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NPL  
Underwater Noise Measurements Seminar  
13. Oct 2005

Acoustic measurements performed at advanced  
subsea oil and gas installations

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Product Manager Naxys AS

# Presentation Contents

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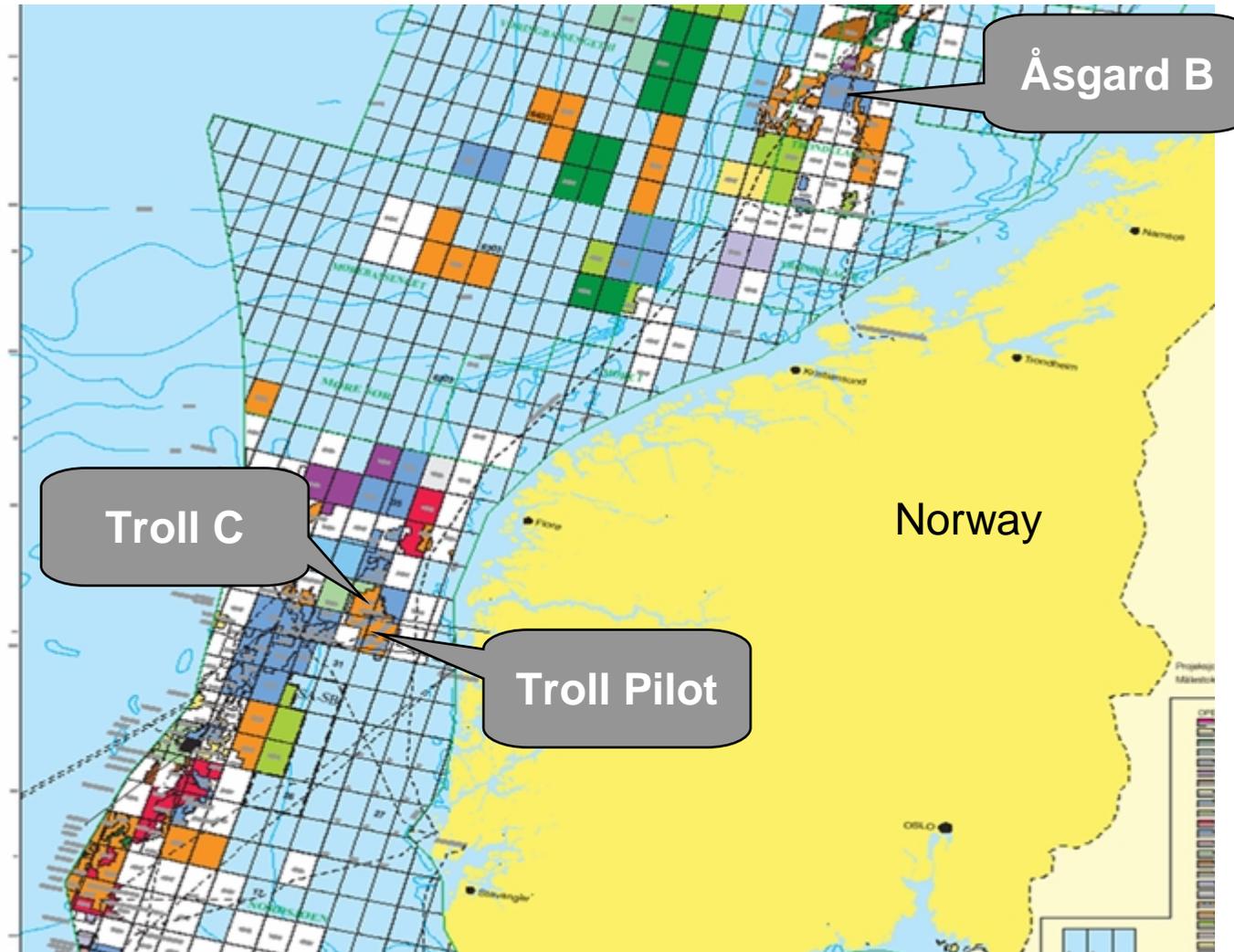
- Subsea Installations Monitored
- Monitoring System
- Measurements
- Interpretations
- Acoustic Condition Monitoring

# Motivation for Monitoring

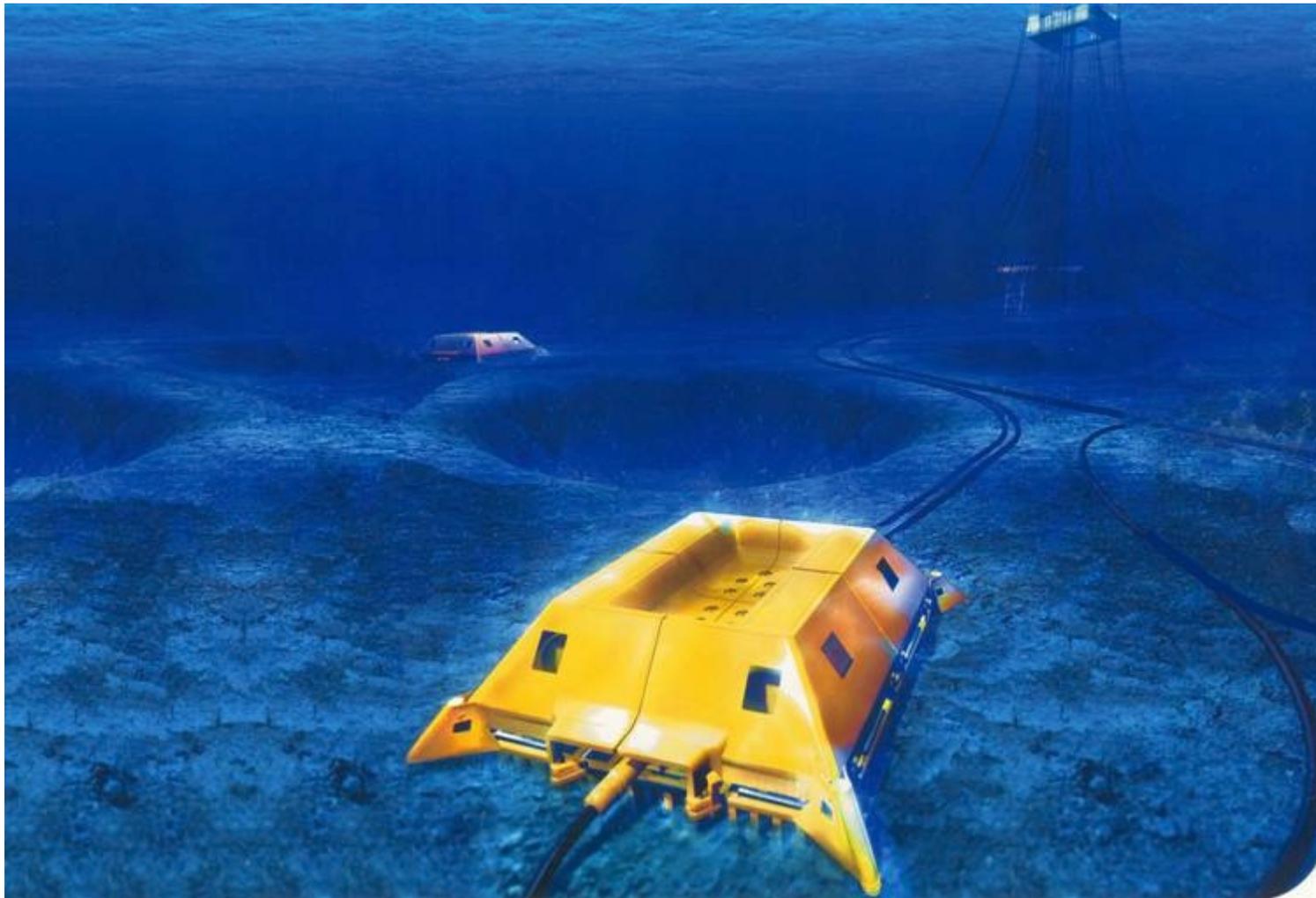
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- Significant global increase in number of subsea installations in the period 2005 – 2009. Complexity will increase.
- New field developments in the arctic region characterized by:
  - Minimize offshore surface installations
  - Requirement for zero pollution / spillage

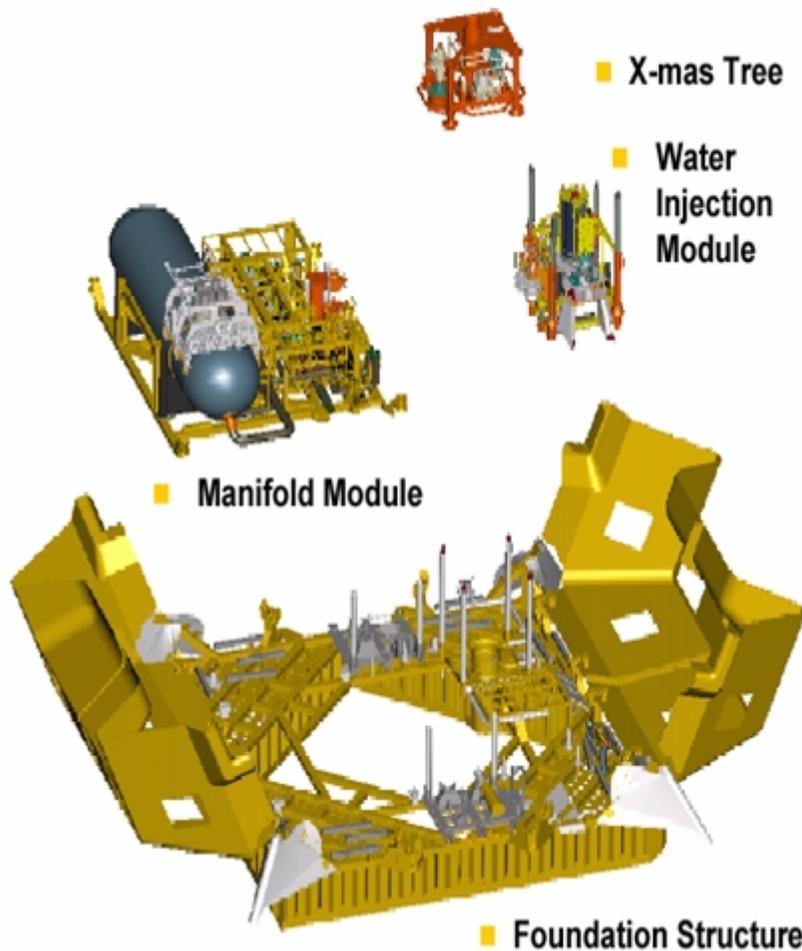
# Installations Monitored



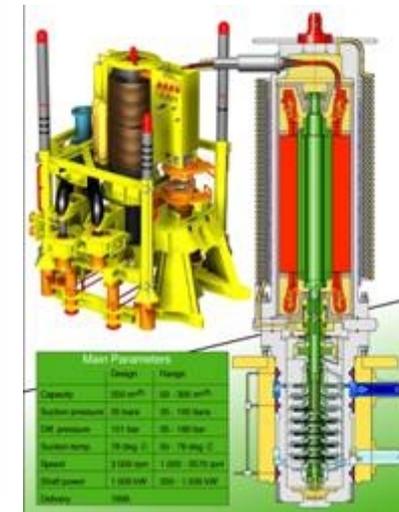
# Troll Pilot



# Troll Pilot



- Total Weight in air: 350 tons
- Size: 17x17x8 metres



# Åsgard B

Åsgard B, Export Riser Base

Size: 15x30x10 m

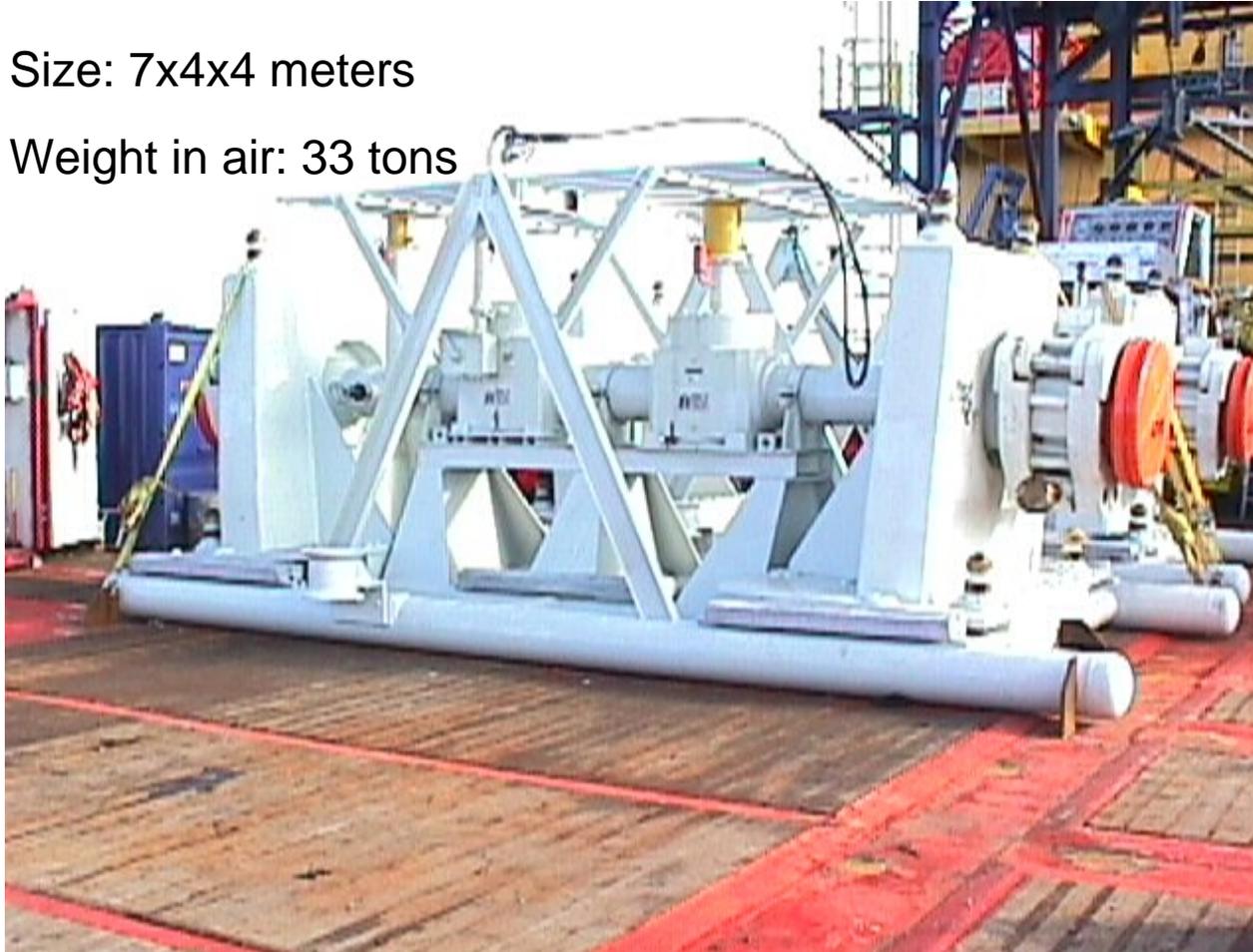
Weight in air: ca. 500 ton



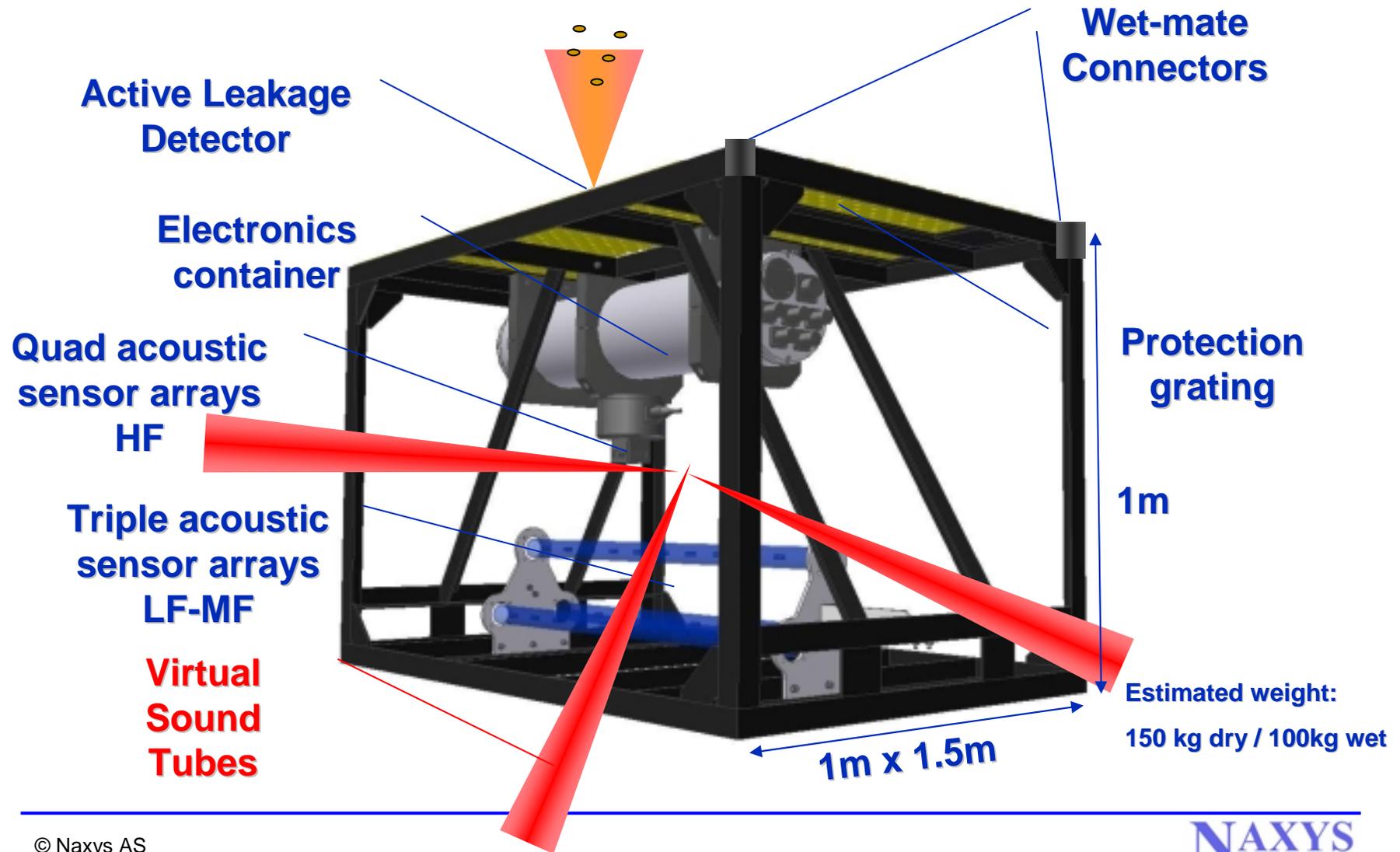
# Troll C PTG valve skid

Size: 7x4x4 meters

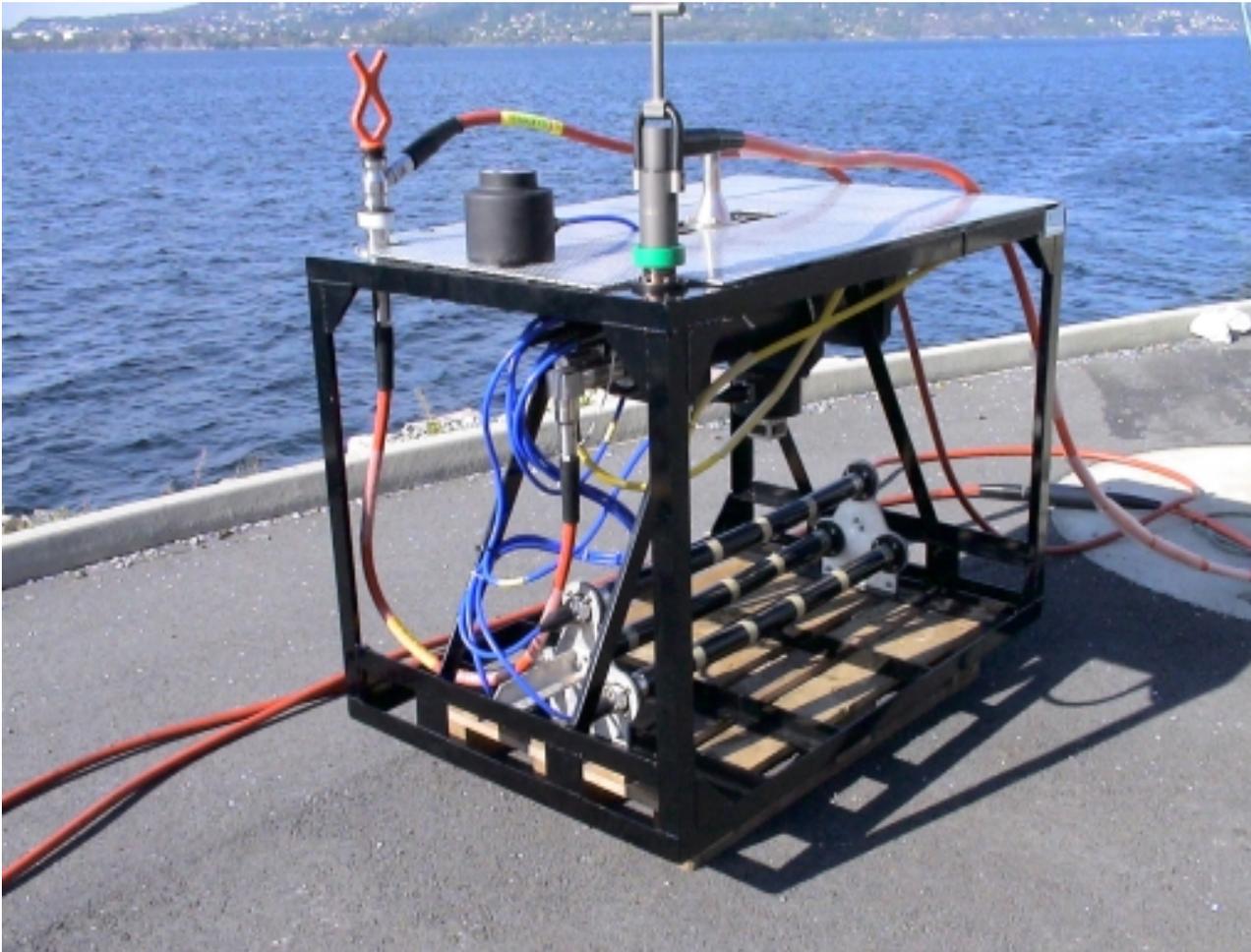
Weight in air: 33 tons



# Acoustic Monitoring System



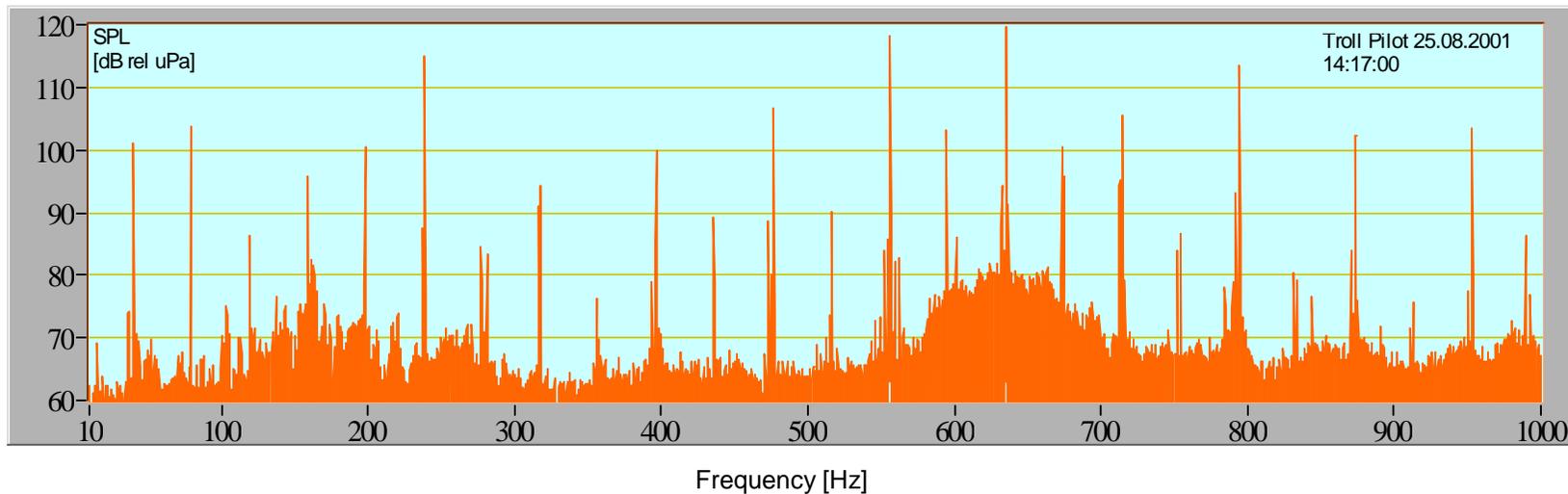
# Acoustic Monitoring System



# Water Injection Pump, Measurements

## ■ Frequency Analysis

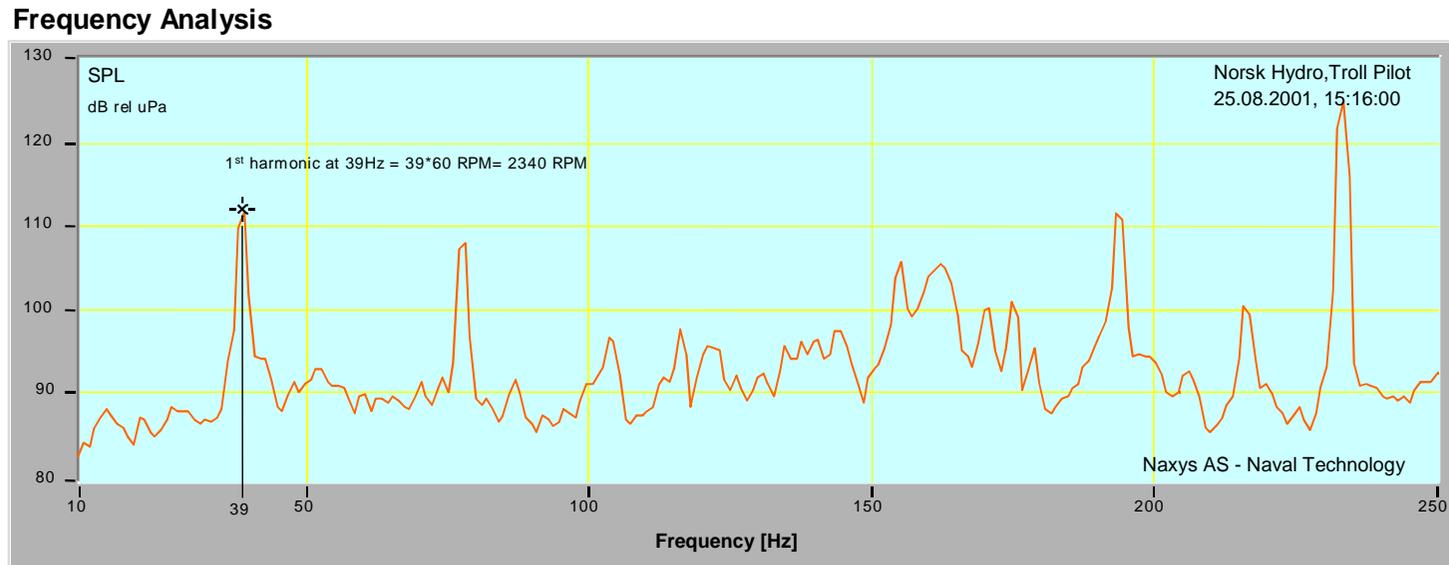
SPL [db rel uPa/rt Hz] vs. Frequency [Hz] (BW=1 Hz)



Click picture for  
pump sound

# Water Injection Pump, Measurements

## ■ FA Interpretation, RPM

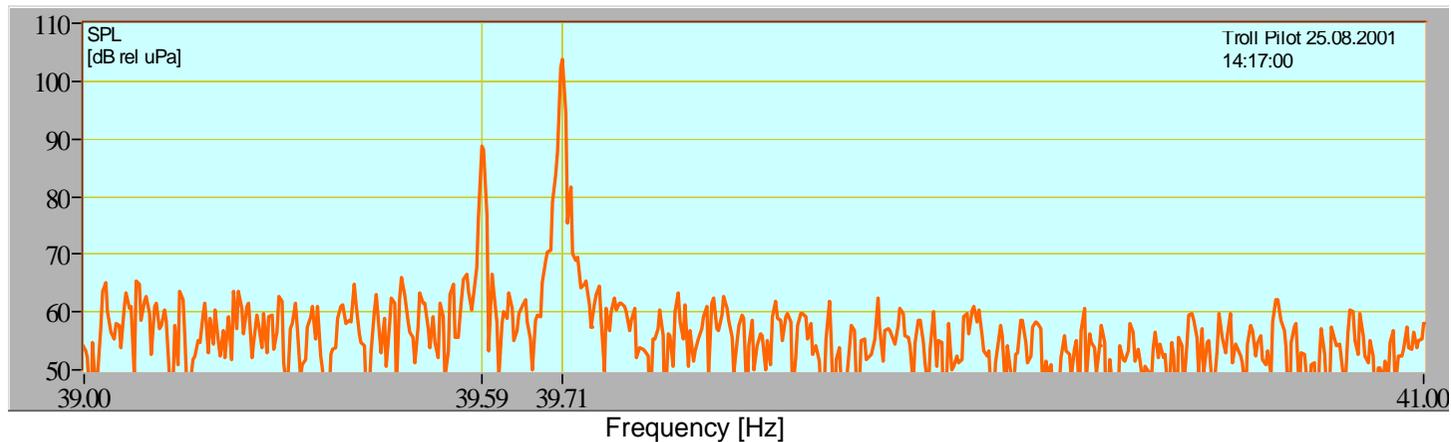


Reference data, from production log:

Date and Time	%trq (PA-18-9901Z6B)	f [Hz] (PA-18-9901Z6C)	RPM (PA-18-9901Z6D)
25.08.2001 15:15:00	30.2	39.0	2342
25.08.2001 15:16:00	30.6	39.0	2342
25.08.2001 15:17:00	30.7	39.0	2342

# Water Injection Pump, Measurements

## ■ FA Interpretation, slip ratio

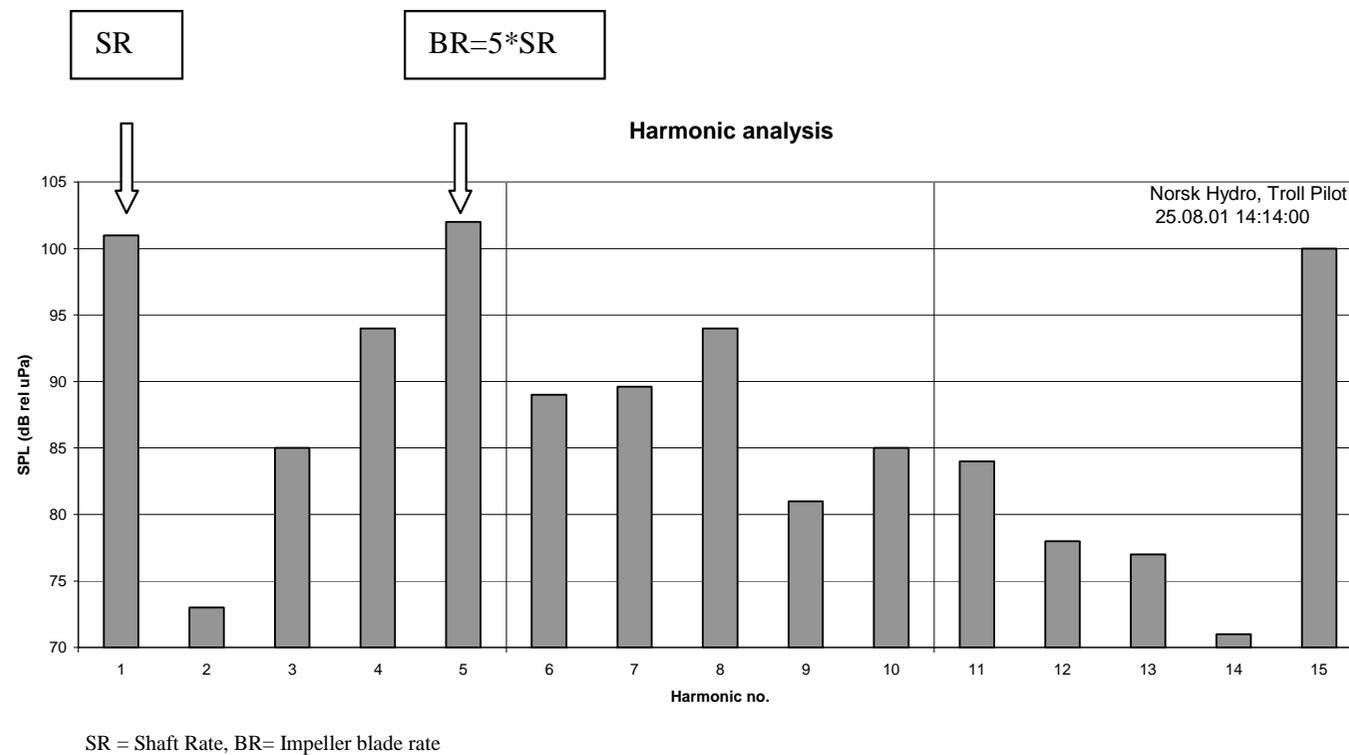


$$Speed = 39.59[Hz] \cdot 60[sec/Hz] = 2375RPM$$

$$SLIP = \frac{39.71 - 39.59}{39.71} \cdot 100\% = 0.3\%$$

# Water Injection Pump, Measurements

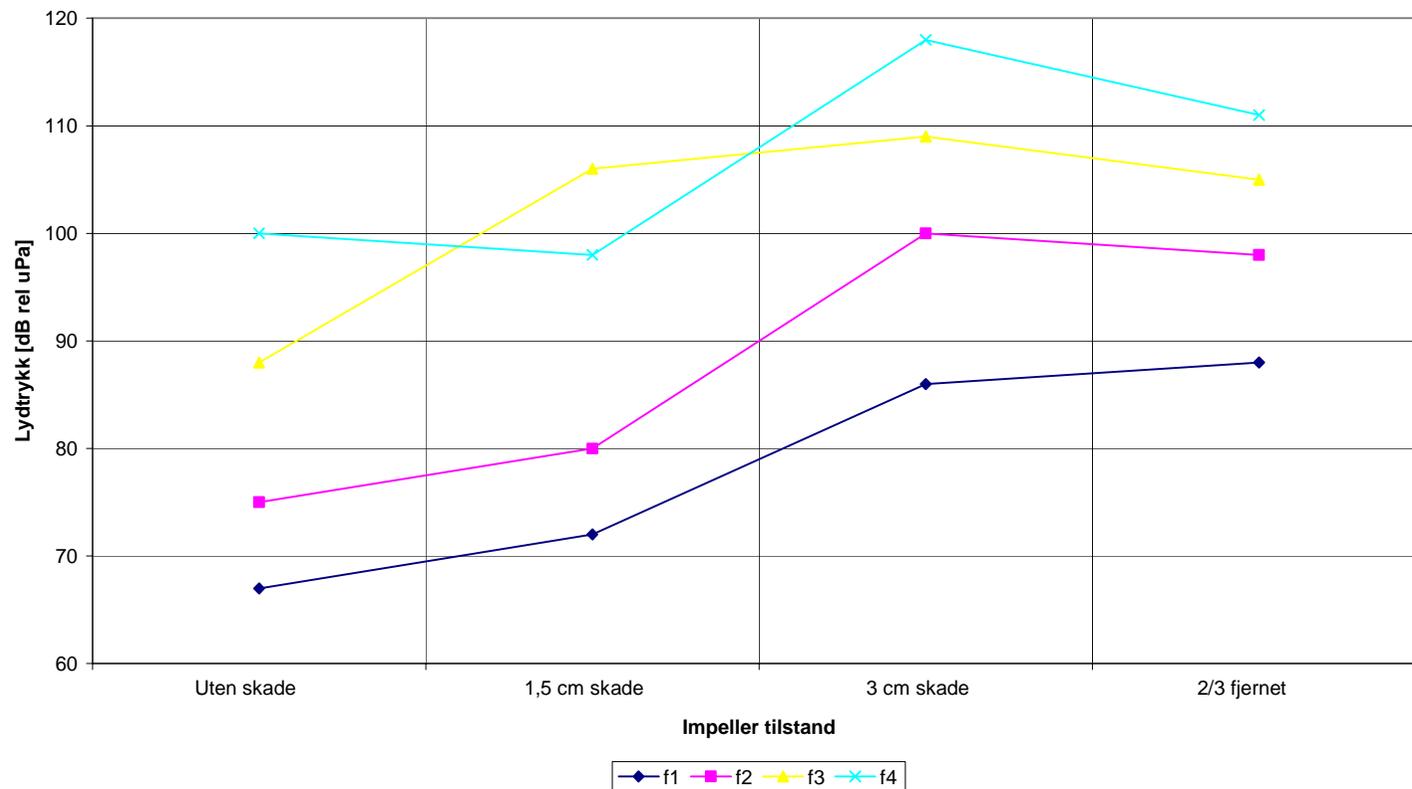
## ■ Harmonic Analysis (HA)



# Water Injection Pump, Measurements

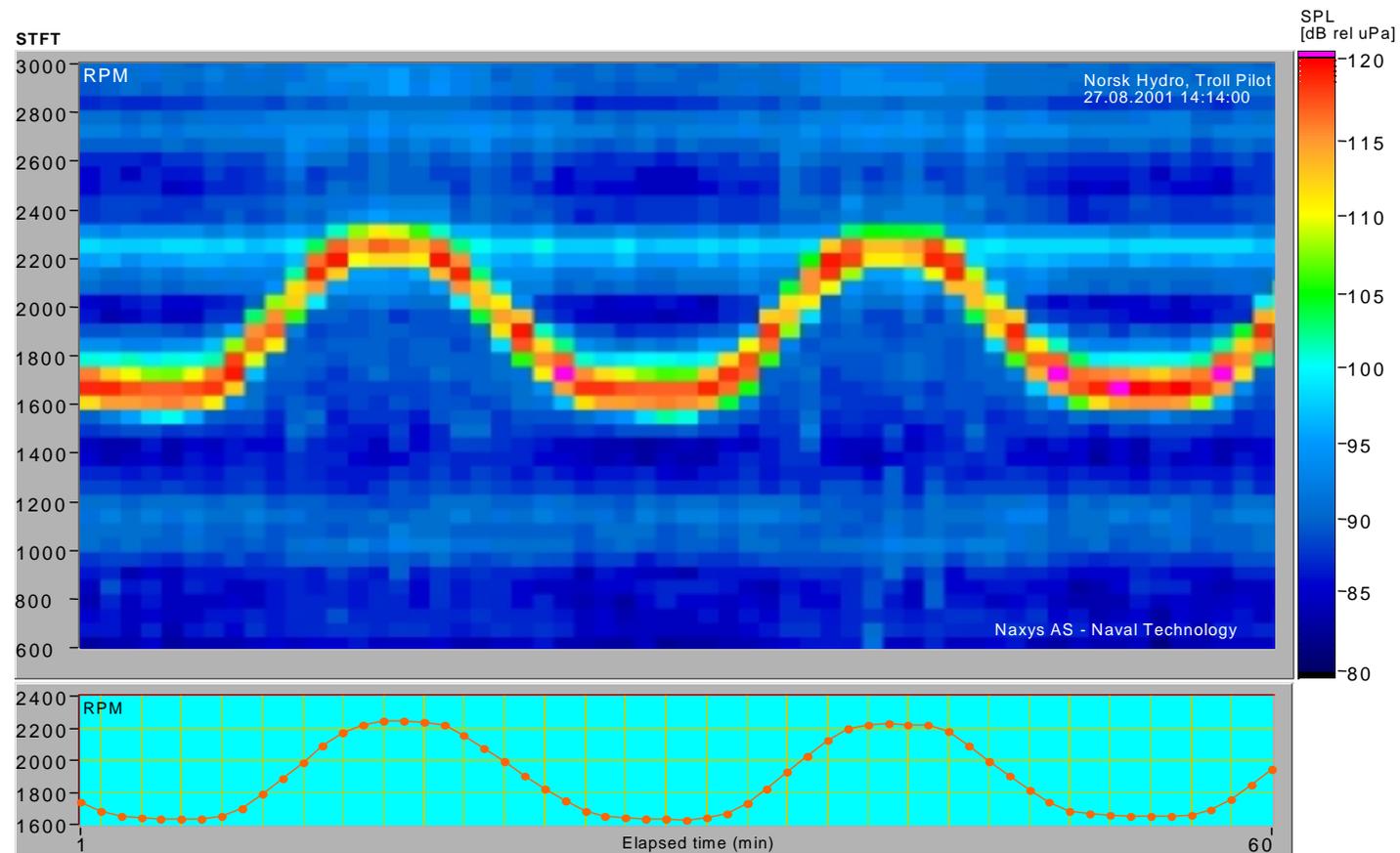
## ■ HA Interpretation, impeller damage to pumps

Harmonisk analyse



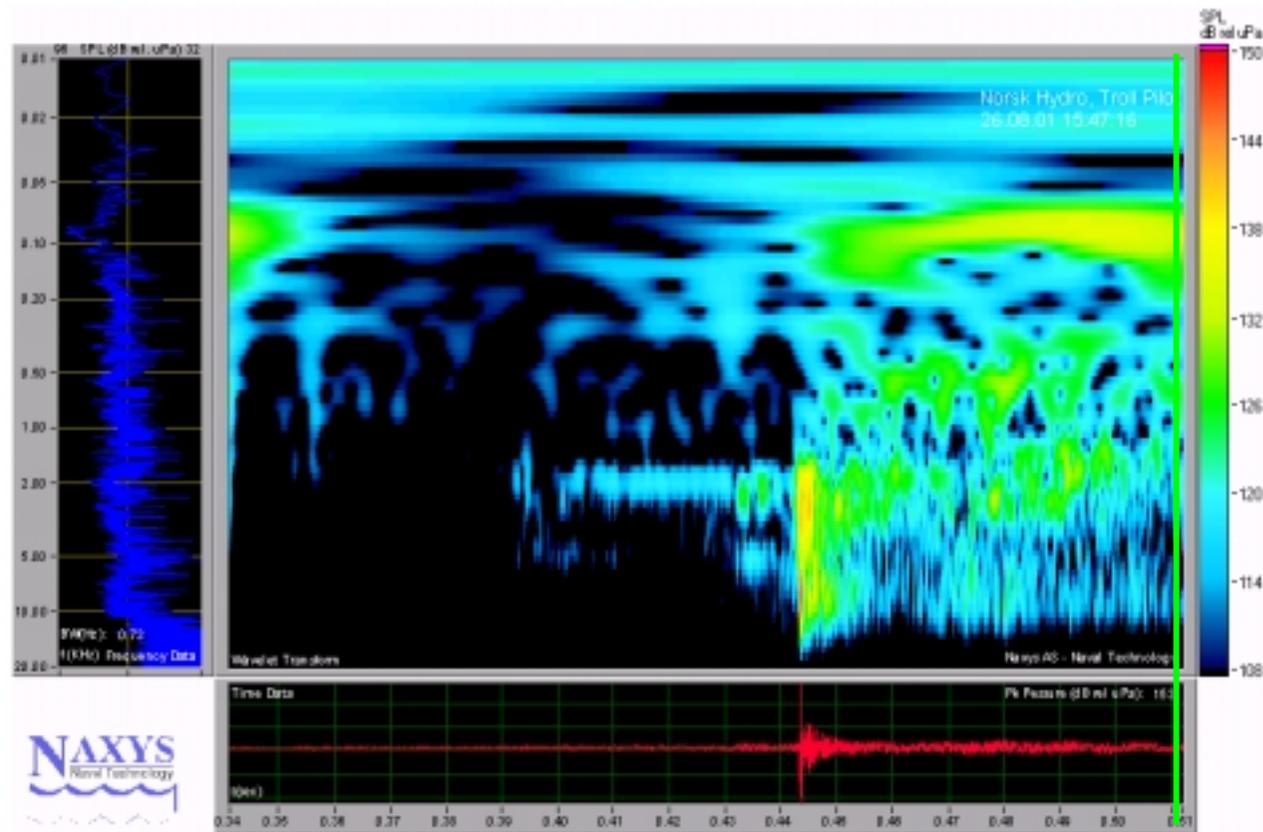
# Water Injection Pump, Measurements

## ■ Time-Frequency Analysis (TFA)



# Ball valve operation, Measurements

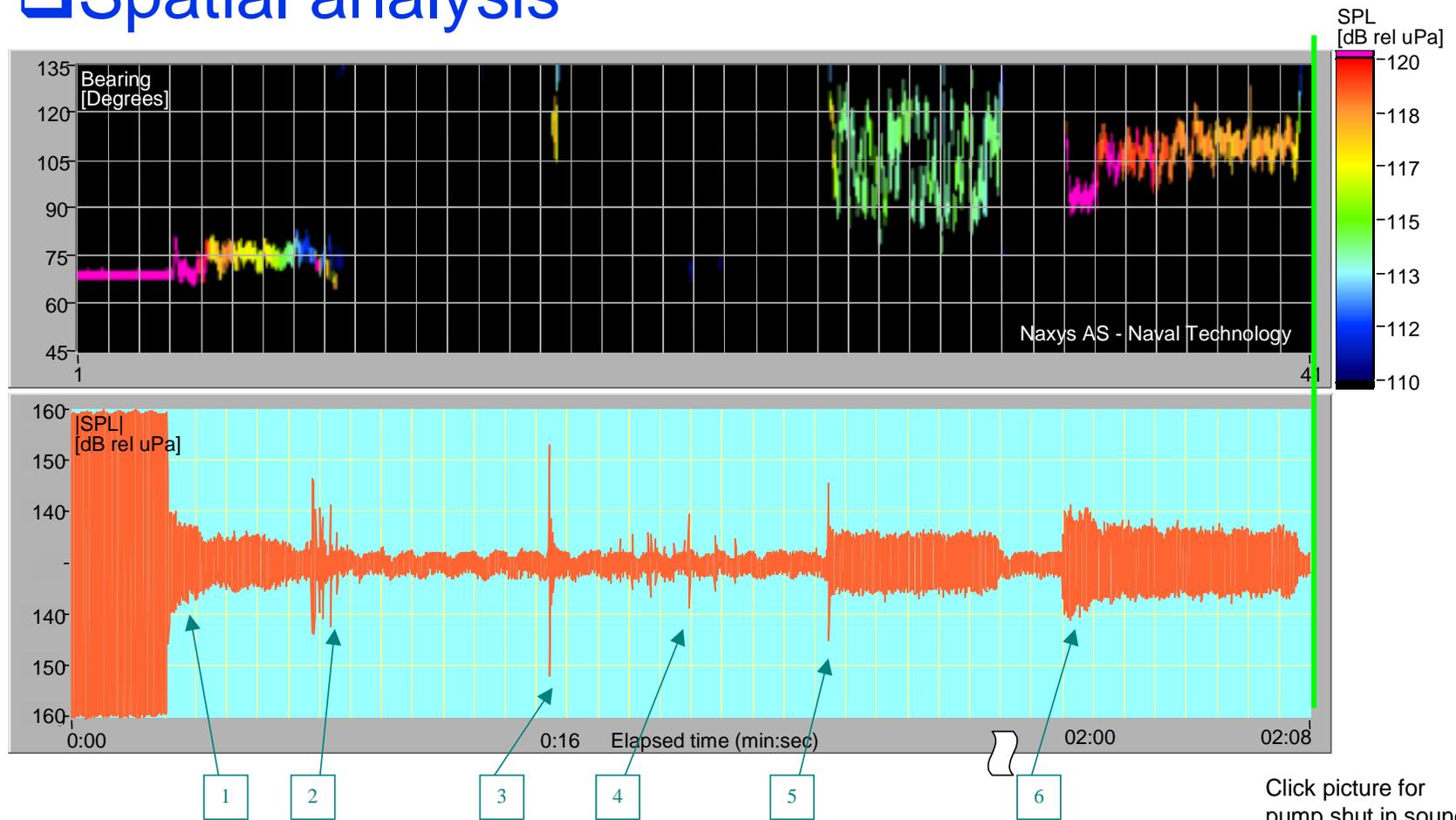
## ■ Transient analysis, (Wavelet)



Click picture for valve sound

# Troll Pilot, Measurements

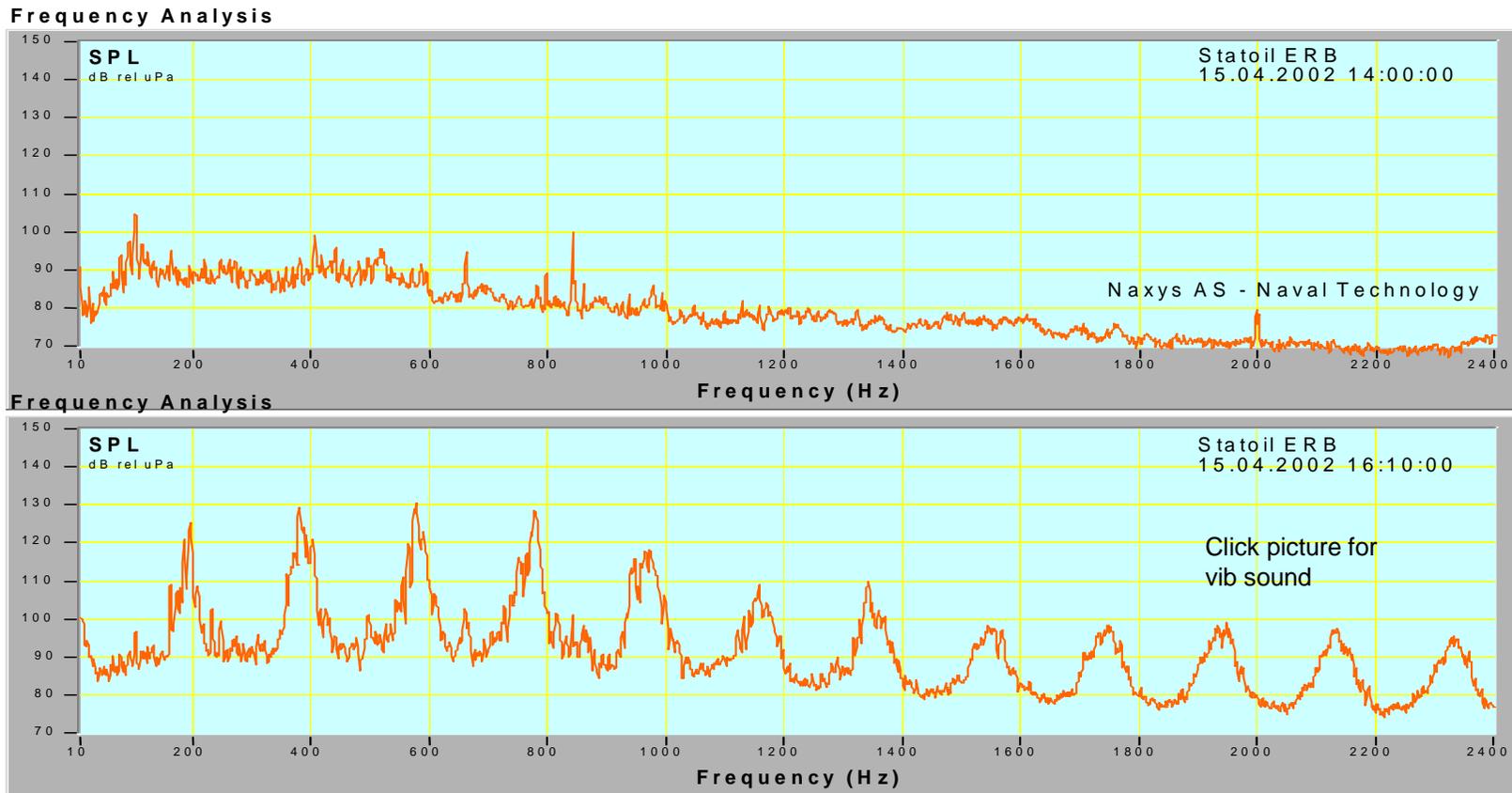
## □ Spatial analysis



# Export Riser Base

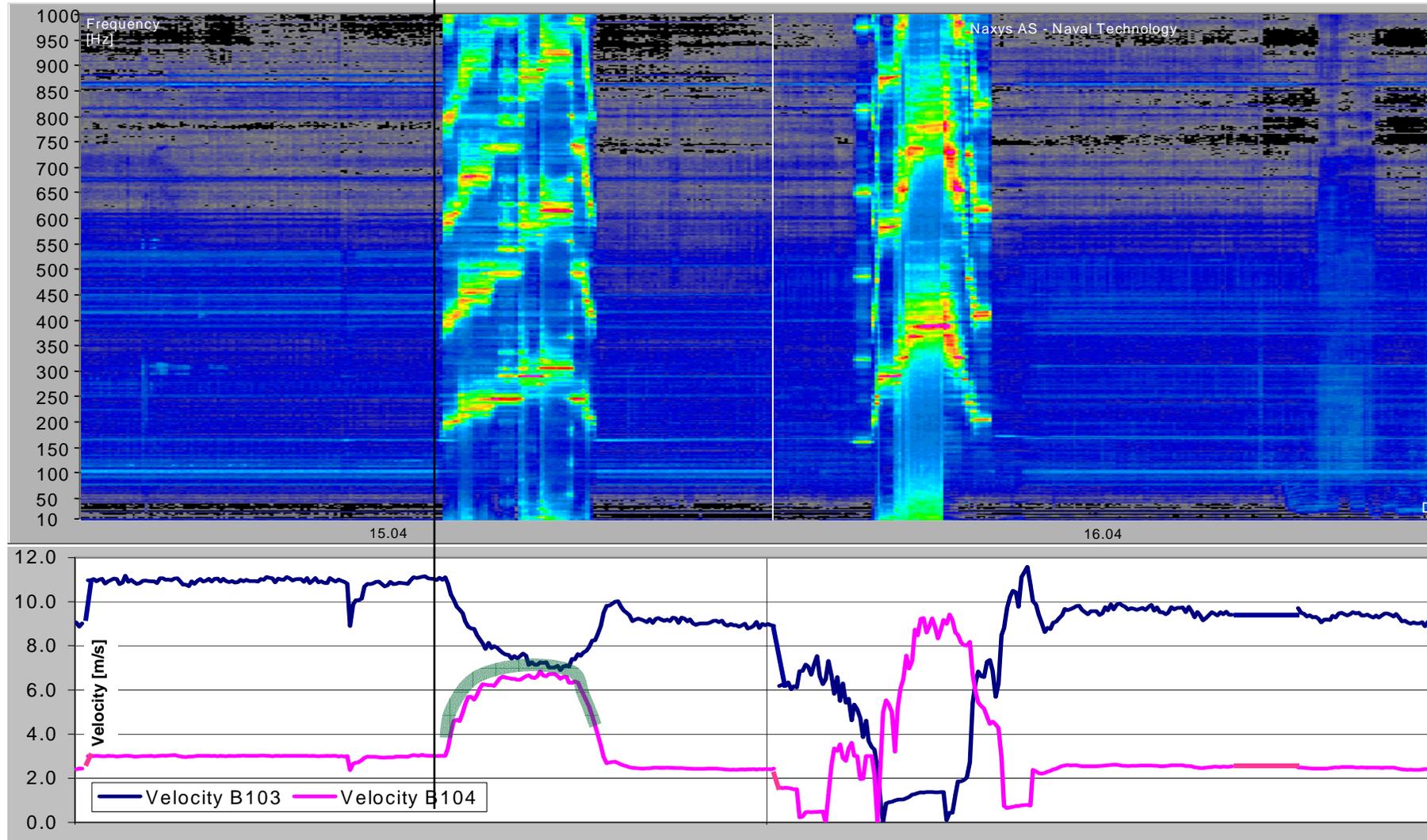
## ■ Frequency Analysis

SPL [db rel uPa/rt Hz] vs. Frequency [Hz] (BW=1 Hz)



# Export Riser Base

## ■ Åsgard ERB, Structural vibration monitoring



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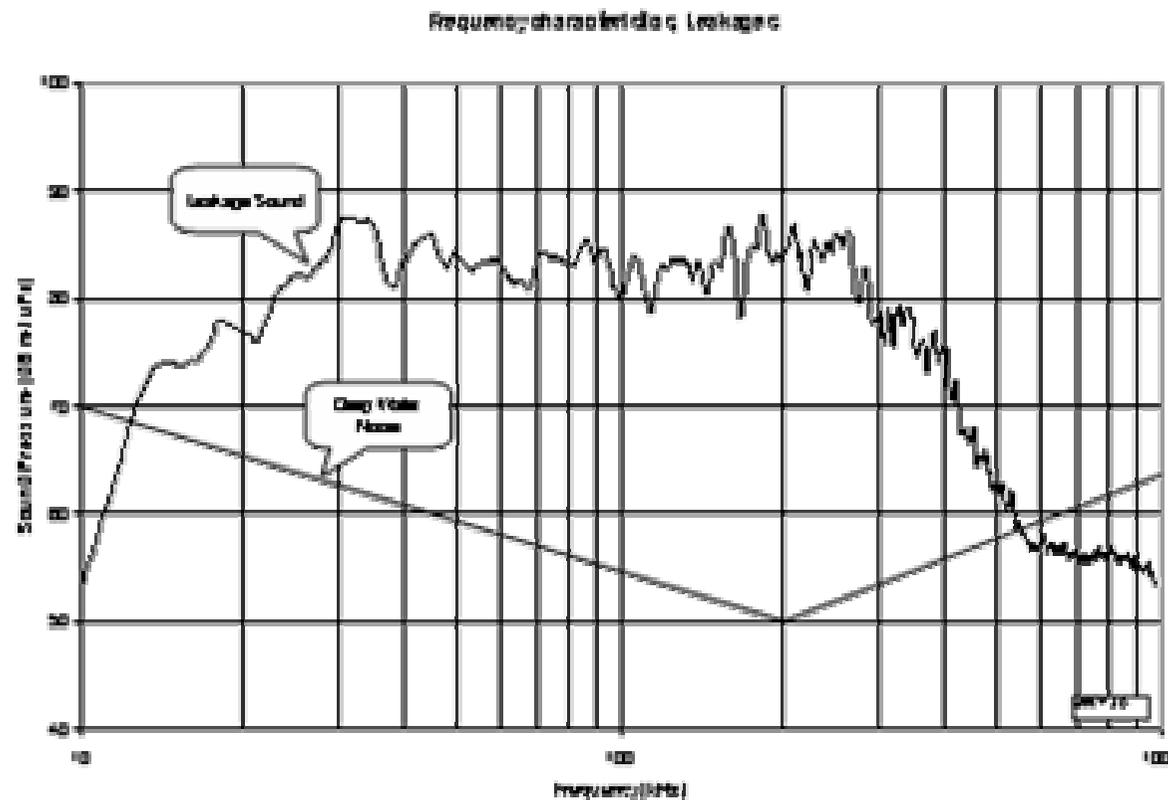
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# Leakage Detection

- Leakage AE is characterized by a wideband frequency spectra

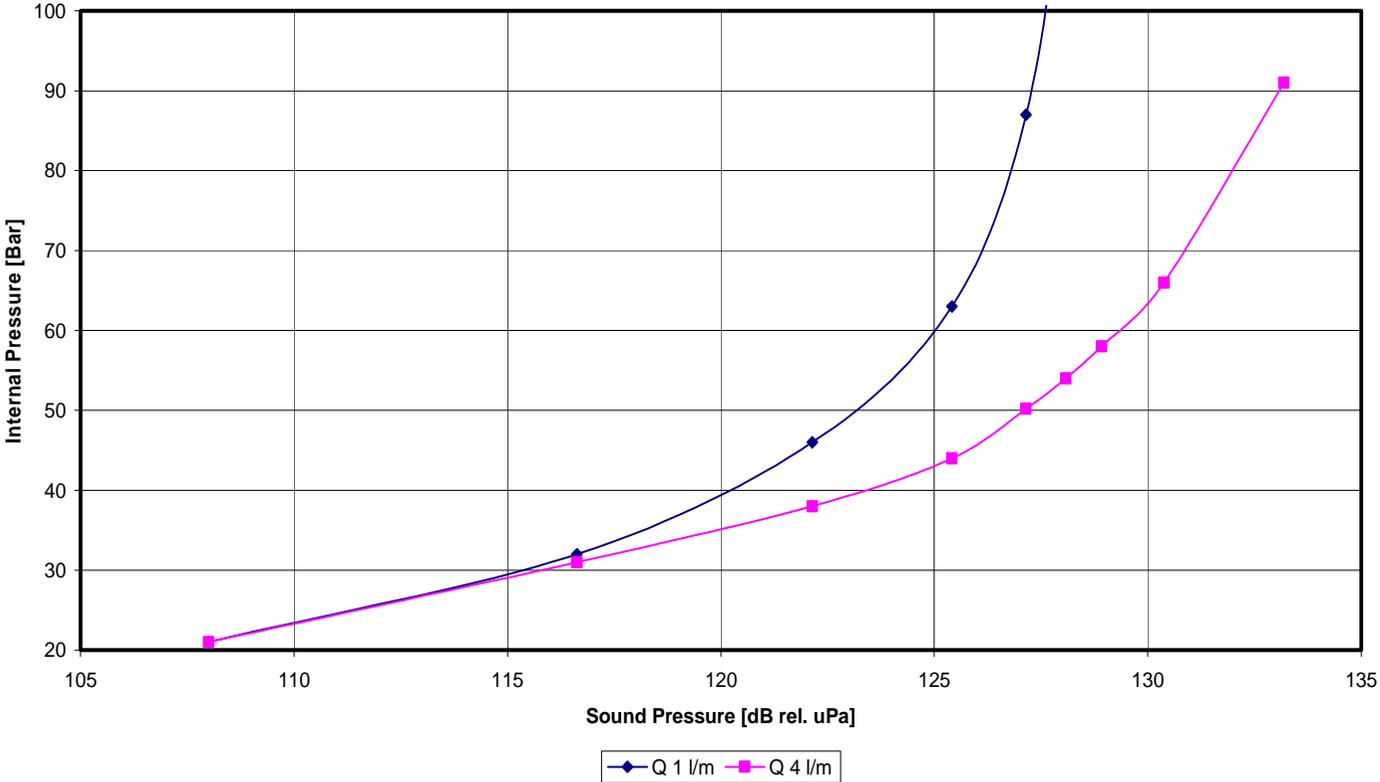


Click picture for leakage sound

# Leakage Detection

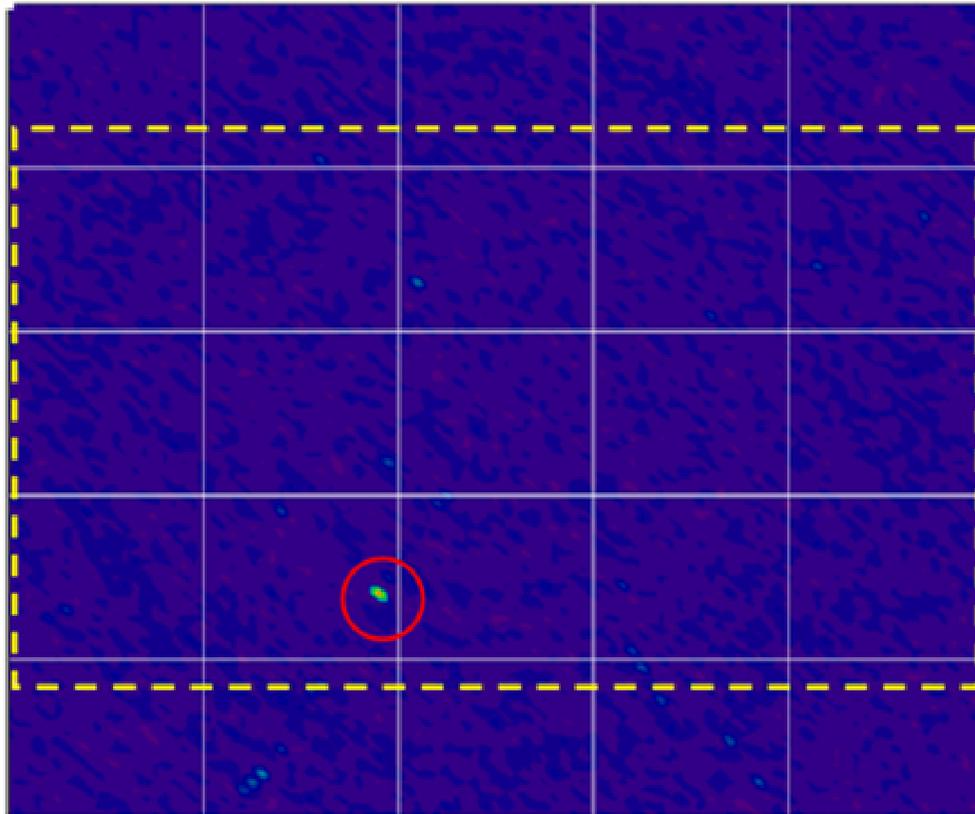
- Empirical relationships

Leakage Quantity vs.  
Sound Pressure and Internal Pressure



# Leakage Detection

## ■ Localization



Leakage Localization:

- Sensor array signal processing is the clue to leakage localization
- Bearing estimate is a classical acoustic antenna application using beamforming
- Distance estimates based on “Passive acoustic ranging” algorithms.

# Acoustic Condition Monitoring

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## **ROBUST & COST EFFICIENT**

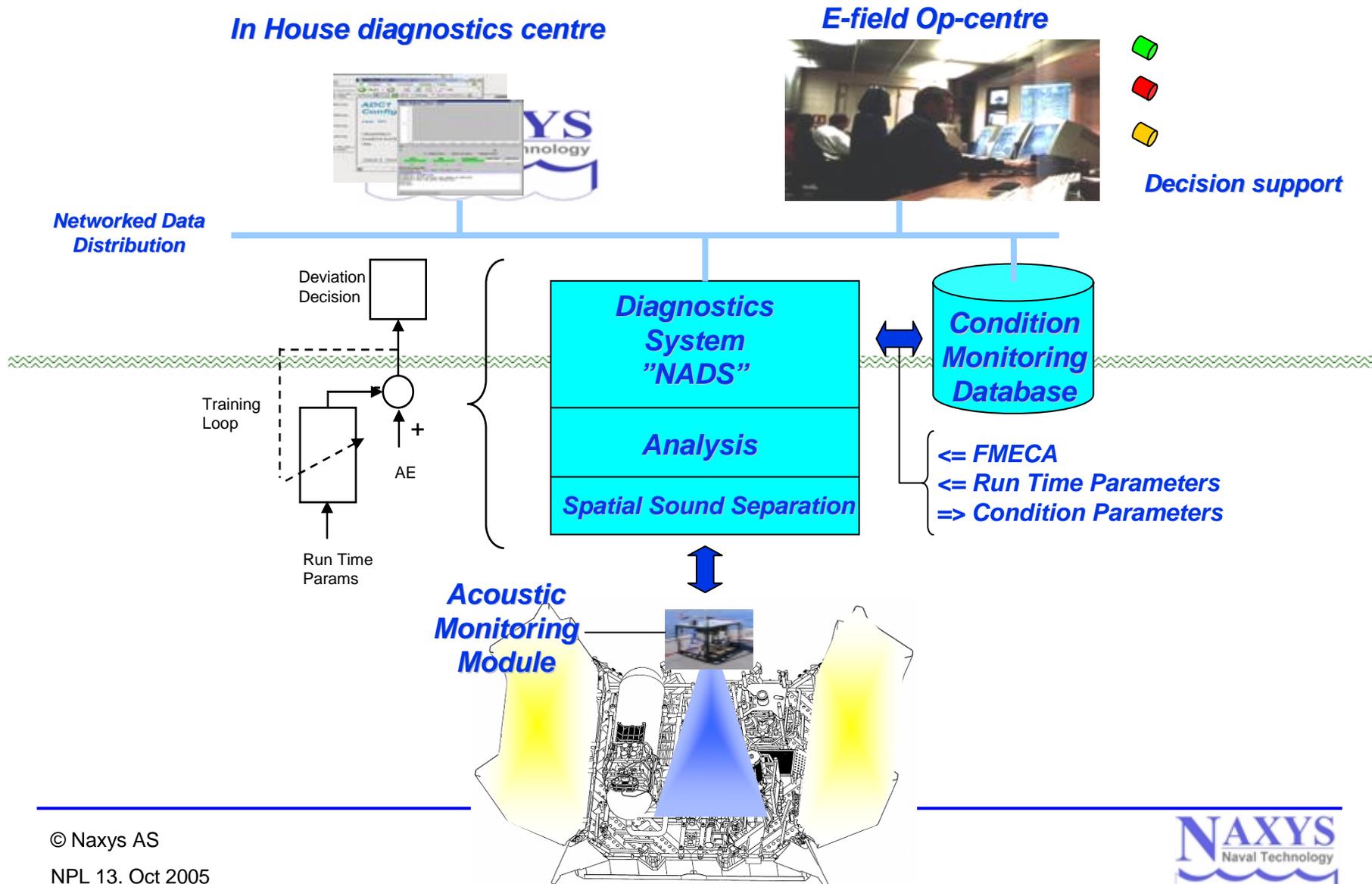
- No Cabling to monitored objects
- No structure mounting of sensors
- Large area and numerous objects monitored with an array of centrally positioned sensors
- No direct interface to monitored object
- Monitoring system can be replaced without intervention on monitored objects

# Failure Modes identifiable by the system

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- ✓ Leaks
- ✓ Choking
- ✓ Cavitations
- ✓ Structural vibrations
- ✓ Erosion
- ✓ Rotational defects (bearing damage, looseness/jamming, unbalance, mechanical breakdown, reduced efficiency)
- ✓ Valve defects
- ✓ Other defects (loose bolts, hits by large objects )

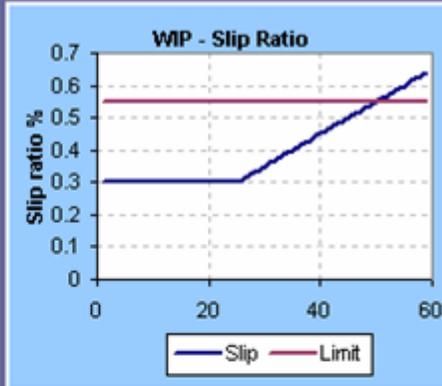
# Acoustic Condition Monitoring



# Control room interface

Latest measured:  
 RPM = 2340  
 SLIP = 0.65%

Navigation:  
 PILOT ▶  
 WIP



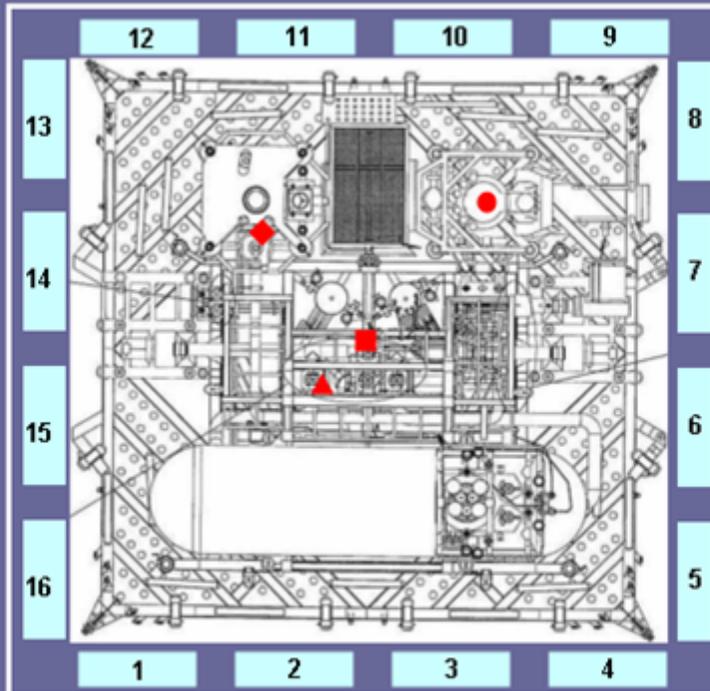
1 hour   1 day   1 week   1 month  
 1 year   3 years   5 years   20 years

Play sound: ▶

Event log	
Description	Time
! Pump shut in	10.09.2005 21:08:35
! Pump slip ratio 0.6% is too high	11.09.2005 08:08:35
! Pump 15th order too high	10.09.2005 21:08:35
! Pump RPM deviates from setting	11.09.2005 08:08:35
! Pump 15th order too high	10.09.2005 21:08:35
! Pump order analysis change	11.09.2005 08:08:35
! Diagnostic mode entered	10.09.2005 21:08:35
! Pump run up	11.09.2005 08:08:35

[more events](#)

## Template overview



VALVES ▲



STRUCTURE ◆



WIP ●



HAMM ■

# History & Qualification:

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- 2000 Development initiated
- 2001 Demonstrated at Troll Pilot
- 2002 Troll C, Åsgard ERB
- 2003 Series of trials carried out:  
Vibrations, Rotational machinery, Leak detection.
- 2003 Concept study for Norne Pilot case
- 2005 Implementation of NADS, Diagnostics System (DEMO 2000, N.Hydro and Statoil)
- 2005 Qualification of 2 systems for Ormen Lange

# Conclusion

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A system characterized by

**Robust and Cost Effective**  
**Provides Pollution Control,**  
**Asset Management and**  
**Regularity**