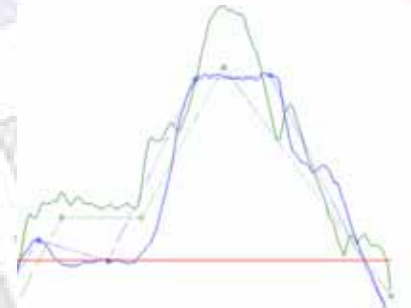
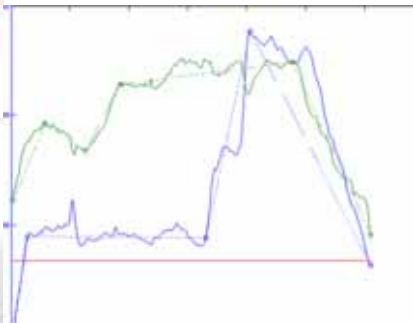
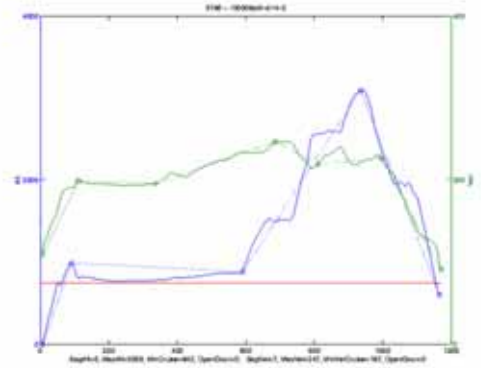
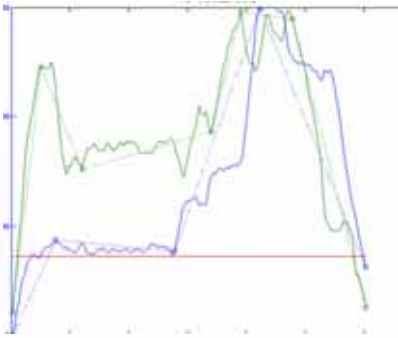
Results Analysis



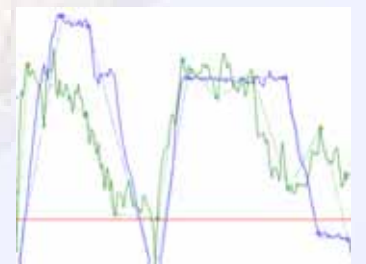
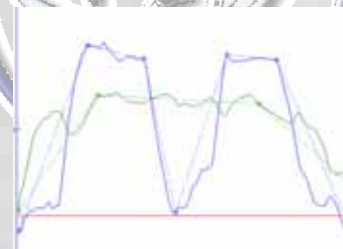
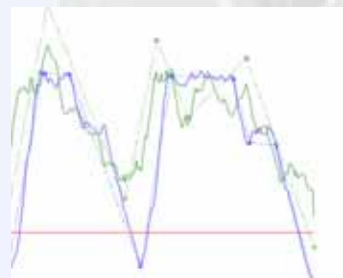
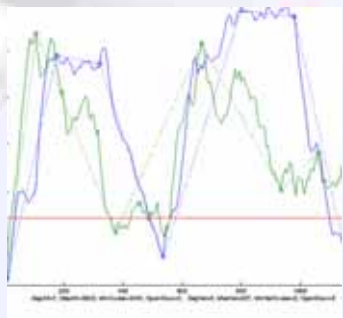
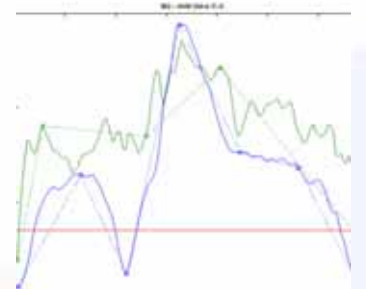
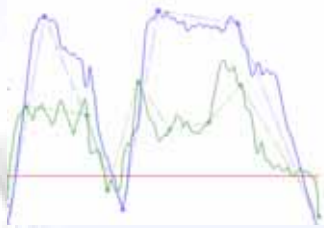
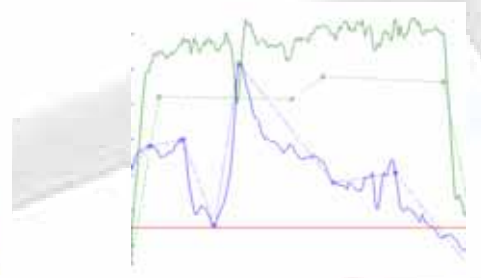
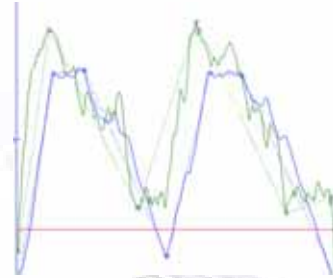
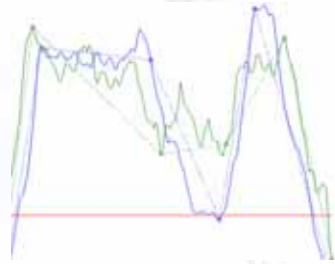
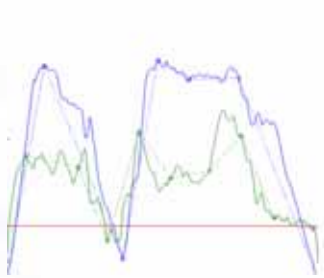
Results Analysis



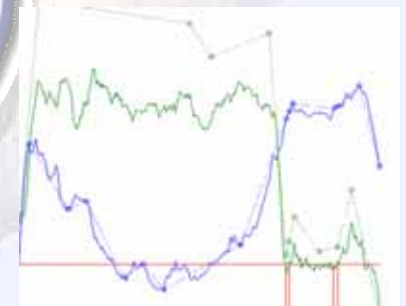
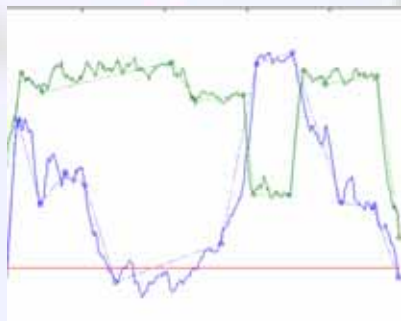
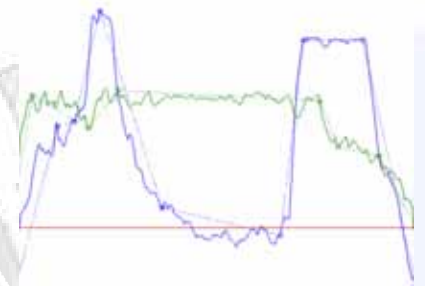
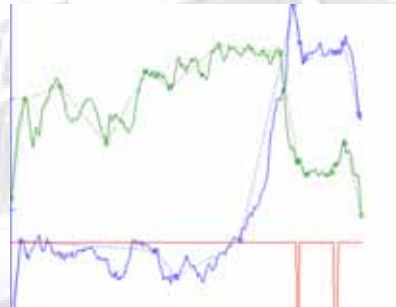
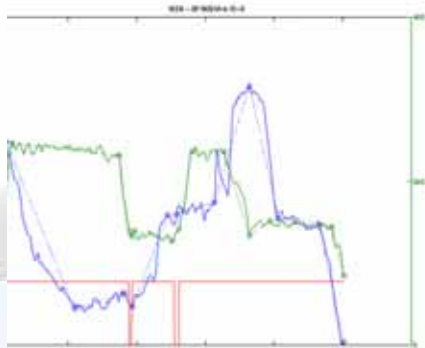
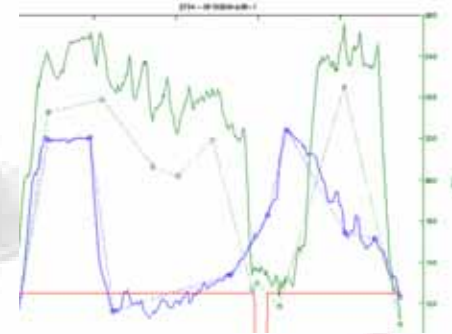
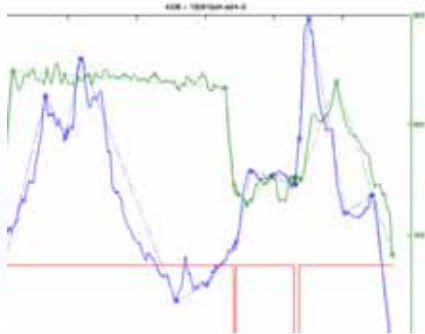
1#



3#



4#



Summary



Summary

- The automated FUSE concept was proved to be feasible:
 - The typical missions are identified automatically.
 - automatically capture the number of typical missions.
 - Mission classification is relatively simple task when using pattern recognition approach.
 - Enable the fleet managers to easily identify usage changes.
- The Operational Data Recorders can be use to increase the reliability of IAT systems.



Summary

- The automated FUSE concept was proved to be feasible:
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 - automatically capture the number of typical missions.
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