Impact of new technology on shipping operations

- Workshop -

Danaos Auditorium, Piraeus, Greece – May 13th

FLAGSHIP SP A2
Key performance indicators for technical operation

MARINTEK - Brage Mo, senior research engineer

Background

- The use of key performance indicators (**KPI**) has become a recognised practice in measuring performance
- The cargo owners and legislation bodies are increasingly focusing on **documented proactive operation**
  - Efficiency
  - Environmentally
  - Safety
- **Aggregated performance models** of ships need to be made by **transparent** and consistent assessments of their **technical condition**

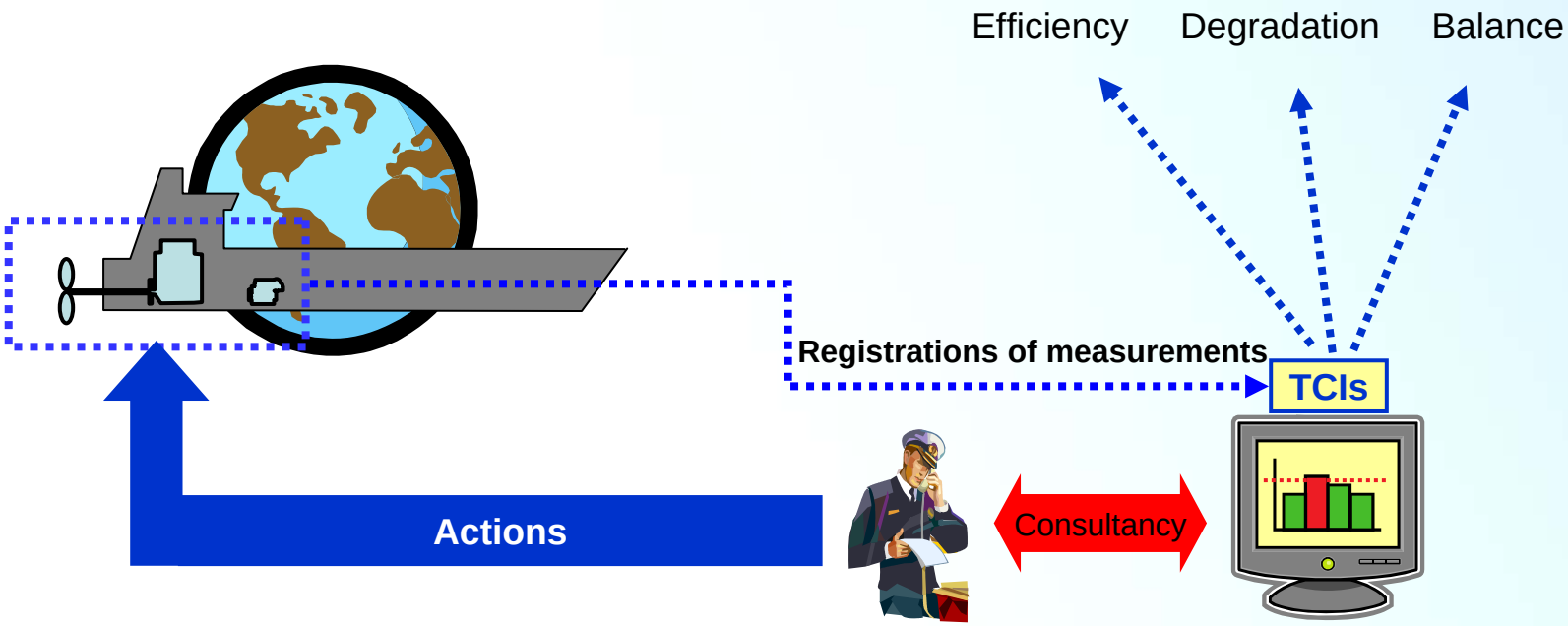
TCI definition

The TCI, the Technical Condition Index, is defined as follows:

- ***The Technical Condition Index, denoted TCI, is defined as the degree of degradation relative to the design condition.***
- *The TCI can apply to equipment, a system, a whole ship or a fleet of ships. It may take values between a minimum and a maximum value, where the maximum value describes the* ***design condition [e.g. sea trial condition], TCI=100, and the minimum value describes the state of total degradation, TCI=0.***
- *The state of total degradation is the condition so unsatisfactory that the equipment, system or ship is prevented from carrying out its primary function.*

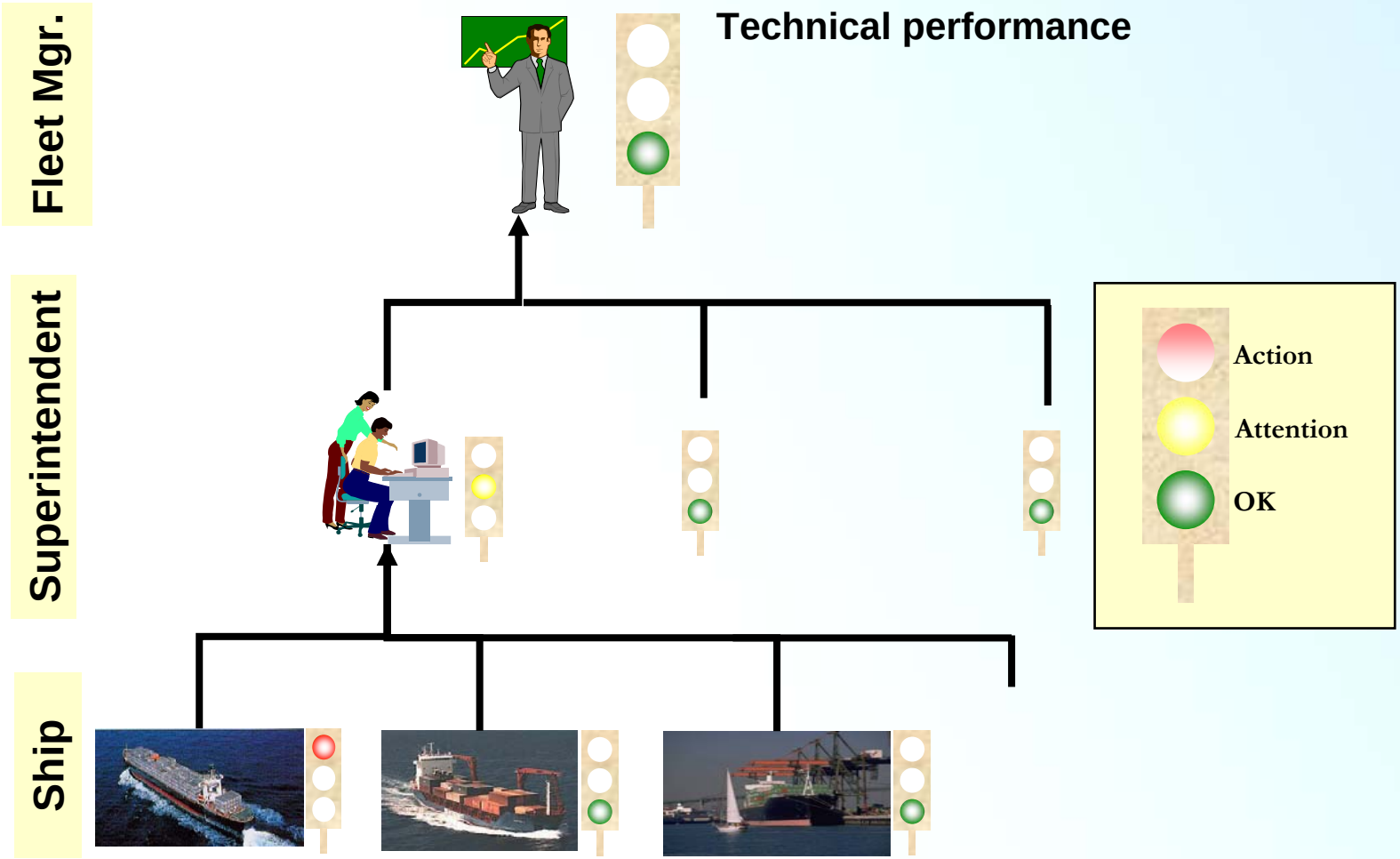
It is important to distinguish between the TCI and the KPI. The KPI are financial and non-financial metrics used to help an organization define and measure progress toward organizational goals [6]. **In some instances the KPI and TCI can be the same thing,** i.e. if one uses fuels cost as a KPI, this will be the same as the TCI fuel consumption.

Ship registrations – decision support

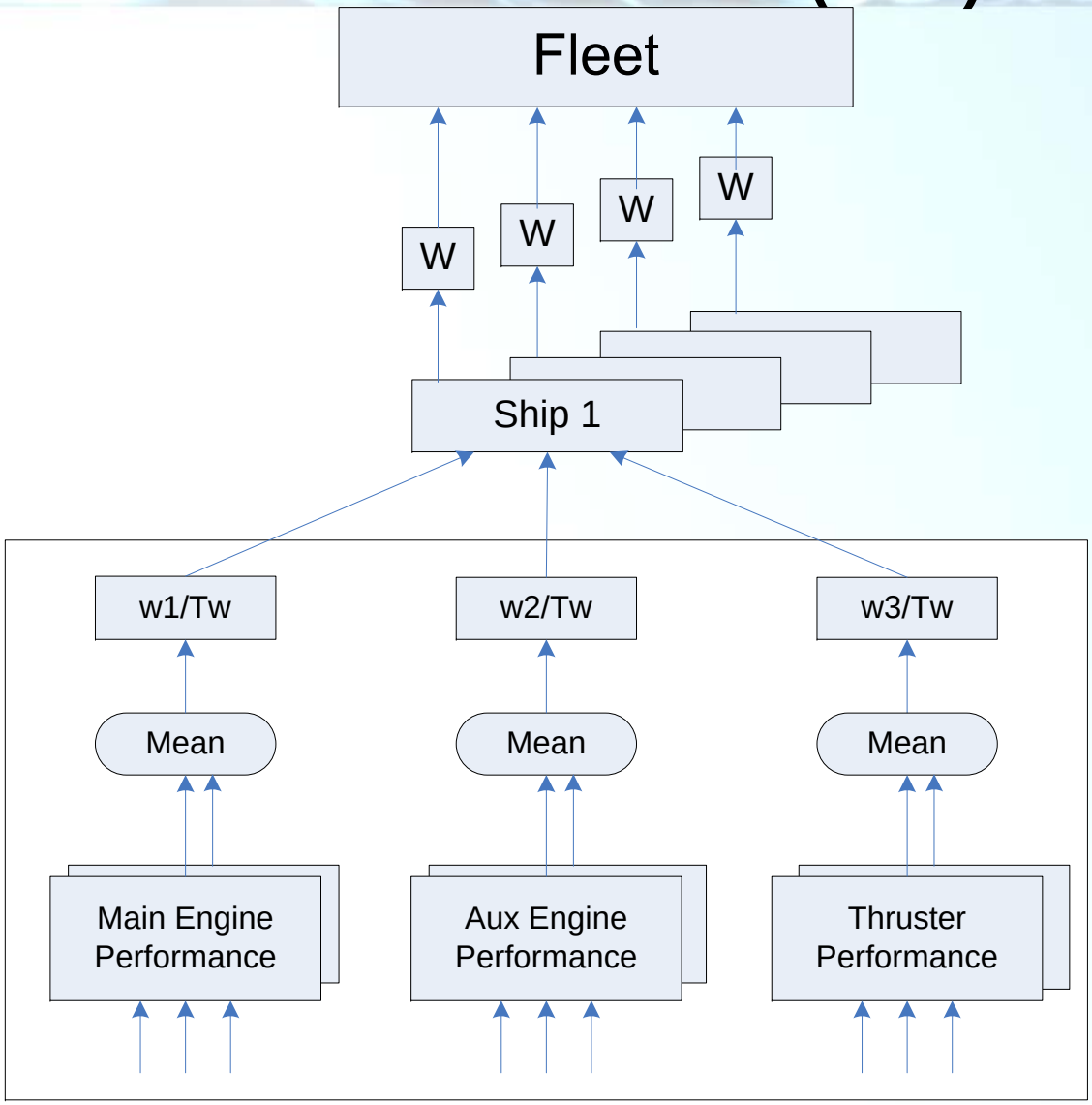


Evaluations and actions in technical issues

Shore also follow-up TCIs

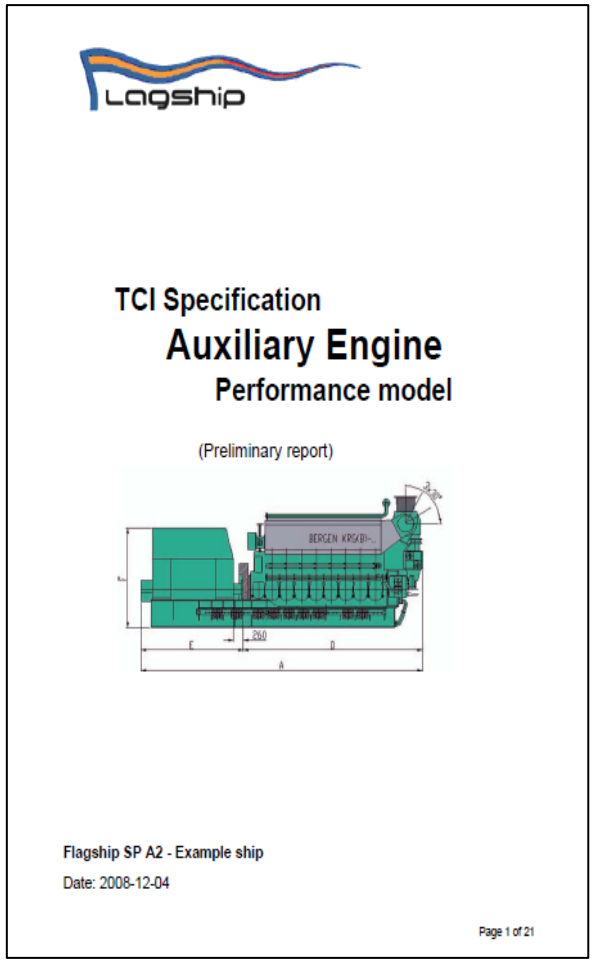


AGGREGATED
SHIP FLEET INDEX (TCIs)



TCI Specification

AE Performance model



TCI Specification

Auxiliary Engine

Performance model

(Preliminary report)

Flagship SP A2 - Example ship

Date: 2008-12-04

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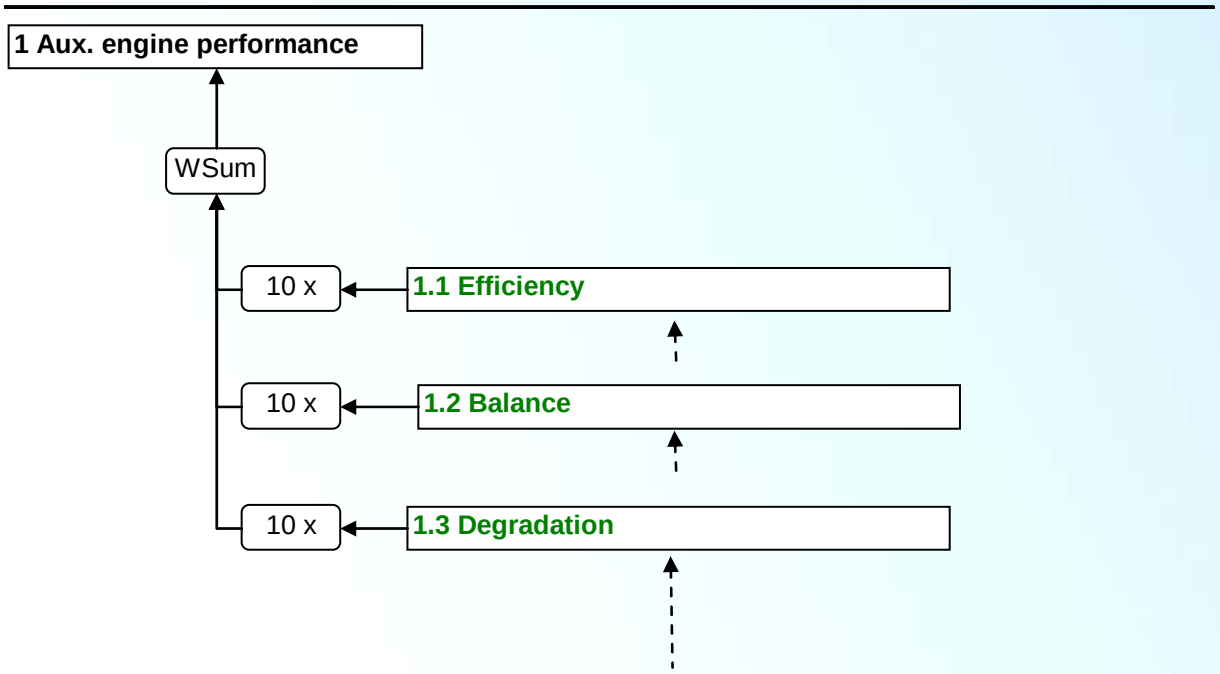
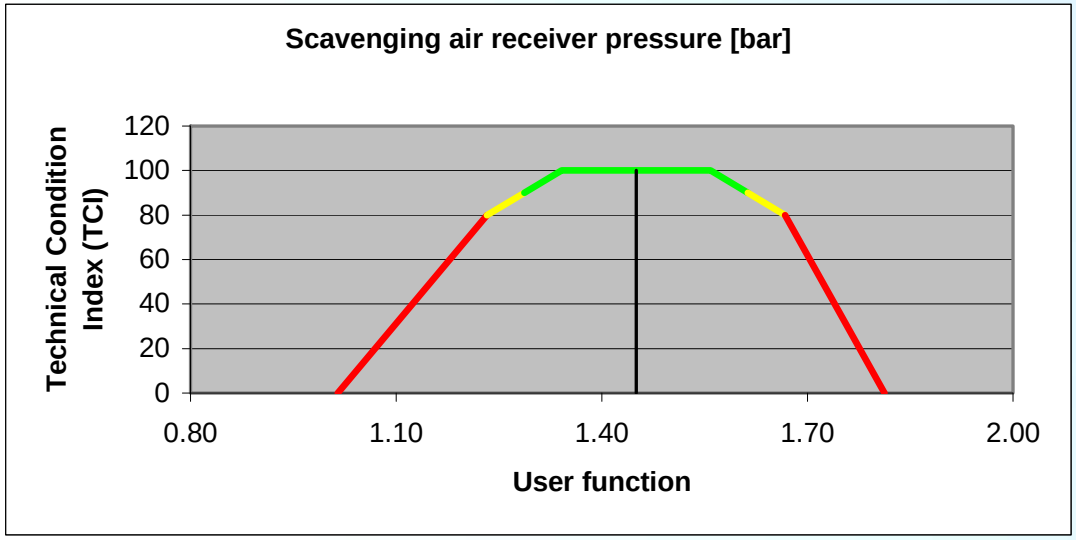


TCI Specification

AE Performance model

Index function

Value	Index	From reference
1.02	0	-30.0 %
1.23	80	-15.0 %
1.29	90	-11.3 %
1.34	100	-7.5 %
1.56	100	7.5 %
1.61	90	11.3 %
1.67	80	15.0 %
1.81	0	25.0 %



TCI Specification
AE Performance model

M10. Pscav Receiver

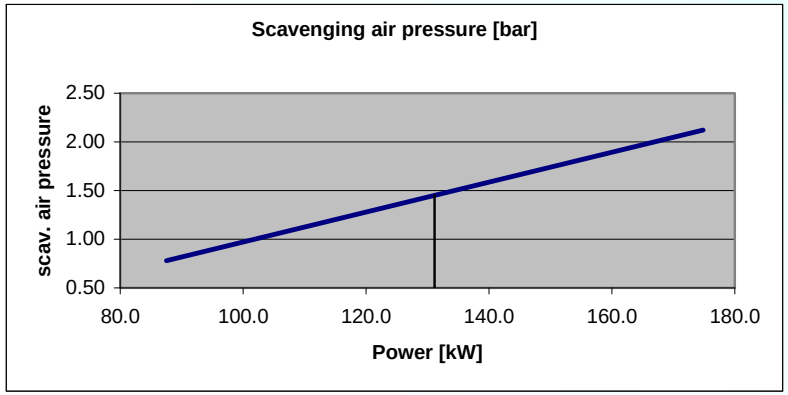
Ideal performance

$$BHP_{M_meas} = \frac{\sum_{i=1}^{n} BHP(i)_{meas}}{n}$$

Engine load	50	75	100	[%]
Scav_air_press	0.78	1.45	2.12	[bar]
BHP	119.0	178.3	237.7	[BHP]
Power	87.5	131.2	174.8	[kW]

Reference value:

1.45



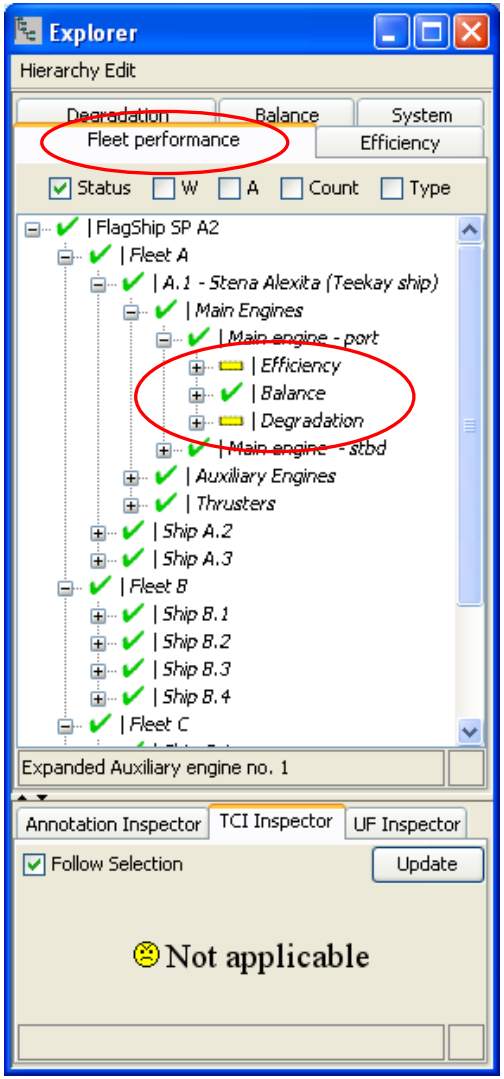
Calculated value:

$$K_{Pscav} = \frac{Pscav_2 - Pscav_1}{Power_2 - Power_1}$$

K_scav = 0.0153

$$Pscav_{corr} = Pscav_{meas} + K_{Pscav}\left(Power_{ref} - Power_{M_meas}\right) + (T_{Eng_room_meas} - 25) \cdot 0,002856 \cdot Pscav_{meas}$$

Example



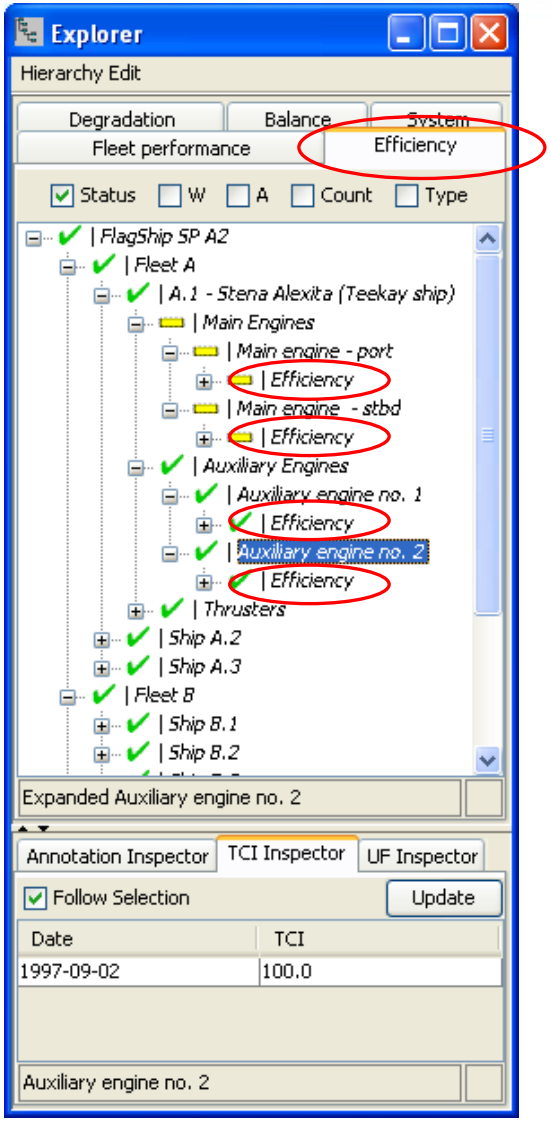
FLEET PERFORMANCE

- A holistic view that assesses units
    - Efficiency
    - Degradation
    - Balance

{Balance - comparing units expected to have equal performance}

- A holistic view that assesses
    - Several Fleets (A, B, C, D,..)
    - with Ships (A1, A2,..,B1,..)

Example



SELECTING CATEGORY of PERFORMANCE

- Reducing holistic view of fleets to e.g.
    - Efficiency

Stakeholders interests defines

- Selection of what to be presented, e.g.
    - Efficiency
    - SFOC (Specific Fuel Oil Consumption)
    - Speed / Fuel oil Consumption
    - …
- New data/ assessments {SP A1, SP B1?}

Implementation Procedure

- Develop forms
- Input ship static data
- Send forms to ship

- Install forms
- Input measure data
- Validate
- Send xml data
  - Use email

- Receive xml/email
- Validate
- Store data
- Analyze
- Produce report
- Send report to ship

- Receive report
- Do maintenance

ME Registrations (Trial/ Ideal)

Main Engine Performance Registration

Report Date

Static informati

Report name
Vessel name
IMO code_ME_I
Measurement fr
No of main engi

Engine ID
Maker
Type
Serial No.
Max power [kW]
Max Revolution
Fuel valve opera
Exhaust valve o

Ship speed mea

Masters name
Start time
Latitude
Longitude
Stop time
Latitude
Longitude
Wind dir. [obs. r
Wind force [Kno

Main Engine Performance Registration

Main Engine measure values

Chief Engineers name	Chief
Total running hours	1
Start time	00:00:00
Stop time	01:00:00
Engine room temp [C]	43,4

Scavenging receive temp [C]	38,9
Scavenging rec press [barO]	2,1
Exhaust receive press [barO]	1
Exh. gas Economizer [mmWC]	100

Revolutions [rpm]	117,7
Fuel pumps index	63,4
Cyl.oil.cons [g/Kwh]	00,00
Eff. power[kW]	8182
Validation	OK
Comment	xxx

Turbocharger ID	1
Revolutions [rpm]	12 052,1
Air inlet [C]	43,4
Air filter pressure drop [mmWC]	65
Exhaust inlet temperature [C]	429,1
Exhaust outlet temperature [C]	293,5

Scavenging air cooler ID	1
Air inlet [C]	300
Air outlet [C]	38,9
Air pressure drop [mmWC]	178,1
Water inlet [C]	28,6
Water outlet [C]	30,0

Cylinder ID	1	2	3	4	5	6	7
Compression pressure [bar]	109,4	109,4	109,4	109,4	109,4	109,4	109,4
Max pressure [bar]	121,7	121,7	121,7	121,7	121,7	121,7	121,7
Mean indicated pressure [bar]	16,9	16,9	16,9	16,9	16,9	16,9	16,9
Exhaust temperature [C]	353,2	353,2	353,2	353,2	353,2	353,2	353,2
Fuel pump index	63,4	63,4	63,4	63,4	63,4	63,4	63,4
Engine Revolutions	117,7	117,7	117,7	117,7	117,7	117,7	117,7
VIT Index	3	3	3	3	3	3	3

Fuel and energy efficiency

Bunkering date	1998-08-24
Supplier	Supplier
Bunkering port	port
Heat value [MJ/kg]	40,27
Density at 15 c [kg/m3]	976,7
Viscosity at 50 c [cSt]	10
Inlet temp at fuel pump [C]	120,5
Inlet pressure at fuel pumps [bar]	1

	Start reading	Stop reading
Fuel flow meter time	00:00:00	01:00:00
Fuel flow meter volume [l]	0	1 741
Fuel flow meter temp [c]	82,8	82,8
Shaft revolution counter time	00:00:00	01:00:00
Shaft total revolution	0	7062
Cyl oil flow meter time	00:00:00	00:00:00
Cyl oil flow meter volume[l]	0	1 000

Density at flow meter [kg/m3]	931,8
Fuel consumption [m3/h]	1,740
Fuel consumption [kg/h]	1 621,40
SFOC - ISO [g/kWh]	184,63
Comment	xxx

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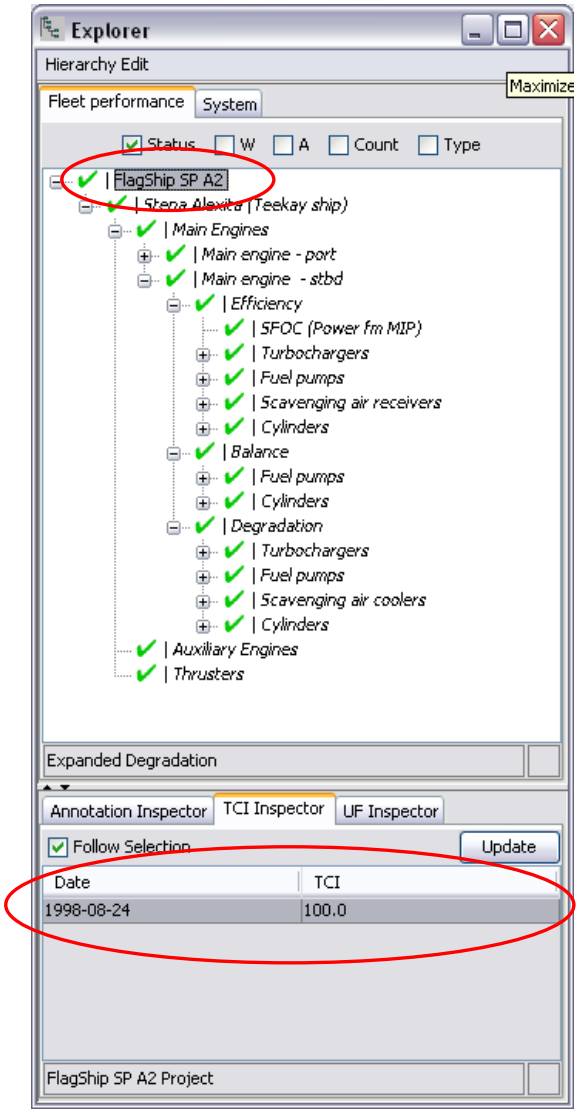
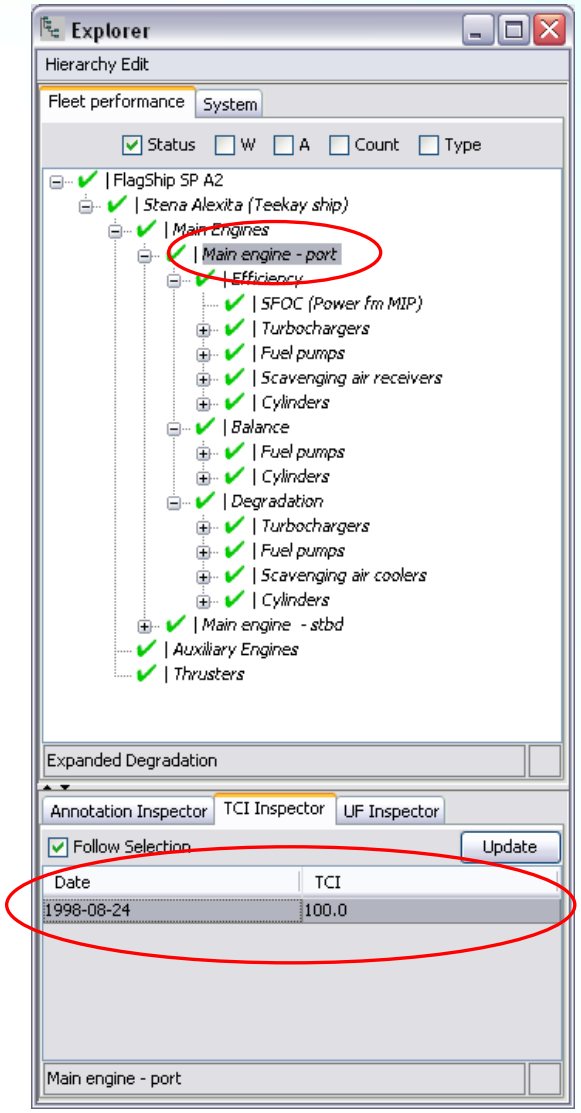
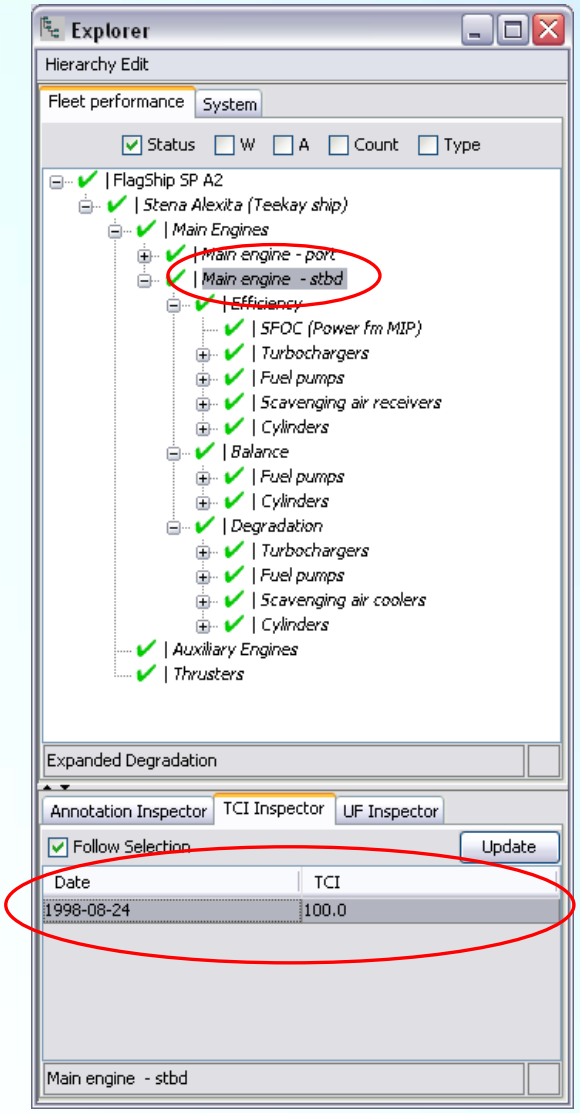
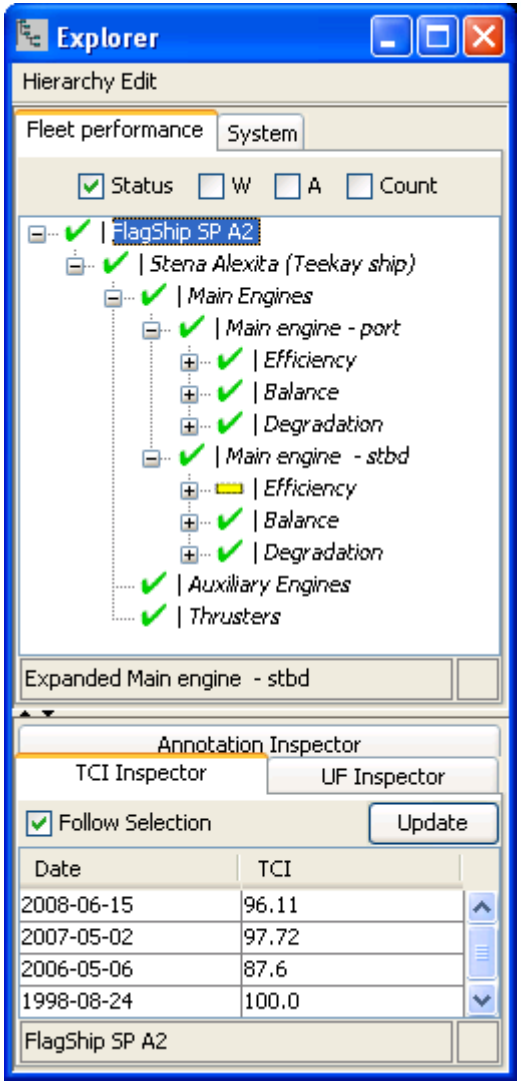
Processing ME sea-trial data

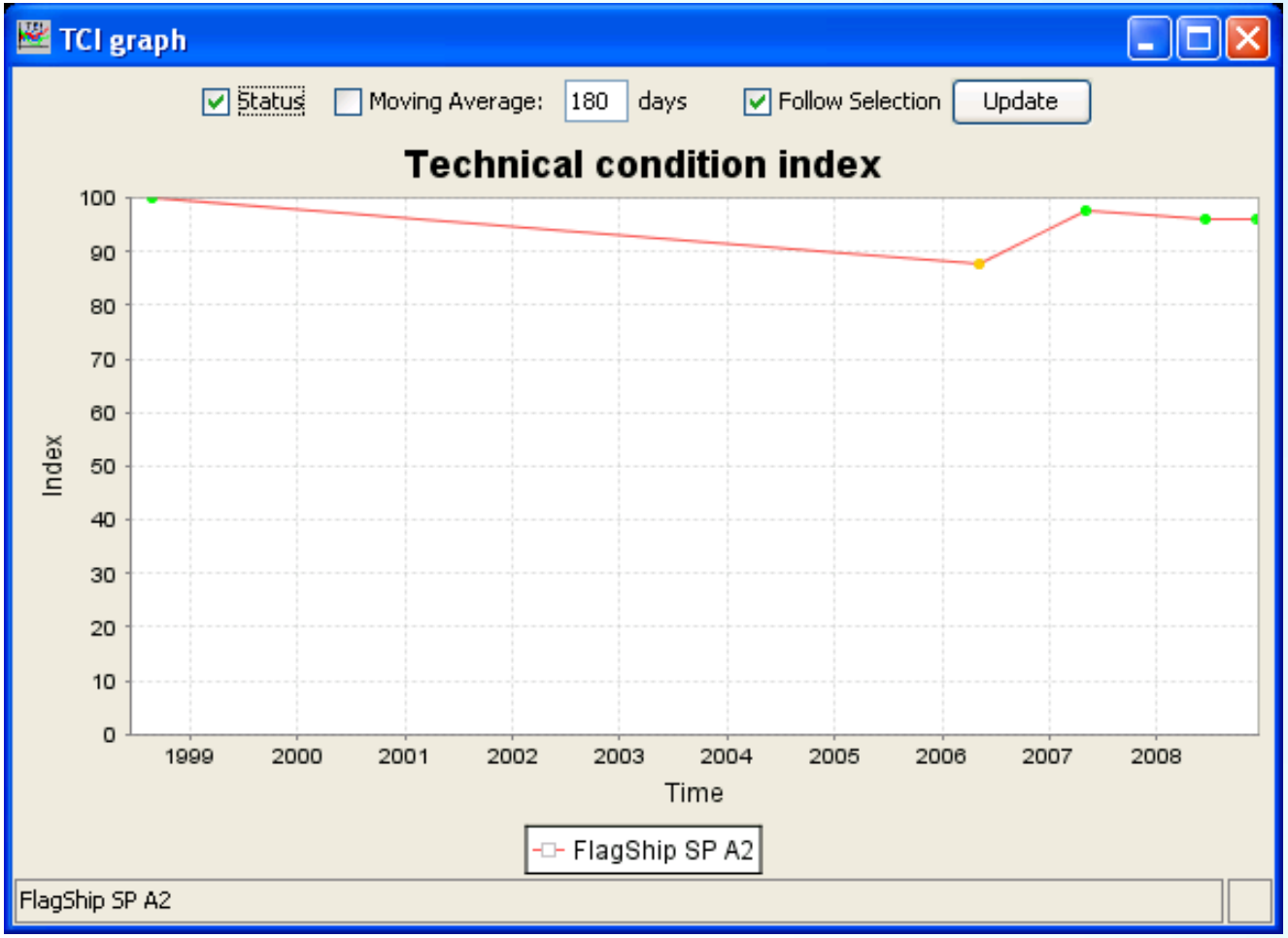




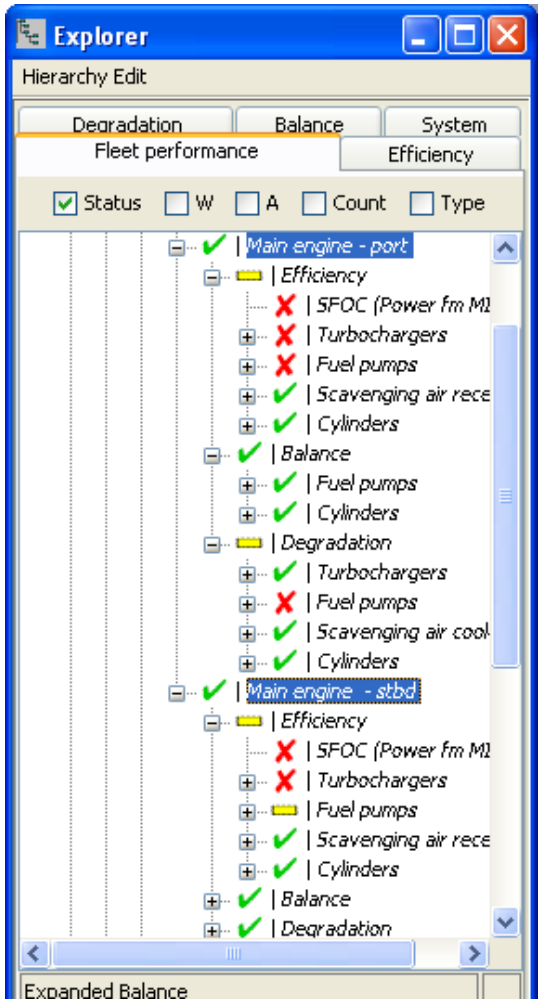


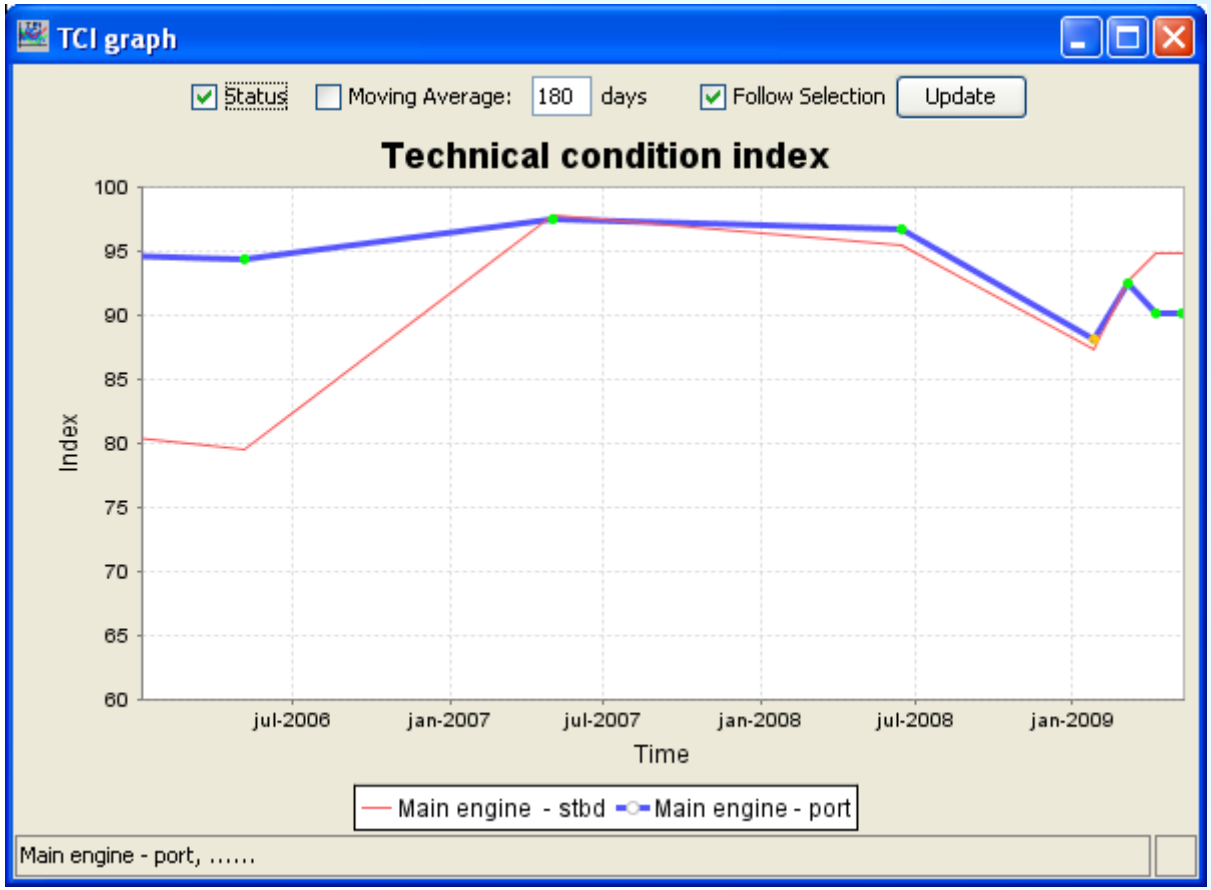
Processing of operational data



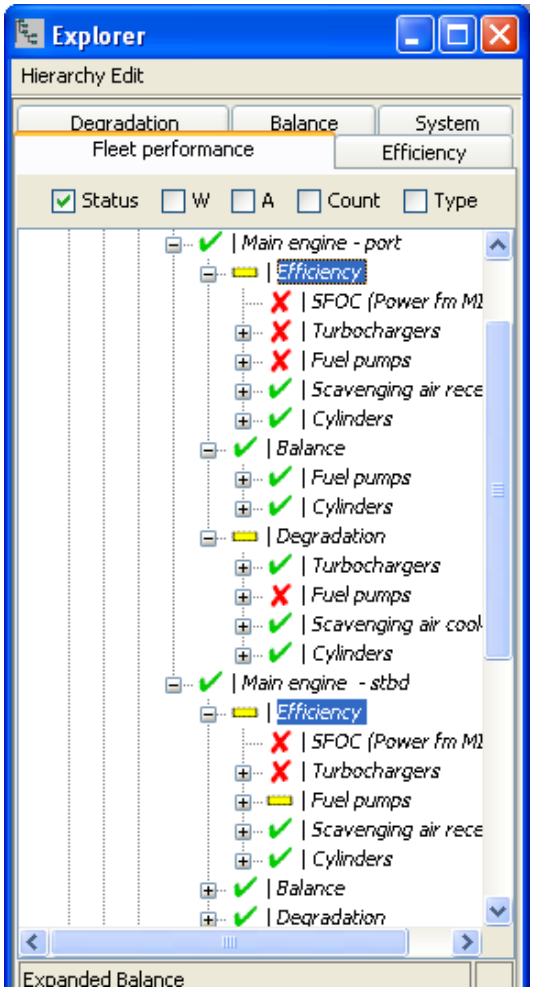


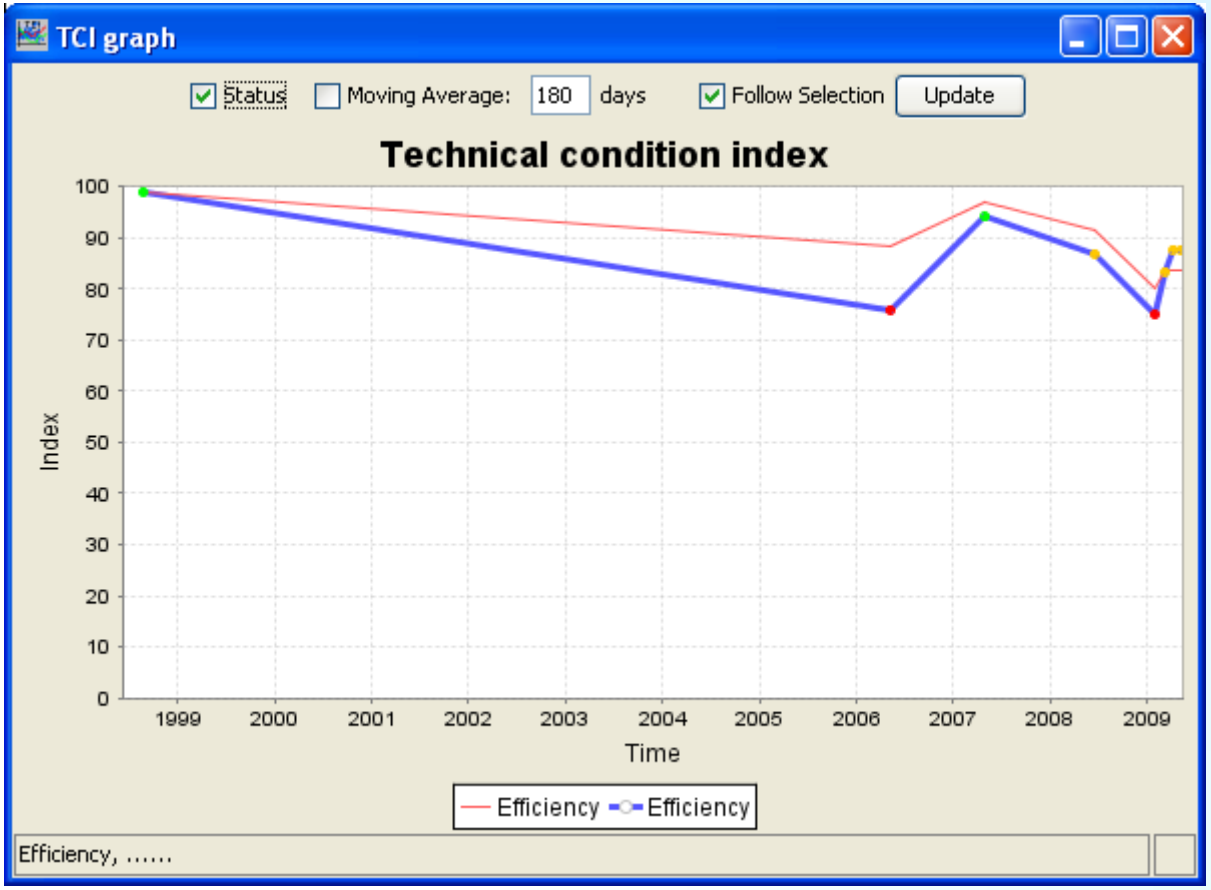
TCI results ME





TCI results ME efficiency





Analysis to Support Ship for ME opt. (automated)

Stena Alexita

Main engine - port (last registration on 2009-04-08)

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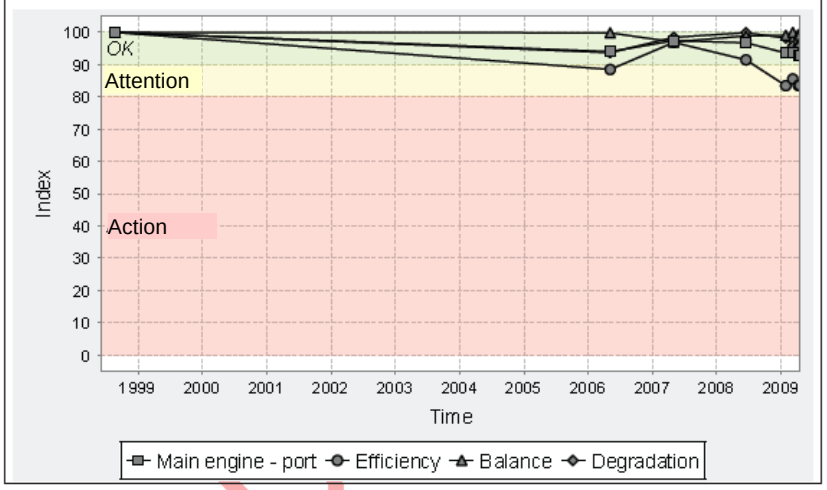
Engine Performance



Top level performance

Status	Index Name	Index Value	1/2 year Trend
✔	Main engine - port	92.8	down
▬	Efficiency	83.5	down
✔	Balance	99.2	up
✔	Degradation	95.8	down

✔ *ok* ▬ *Keep attention* ✘ *Follow up required, see remarks*

Analyses are based on following calculated values. Only values which need further attention (alarm and alert state) are shown

Analysis of 'Efficiency' is based on

Status	Index Name	Index Value	1/2 year Trend	Corr. Value	Raw Value	Ref. Value	Unit	Remark
✘	SFOC (Power fm MIP)	77.2	down	170.77	170.77	180.46	[g/kWh]	[1]
✘	TempdropExh TC1	0.0	down	81.71	78.0	135.57	[°C]	[2]
✘	IndexAverage FPs	61.6	down	71.87	69.57	63.36	[-]	[3]

Analysis of 'Degradation' is based on

Status	Index Name	Index Value	1/2 year Trend	Corr. Value	Raw Value	Ref. Value	Unit	Remark
▬	Pcomp Cyl3	84.3	down	101.87	116.8	109.4	[bar]	
✘	Pcomp Cyl5	75.7	down	100.29	115.1	109.4	[bar]	[4]
▬	Pcomp Cyl6	85.7	down	102.24	117.2	109.4	[bar]	
▬	Pcomp Cyl7	82.6	down	101.4	116.3	109.4	[bar]	

Remarks to Indices

[1] SFOC too low, possible causes:
(- Indicated cylinder pressure incorrect (too high), check MIP Calculator TDC setting)
- Errors in readings / instruments for, power, rpm, density, heat value or flow volume
- Check guideline for main engine performance test
- Fuel flow meter need calibration, check date when last calibrated

[2] Exhaust temperature drop TC too low, possible causes:
- Heavy deposited exhaust turbine
- Defect temperature sensor
- Indicated cylinder pressures incorrect (too high), resulting in incorrect power correction, check MIP Calculator TDC setting

[3] Average pump index too high, possible causes:
- Degraded fuel pumps.
- Instrument or reading error; MIP, FPI, specific gravity or heat value.
- Low efficiency of engine.

[4] Compression pressure in cylinder too low, possible causes:
- Scavenging pressure too low
- Erroneous measured scavenging pressure (too high), resulting in incorrect power correction
- Erroneous cylinder indication, check correlation with max cylinder pressure (normal)
- Poor cylinder condition, check correlation with max cylinder pressure (too low)

Draft

AE Registrations (Trial/ Ideal)

Auxiliary Engine Performance Registration

Auxiliary Number	1
Report_time	19
Id	1
Maker	U
Type	K
Serial Number	3
Maxpower [kW]	1,
Bore	25
Stroke	30
Coolant	Fr
No of cylinders	9
Fuel valveoperation	Ca

Auxiliary Engine Performance Registration

Auxiliary measure values

Chief Engineers name	No name	Scavenging receive temp [C]	51.0	Fuel pumps index	26.00
Total running hours	200	Scavenging rec press [barO]	1.93	Generator power	1,410
Mean gen load since last test [Kw]	1,500			Gen.shaft power	1,468.75
Start time	9:00:00 AM			Engine power	1,469.66
Stop time	11:00:00 AM				

				Comment
Turbocharger ID	1	Scavenginge air cooler ID	1	No comment
Revolutions [Rpm]	26,891	Air inlet [C]		
Air inlet [C]	24.1	Air outlet [C]		
Air filter pressure drop [mmWC]	72.0	Air pressure drop [mmWC]	108	
Exhaust inlet temperature [C]	408	Water inlet [C]	25.0	
Exhaust outlet temperature [C]	292	Water outlet [C]		

Cylinder ID	1	2	3	4	5	6	7	8	9
Compression pressure [bar]	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
Max pressure [bar]	129	129	129	129	129	129	129	129	129
Mean indicated pressure [bar]	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Exhaust temperature [C]	364	364	364	364	364	364	364	364	364
Fuel pump index	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
Engine RPM	720	720	720	720	720	720	720	720	720

Fuel and energy efficiency

			Start reading	Stop reading		
Bunkering date	1997-09-02					
Supplier	No supplier	Flow meter time	9:00:00 AM	11:00:00 AM	Density at flow meter [kg/m3]	847.4
Bunkering port	No port	Flow meter volume [l]	2,500	3,210	Fuel consumption [m3/h]	.3550
Heat value [MJ/kg]	42.7	Flow meter temp [c]	19.4	19.4	Fuel consumption [kg/h]	300.83
Density at 15 c [kg/m3]	850	Energy production time	9:00:00 AM	11:00:00 AM	SFOC - ISO [g/kWh]	202.63
Viscosity at 50 c [cSt]	3.10	Energy production [Kwh]	150,000	152,820	Comment	No comment
Inlet temp at fuel pump [C]	35.4					
Inlet pressure at fuel pumps [bar]						

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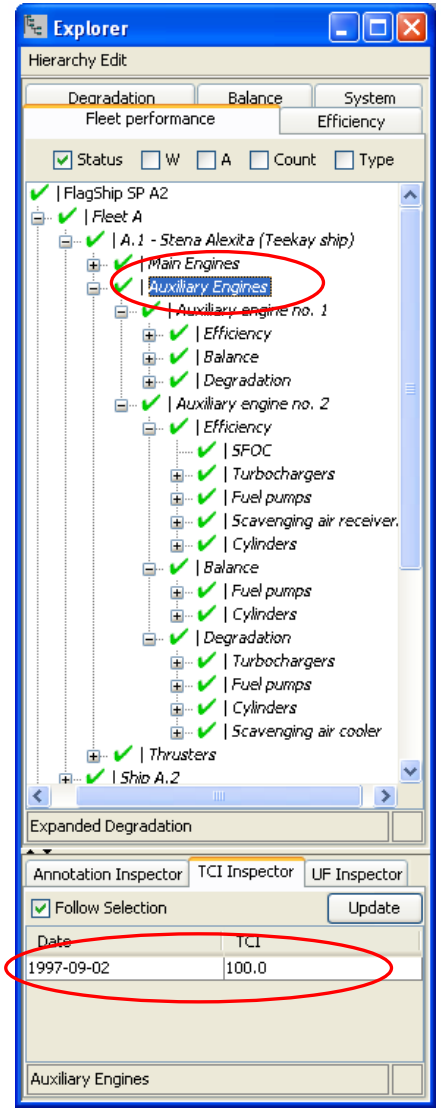
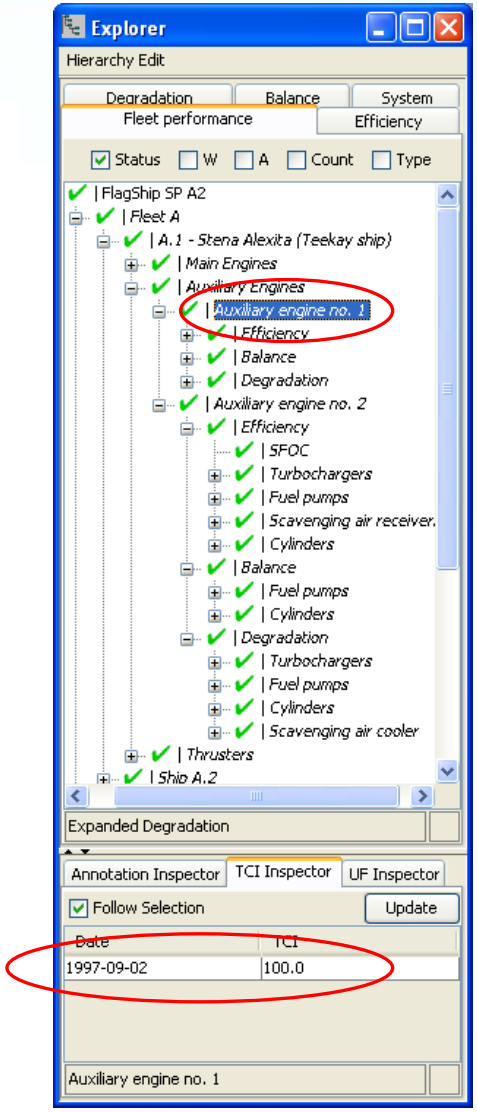
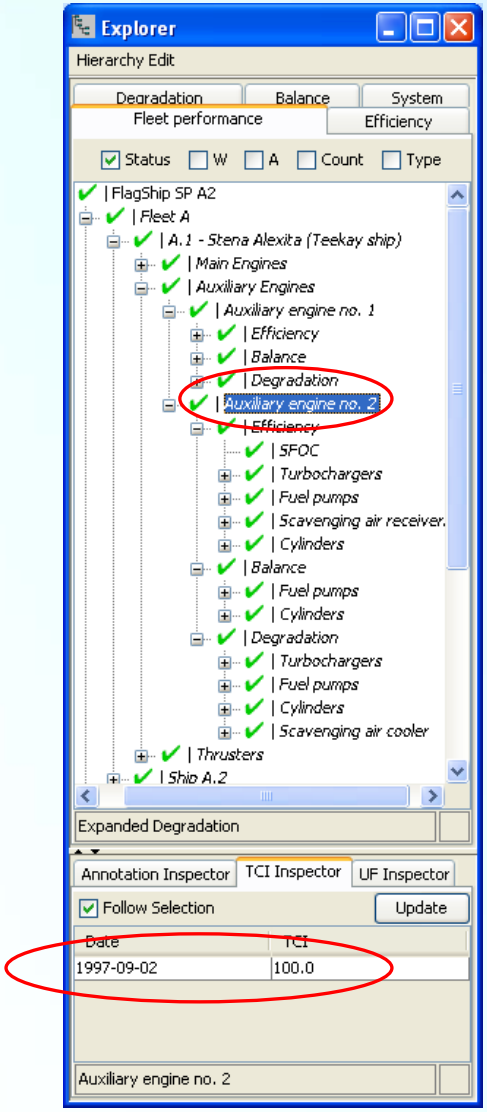
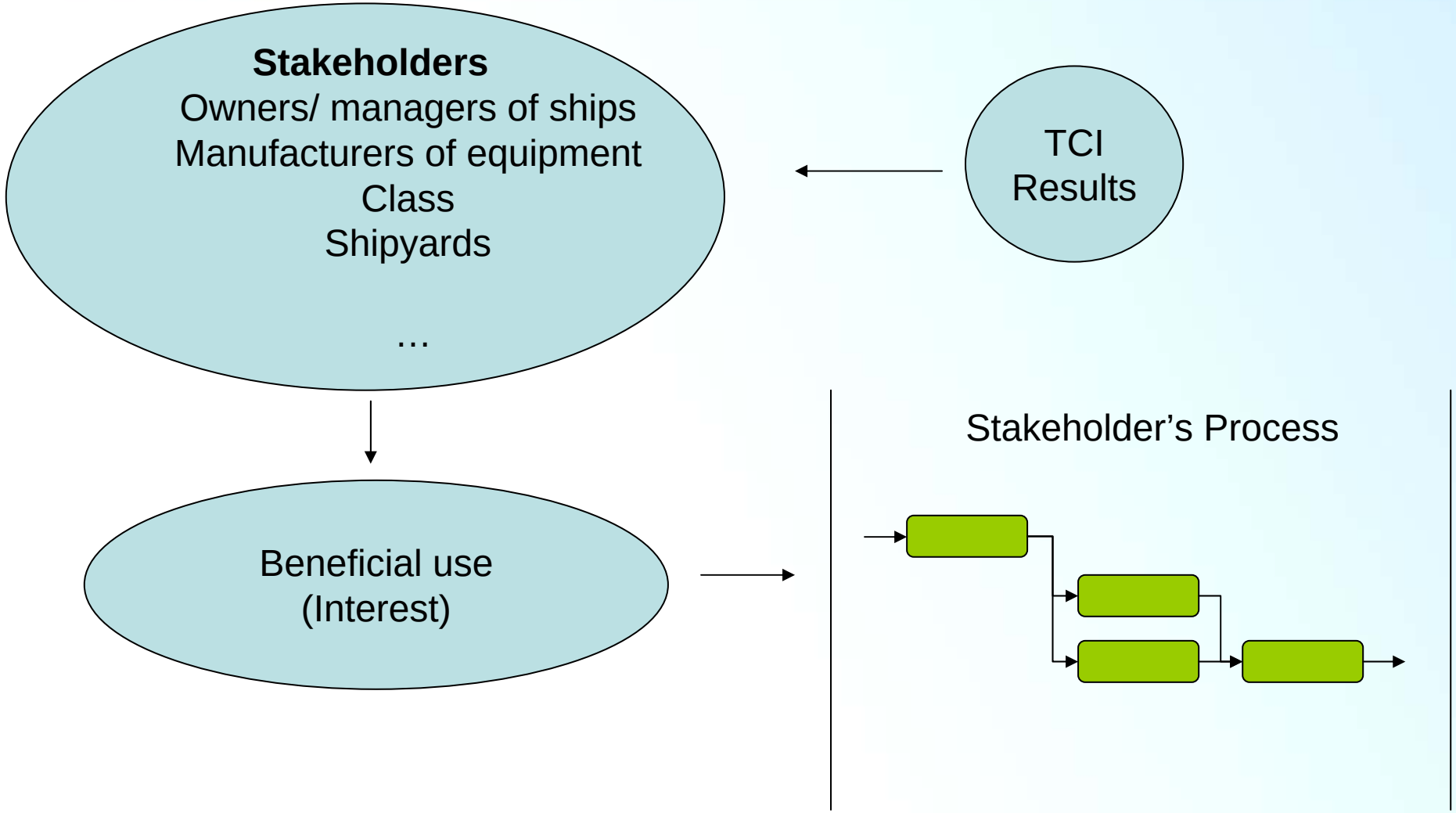
Processing AE Trial data





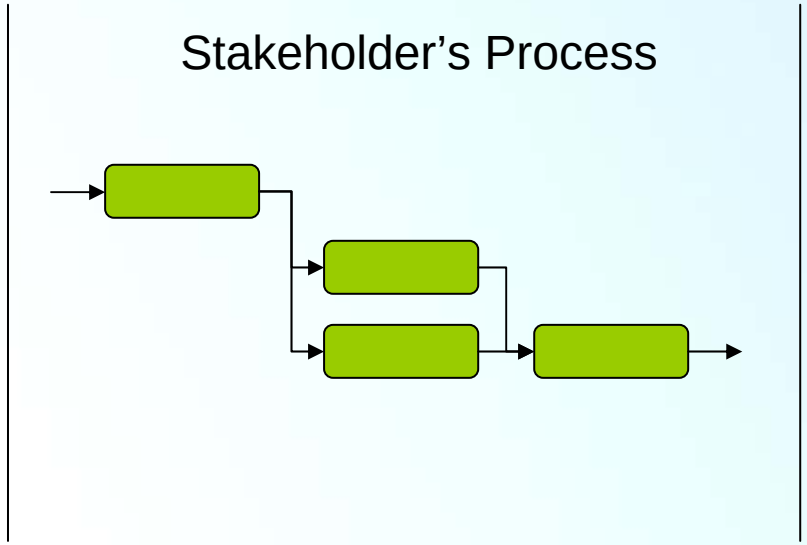


Implement TCI results into business processes



Business process revision

- Business processes might be different within similar businesses
- Stakeholders know best how TCI results fit into their business processes
- Consequently, stakeholders identify/ describe/ illustrate/ exemplify how the results fit into their organisations processes



Thank you for your attention!