

**Ocean Structures and Materials  
Dr. Srinivasan Chandrasekaran  
Department of Ocean Engineering  
Indian Institute of Technology, Madras**

**Module - 4  
Lecture - 2  
Structural health monitoring**

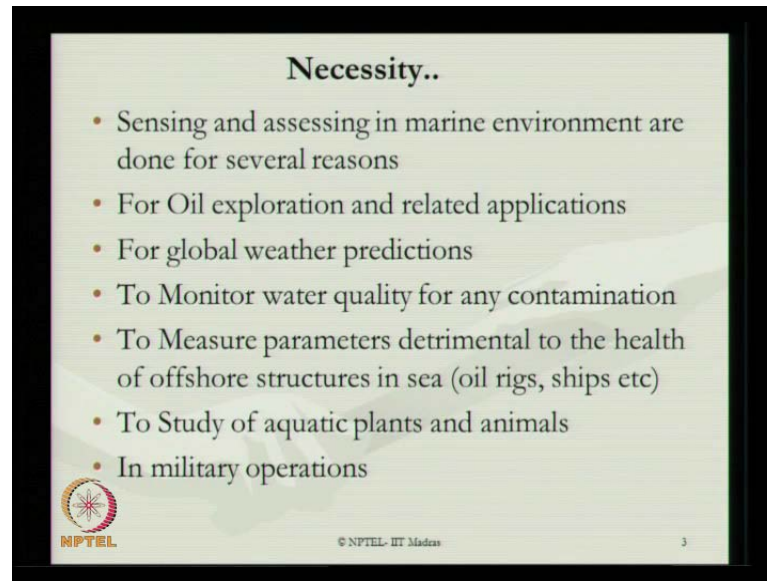
Welcome to the second lecture module four on Ocean Structures and Materials. In this lecture, we will talk about structural health monitoring and its application aspects to offshore structures.

(Refer Slide Time: 00:26)




Let us in detail discuss, the development of an integrated system for monitoring and assessment of marine structures. Before we understand the details of wireless sensor networking and deploying structural health monitoring schemes on marine structures and other examples, let us look at the necessity why we should do this.

(Refer Slide Time: 00:49)



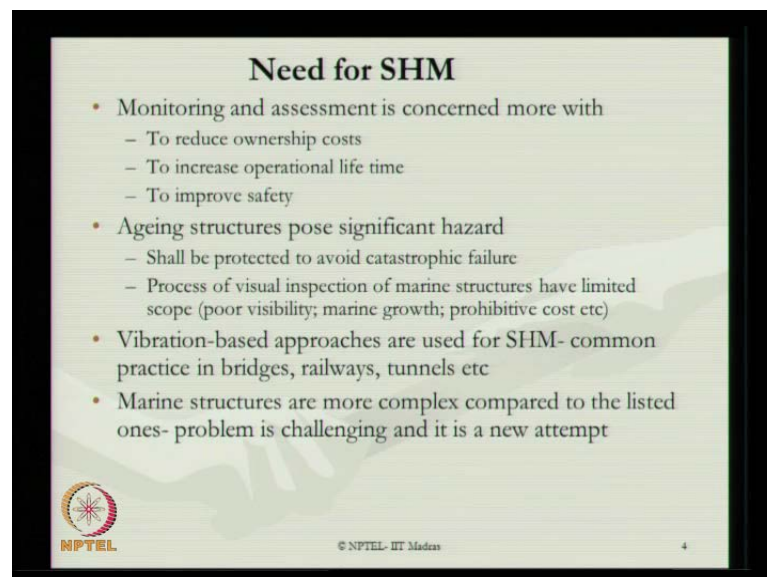
**Necessity..**

- Sensing and assessing in marine environment are done for several reasons
- For Oil exploration and related applications
- For global weather predictions
- To Monitor water quality for any contamination
- To Measure parameters detrimental to the health of offshore structures in sea (oil rigs, ships etc)
- To Study of aquatic plants and animals
- In military operations

 © NPTEL- IIT Madras 3


Sensing and assessing in marine environment are done for several reasons. For oil exploration and related applications; for global weather predictions; to monitor water quality for any contamination happen; to measure parameters detrimental to the health of offshore structures in sea, for example, oilrigs, ships etcetera. To study aquatic plants and animals and off course used in military operations.

(Refer Slide Time: 01:22)



**Need for SHM**

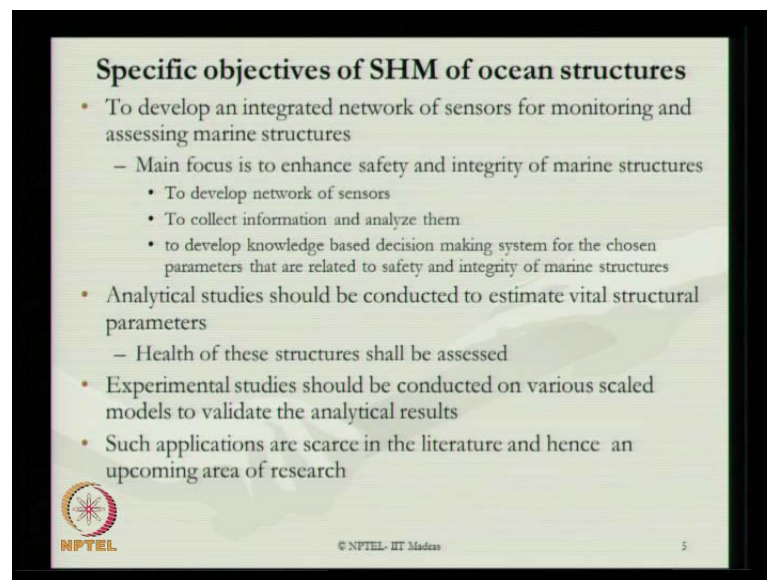
- Monitoring and assessment is concerned more with
  - To reduce ownership costs
  - To increase operational life time
  - To improve safety
- Ageing structures pose significant hazard
  - Shall be protected to avoid catastrophic failure
  - Process of visual inspection of marine structures have limited scope (poor visibility; marine growth; prohibitive cost etc)
- Vibration-based approaches are used for SHM- common practice in bridges, railways, tunnels etc
- Marine structures are more complex compared to the listed ones- problem is challenging and it is a new attempt

 © NPTEL- IIT Madras 4

If we look at the need for structural health monitoring which is abbreviated as SHM, for monitoring and assessment is concerned, it is more connected with reduction of

ownership costs, to increase operational lifetime, and of course, most importantly to improve safety and operability of the platforms. If we look at ageing structures, which pose a significant hazard then they can be protected to avoid catastrophic failure, if they are assessed in advance. Process of visual inspection of marine structures has limited scope as we discussed in the last lecture. The reasons are due to poor visibility, marine growth and prohibitive cost. Vibration based approaches are also used and becoming increasingly common for structural health monitoring scheme. And they are generally practiced broadly in bridges, railways and tunnels. Marine structures are complex when compared to the listed ones, of course, therefore, the problem is more challenging and it will be a new attempt and search front in marine structure design.

(Refer Slide Time: 02:36)



**Specific objectives of SHM of ocean structures**

- To develop an integrated network of sensors for monitoring and assessing marine structures
  - Main focus is to enhance safety and integrity of marine structures
    - To develop network of sensors
    - To collect information and analyze them
    - to develop knowledge based decision making system for the chosen parameters that are related to safety and integrity of marine structures
- Analytical studies should be conducted to estimate vital structural parameters
  - Health of these structures shall be assessed
- Experimental studies should be conducted on various scaled models to validate the analytical results
- Such applications are scarce in the literature and hence an upcoming area of research

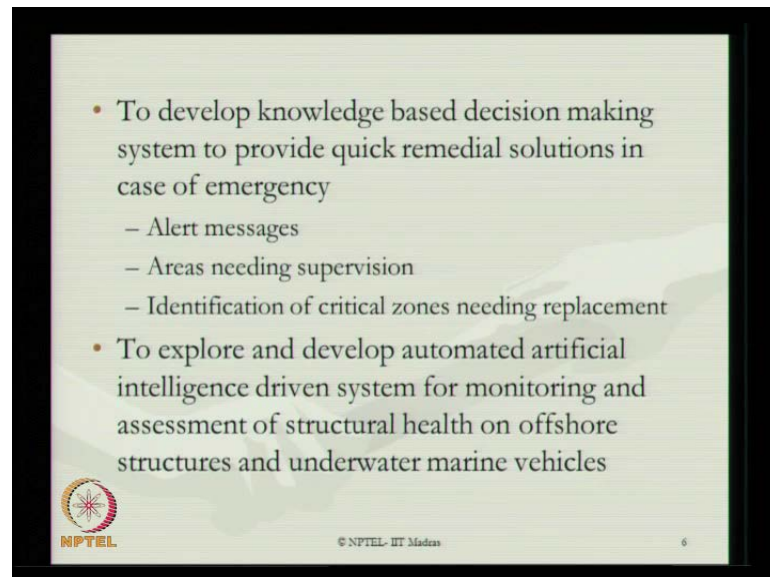
NPTEL © NPTEL- IIT Madras 5

If we look at the specific objectives of SHM applied to ocean structures, there is a need to develop an integrated network of sensors for monitoring and assessing marine structures. The main focus should be to enhance safety and integrity of marine structures. In this network, we should say I should be able to develop network of sensors, to collect information, and subsequently analyze this information to develop knowledge based decision making system for the chosen parameters that are related to safety and integrity of the structural system.

Analytical studies are also important and they should be carried out to estimate the vital structural parameters, which are related to assessing of health of the structures.

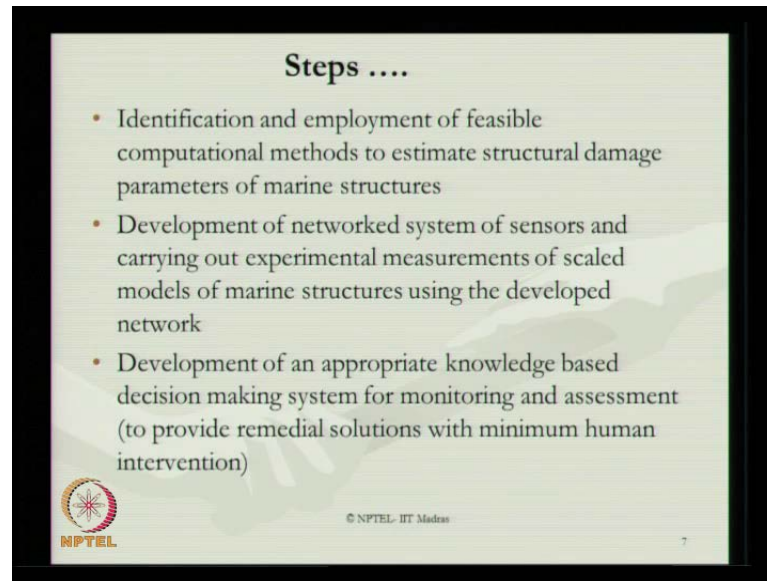
Experimental studies are also important and they should be conducted on various scaled models to validate the analytical results what we see for assessing the health of structures. Such applications are gentlemen, they are very scarce in literature and hence it has got an upcoming area of research.

(Refer Slide Time: 03:43)




To develop knowledge based decision-making system and to provide quick remedial solutions in case of emergency, we should generate alert messages, and therefore areas needing supervision should be highlighted. Identification of critical zones needing replacement should be an outcome of these kinds of studies. They are also important to explore and develop automated artificial intelligence driven systems for monitoring and assessment of health of structures and underwater marine vehicles.

(Refer Slide Time: 04:21)



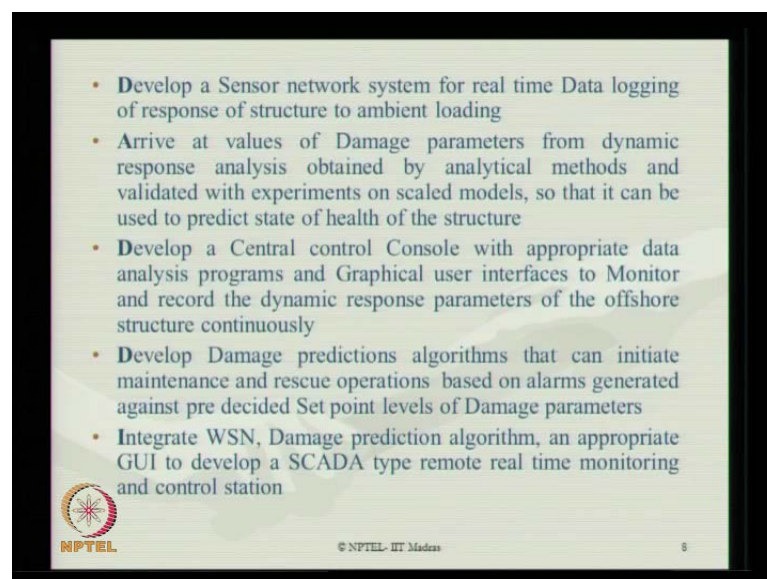
**Steps ....**

- Identification and employment of feasible computational methods to estimate structural damage parameters of marine structures
- Development of networked system of sensors and carrying out experimental measurements of scaled models of marine structures using the developed network
- Development of an appropriate knowledge based decision making system for monitoring and assessment (to provide remedial solutions with minimum human intervention)


 © NPTEL- IIT Madras 7

Lets us now look at the steps involved in development of SHM applied to marine structures. Identification and employment of feasible computational methods to estimate structural damage parameters of marine structures, development of networked systems of sensors and carrying out experimental measurements of scaled models on marine structures using the developed network. Development of an appropriate knowledge based decision-making system for monitoring and assessment, because this is very important to provide remedial solutions with minimum human intervention.

(Refer Slide Time: 05:00)



- Develop a Sensor network system for real time Data logging of response of structure to ambient loading
- Arrive at values of Damage parameters from dynamic response analysis obtained by analytical methods and validated with experiments on scaled models, so that it can be used to predict state of health of the structure
- Develop a Central control Console with appropriate data analysis programs and Graphical user interfaces to Monitor and record the dynamic response parameters of the offshore structure continuously
- Develop Damage predictions algorithms that can initiate maintenance and rescue operations based on alarms generated against pre decided Set point levels of Damage parameters
- Integrate WSN, Damage prediction algorithm, an appropriate GUI to develop a SCADA type remote real time monitoring and control station

 © NPTEL- IIT Madras 8

So, the first step could be to develop a sensor network system for real time data logging of response of structural to ambient loading. Then arrive at values of damage parameters from dynamic response analysis obtained by analytical techniques and then they are subsequently validated with experiments on scaled models, so that these values can be used to predict the state of health of an existing structure. Then develop a central control console with appropriate data analysis programs and graphical user interface to monitor and record, the dynamic response parameters of the offshore structures continuously.

To develop damage predictions algorithms that can initiate maintenance and rescue operation based on alarms generated during pre decided set point levels of damage parameters. For example, if one is able to estimate and establish the damage parameters, and one can design development of SMS and alarm based on these damage parameters then they can play a very important role in establishing and safety during operation of offshore platform. Then off course to generate and integrate wireless sensor networking, damage prediction algorithm and appropriate graphic user interface must be develop using what we called a SCADA type remote real time monitoring and control station techniques.

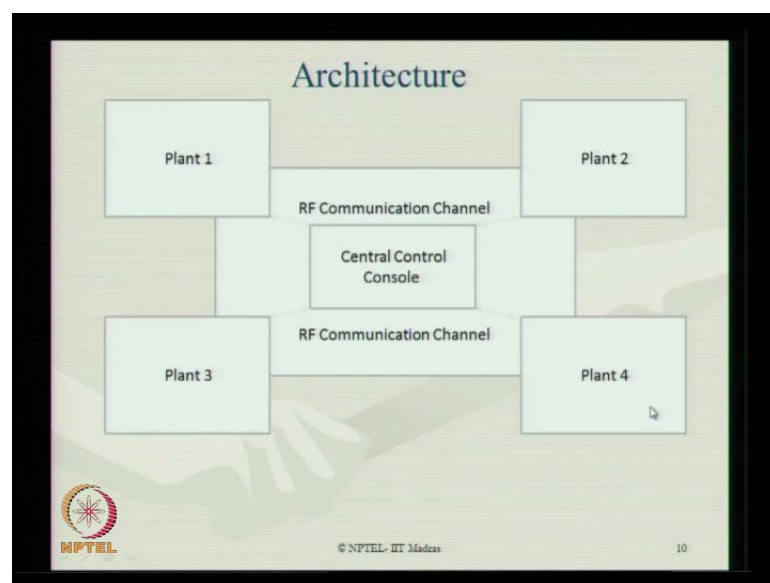
(Refer Slide Time: 06:43)



If we look at the SHM system architecture, which is a very important design and development, it should have a plant unit. The plant unit should consider and consist of sensor network topology, associated data actuation system, RF communication devices.

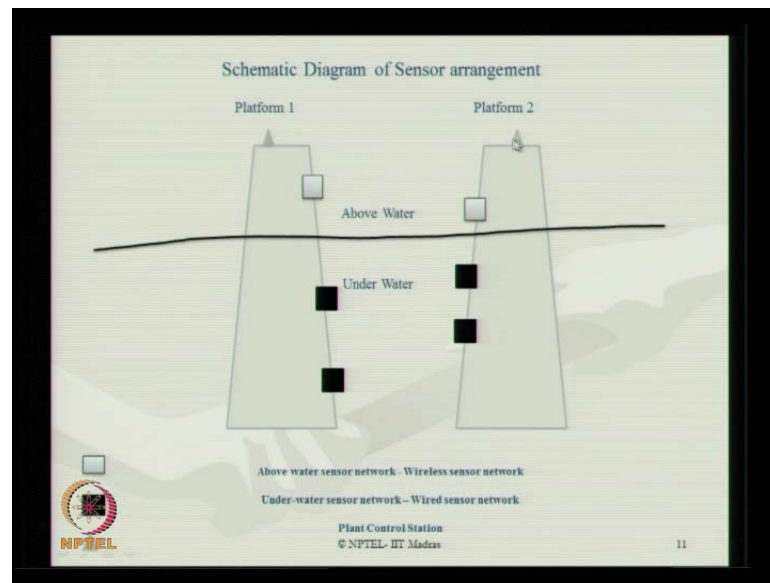
If you look at the communication channel, they must have RF for limited distance. Then of course, if the distance is very large then one must use satellite transmission through the internet and intra net services. Data encryption is also to be done for secure transformation. If we look at the central control console then it should have data storage; it must have data analysis capabilities for data reporting and alarm generation and graphical user interface development and of course, to generate sensor calibration and testing possibilities. Remote sensor configuration though it is optional, it is becoming very important recent advancement of SHM system architecture.

(Refer Slide Time: 07:48)



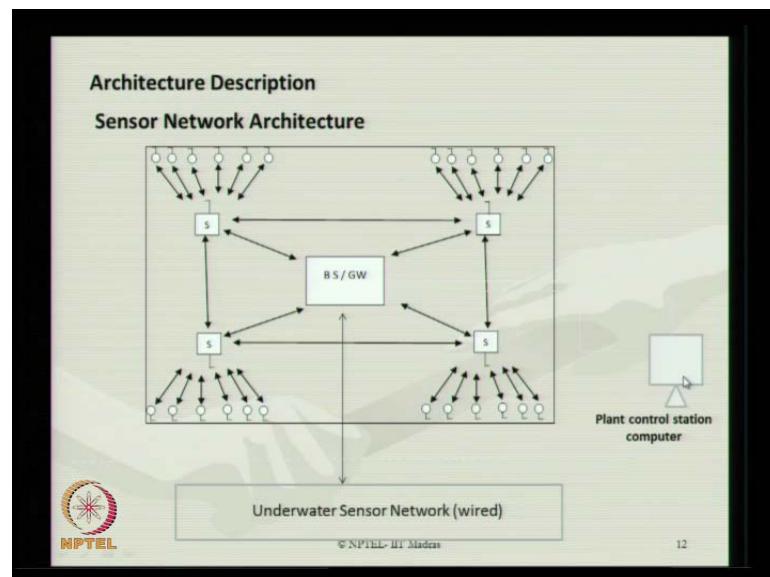
Now this is the layout of the architecture, for example, if you got couple of offshore plants located in closer vicinity, because generally you see the drilling units are always located to the closer vicinity for the central well. So, I got production platform, operational platform, drilling units as plant 1, 2, 3 and 4, I must connect them using a SHM architecture is what we call as RF communication channel. Then I must have a central control console, which can then connect these plants using radio frequency communication channels.

(Refer Slide Time: 08:27)



The schematic diagram of sensor arrangement shown in the picture here, for example, I have got two platforms, some of the sensors must be located in the water and some of them of course above water and these are the platform local control station which is located much above the water level.

(Refer Slide Time: 08:47)

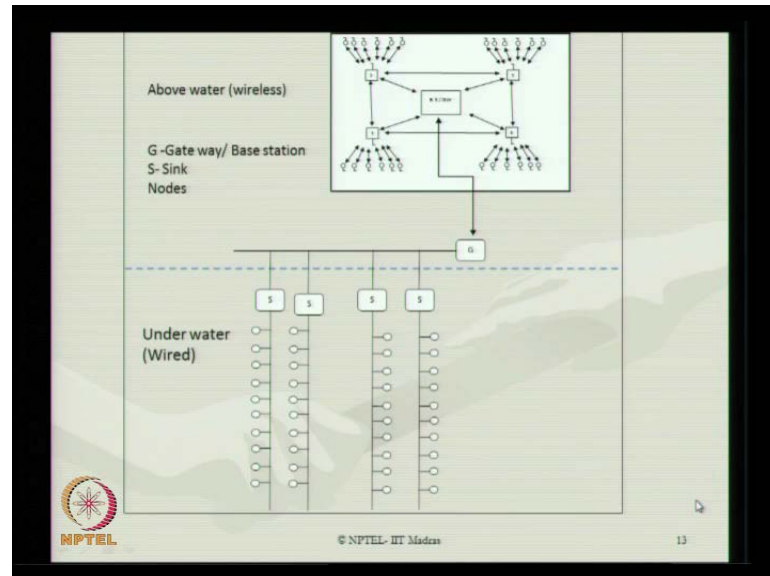


Now the architectural descriptions are shown in the picture here. The sensor network architecture should have the underwater sensor network which is generally done with wires, and above water are generally done with wireless sensor networking. All of them



have been connected together using RF communication to the plant control station, the computer control which is localized for a specific plant.

(Refer Slide Time: 09:14)



The above water sensors will be essentially a wireless, and the underwater sensors essentially will be wired. Both of them should be connected by using a gateway what we call as a base station or a gate way station. And of course, I must use different sinks which are locally connecting all the nodes to the sink and from the sink they are connected and communicated to the gateway.

(Refer Slide Time: 09:40)

### Use of MEMS devices

- MEMS devices may be attached to
- Ships
- Floating devices in the sea
- Fixed type ocean structures (rigs)
- Sea bed using links
- AUVs

NPTEL

© NPTEL- IIT Madras

14

You can also use MEMS devices for marine applications. Let us quickly look at what are the possible uses of MEMS devices in SHM. MEMS devices may be attached to ships, floating devices in the sea fixed type ocean structures, for example, drilling rigs and seabed using links and off course in underwater-automated vehicles.

(Refer Slide Time: 10:06)



**MEMS in oil exploration and related applications**

- To find potential oil reserves
- To detect oil leakage from pipe lines
- In case of oil spills
  - MEMS sensors can help to sense information about ocean currents
  - It is also possible to predict for oil slick transportation
  - This can also aid cleaning operation



 © NPTEL- IIT Madras 15

MEMS are widely used in oil exploration and related application is essentially to find potential oil reserves. It detects oil leakage from pipelines in case of oil spills. MEMS sensor can help to sense information about the ocean currents therefore, you can prevent the further spreading of oil spill from the local area to the global surface. It is also possible to predict for oil slick transportation, it is very important an uncontrollable problem in case of oil spill accident this can also aid cleaning operation very large extent.

(Refer Slide Time: 10:44)

**MEMS applications in finding potential oil and gas reserves**

- MEMS geophones and accelerometers can sense the vibrations sent up from earth's belly
- An array of MEMS geophones are planned over a wide area on the sea bed
- Vibrations are intentionally produced on the ground surface using some techniques
- MEMS devices measure the reflection of these waves from different layers in the earth's belly
- These readings are then used to create a geological map
  - This indicates the size and location of the oil/gas reservoir

NPTEL © NPTEL- IIT Madras 16

MEMS applications are finding increasing values in potential oil and gas reserves identification. MEMS geophones and accelerometers can sense the vibrations sent by the earth's belly. An array of MEMS geophones are planned over a wide area on the sea bed. Vibrations are intentionally produced on the ground surface using some techniques, and MEMS devices measure the reflection of these waves from different layers in the earth's belly. And these readings are then used to create a geological mapping, which indicates the size, location and availability an oil and gas reservoirs which are recent advancements using MEMS application to identify the oil reserves in sea bed.

(Refer Slide Time: 11:31)

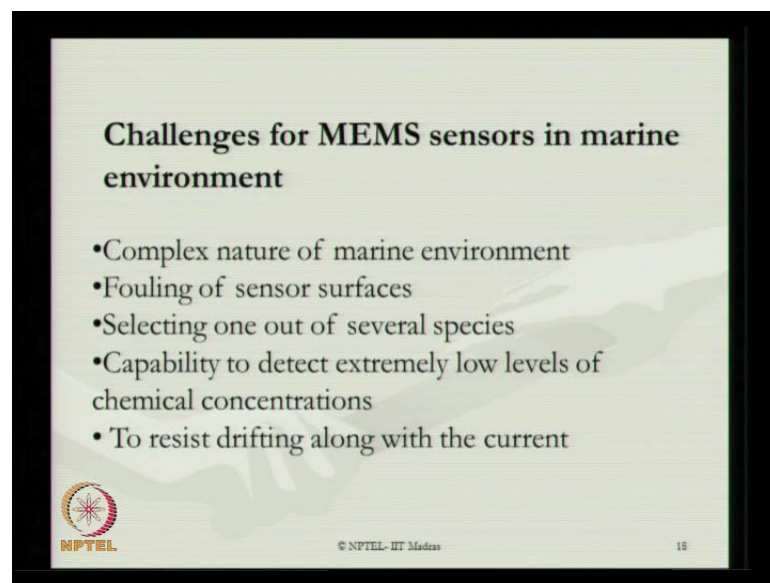
**Use of MEMS in Marine military operations**

- An array of MEMS sensors, spread on the sea floor could detect the submarines
- MEMS sensors are also used to locate anti-torpedo weapons on ships and submarines
- MEMS sensors in torpedoes are responsible for
  - Detonating the torpedo at the night time
  - Hitting the target in a crowded environment
  - To prevent any pre-mature explosion

NPTEL © NPTEL- IIT Madras 17

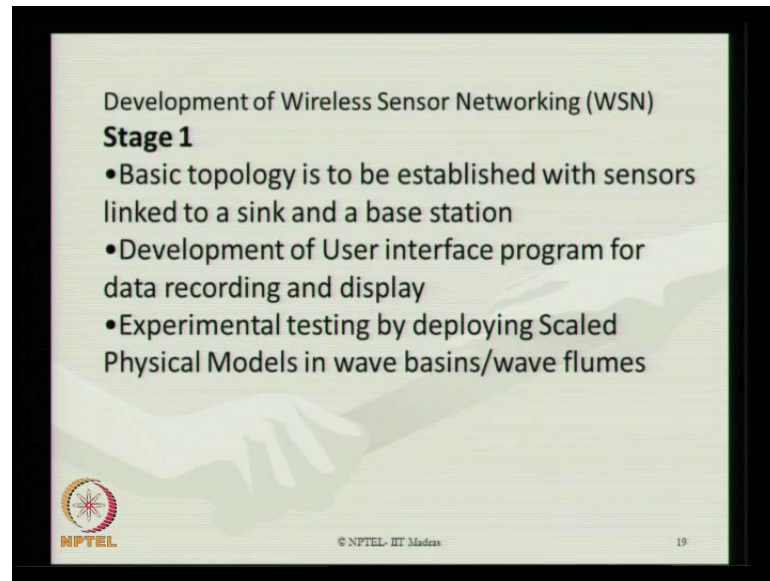
We can also use MEMS very widely in marine military operations. An array of MEMS sensor is spread on the sea floor which can detect the submarine approaching your specific segment of strategic importance. MEMS sensor are also used to locate anti-torpedo weapons on ships and submarines. MEMS sensors in torpedo are essentially responsible for detonating the torpedo at the right time hitting the target in a crowded environment and off course to prevent any pre-mature explosion.

(Refer Slide Time: 12:07)



There are some challenges associated with MEMS sensor when deploy in marine environment that say the complex nature of marine environment:. The fouling of sensor surfaces, selection of outlet of several species, capabilities to detect extremely low levels of chemical concentrations, which arise from marine pollution, and of course resist drifting of the sensor along with the current.


(Refer Slide Time: 12:37)



Development of Wireless Sensor Networking (WSN)

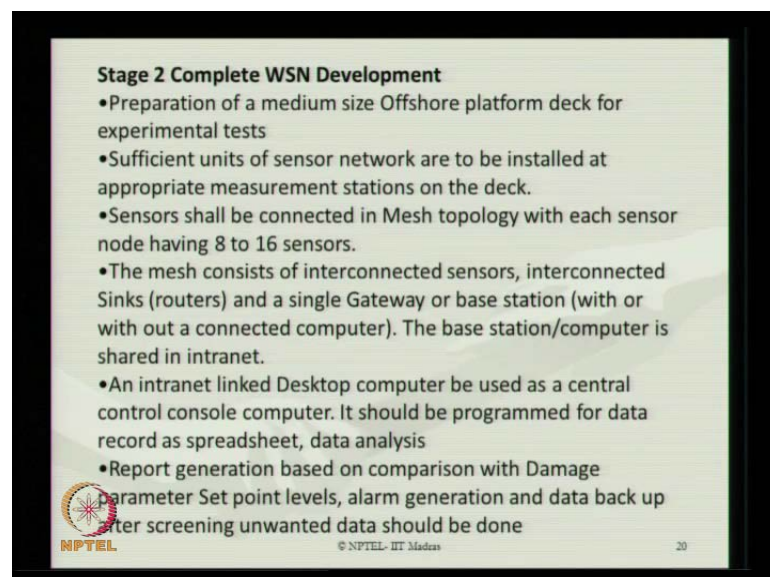
**Stage 1**

- Basic topology is to be established with sensors linked to a sink and a base station
- Development of User interface program for data recording and display
- Experimental testing by deploying Scaled Physical Models in wave basins/wave flumes

 © NPTEL- IIT Madras 19


Let us now look at different stages involved in development of wireless sensor networking, which is a very common application in marine environment. The stage one we develop a basic topology, which is to be established with sensors linked to a sink and the base station. The development of user interface program for data recording and display is also the part of the stage one, and off course one must consider conducting experimental testing on deploying scaled models in wave basins and in wave flumes to assert times whether the establish specific topology is properly activated an efficiently design.

(Refer Slide Time: 13:19)



**Stage 2 Complete WSN Development**

- Preparation of a medium size Offshore platform deck for experimental tests
- Sufficient units of sensor network are to be installed at appropriate measurement stations on the deck.
- Sensors shall be connected in Mesh topology with each sensor node having 8 to 16 sensors.
- The mesh consists of interconnected sensors, interconnected Sinks (routers) and a single Gateway or base station (with or with out a connected computer). The base station/computer is shared in intranet.
- An intranet linked Desktop computer be used as a central control console computer. It should be programmed for data record as spreadsheet, data analysis
- Report generation based on comparison with Damage Parameter Set point levels, alarm generation and data back up after screening unwanted data should be done

 © NPTEL- IIT Madras 20

Once stage one is completed, in stage two - one can think of complete wireless sensor networking development. In this stage preparation of a medium size offshore platform deck is very important for conducting experimental test. Sufficient units of sensor networks are to be installed at appropriate measurement stations on the deck. Sensors then shall be connected in what we called a mesh topology with each sensor having node form 8 to 16 sensors. The mesh consists of inter connecting sensors, interconnected sinks which are called as routers and single gateway or base station; it can be with or without connected to the computer. The base station is then shared in the intranet. An intranet linked desktop computers is generally used as central control console. It should be programmed for data recording in the form of spreadsheet and data analysis. The report generation shall be based on comparison with the damage parameter set point levels, which are established based on the experimental studies conducted on the deck in stage two itself.

Then one can think of generating alarm generation and data back up after screening unwanted data, which are wide noise produce during measurement techniques.

(Refer Slide Time: 14:44)

The slide is titled "Setting up sensor network" and contains the following text:

- Sensor network below water is wired and above water is Wireless
- The sensor network is divided in to three levels by hierarchy
- **Sensor interface nodes** – RF communication unit augmented with necessary DAQ- Sensor node is the first level device which collects the platform response measurement. (Green dots in figure below)
- **Data sinks** – Sink collects data from various sensor nodes and sends to Gateway (Blue dots in figure below)
- **Data Aggregator Gateways**- Collects data from sinks and transmits to the Central control station by WAP based internet connection or it is plugged to a Plant Computer and then transmitted to central control over internet (Yellow dot)
- The complete Sensor network of Wireless and Wired network includes both Mesh and star topology in a hybrid hierarchical model

The diagram shows a hierarchical network structure with a yellow dot at the top, a blue dot in the middle, and several green dots at the bottom, connected by lines.

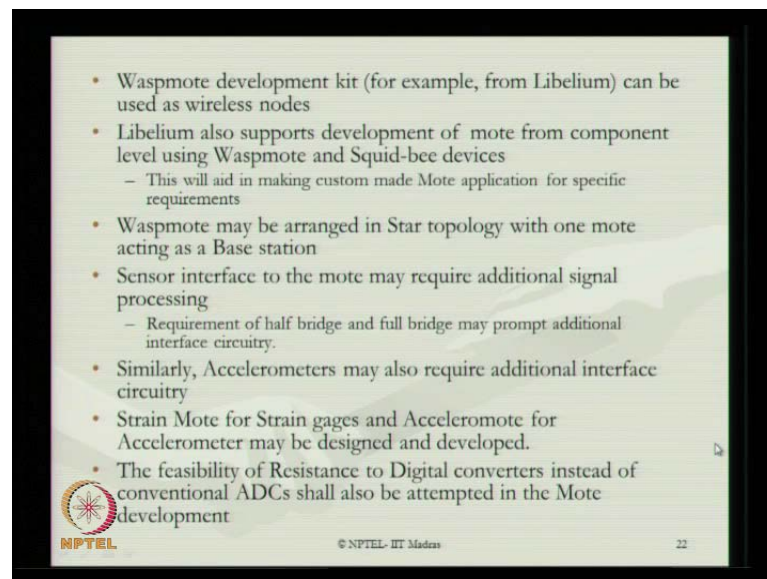
NPTEL logo is visible in the bottom left corner. Copyright notice: © NPTEL- IIT Madras. Page number: 21.

If you think of setting up a sensor network for wireless sensor networking for marine structures then the sensor network below water is wired preferably an above water is generally kept wireless. The sensor network is divided into three levels by hierarchy; the sensors interface nodes which are generally done with RF communication unit

augmented with necessary data actuation units. The sensor node is the first level device which collects the platform response measurements. Now in this picture shown here, these are all the sensor interface nodes which are S mark which are actually used to collect the data from the platform. Once the data is collected then the establishment what we called data sinks.

The sinks collect the data from various sensor nodes and senses it to the gateway. Now the blue point what you see here are what we called as data sinks, these data sinks collect data from the zone sensor interface nodes which are already located on the platform or on the deck at different places. Once the sinks receives the data then the third level is data aggregated gateway, these collect data from the sinks and further transmits these data to the central control station by WAP based internet connection or it is plugged to a plant computer. The complete sensor network of wireless and wired networking includes both mesh and star topology in a hybrid hierarchical model.

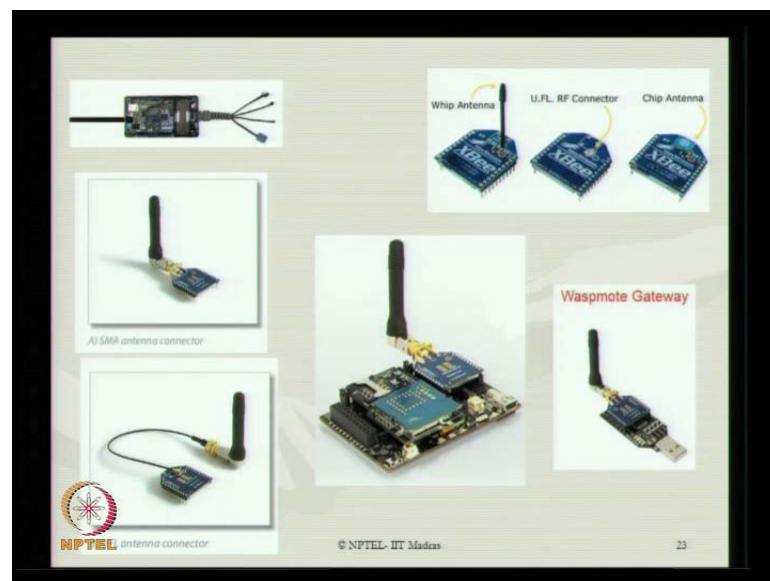
(Refer Slide Time: 16:25)



Under this frame, we are what is called wasp mote development kit. For example, the typical kit is developed libelium USA, which can used as an wireless nodes. Libelium also support development of mote from component level using wasp mote and squid-bee devices. This will aid in making the custom-made waspmote or mote application for specific requirements. Wasp mote may be arranged in star topology with one mote acting as a base station.

The sensor interface to the mote may require additional signal processing which can be developed. A half bridge and half bridge may prompt additional interface circuitry as well. Similarly, an accelerometer can also require additional interface circuits. The strain mote is generally used for strain gauges and an acceleromote generally used for an accelerometer should be designed and developed which can be compatible with a WSN network which has been used for the measurement. The feasibility of resistance to digital converters should be thought of instead of conventional ADC should be attempted in the mote development stage itself.

(Refer Slide Time: 17:41)



These are some of the interesting antennas which are used by libelium, which is SMA antenna connector which can also be used as whip antennas, RF connectors, and chip antennas. This is the typical Waspote Gateway which has got the receiver which can receive signal from the sinks and also directly from the sensor. The whole assembly of the sink on the gateway with a receiver looks like this, which can be housed in the metal box which can be protected from external damage.

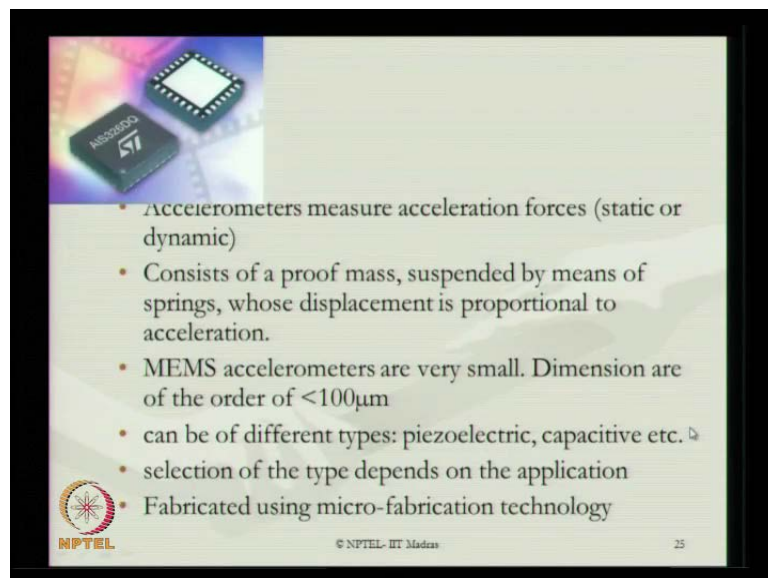


(Refer Slide Time: 18:18)



This is how a specific network of different sinks and connectors are being used and that becomes my network of all these wireless sensor networking as you see in this picture.

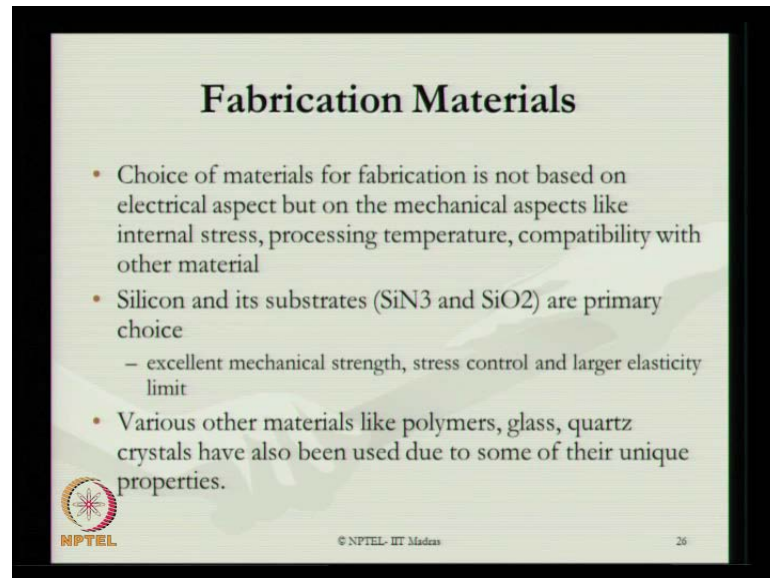
(Refer Slide Time: 18:31)



We also talk about MEMS accelerometers. Accelerometers are generally used for measuring acceleration forces; it can be static or it can be dynamic in nature. It consists of a proof of mass suspended by means of spring, whose displacement is made proportional to the acceleration of the body. MEMS accelerometer are very commonly used, because they are very small in size and the dimension are very thin to the order of


less than 100  $\mu\text{m}$ . Can be used of different types piezoelectric and capacitive types selection of type off course depends on the application. They are also used and fabricated using micro fabrication technology.

(Refer Slide Time: 19:18)



**Fabrication Materials**

- Choice of materials for fabrication is not based on electrical aspect but on the mechanical aspects like internal stress, processing temperature, compatibility with other material
- Silicon and its substrates ( $\text{SiN}_3$  and  $\text{SiO}_2$ ) are primary choice
  - excellent mechanical strength, stress control and larger elasticity limit
- Various other materials like polymers, glass, quartz crystals have also been used due to some of their unique properties.

 © NPTEL- IIT Madras 26

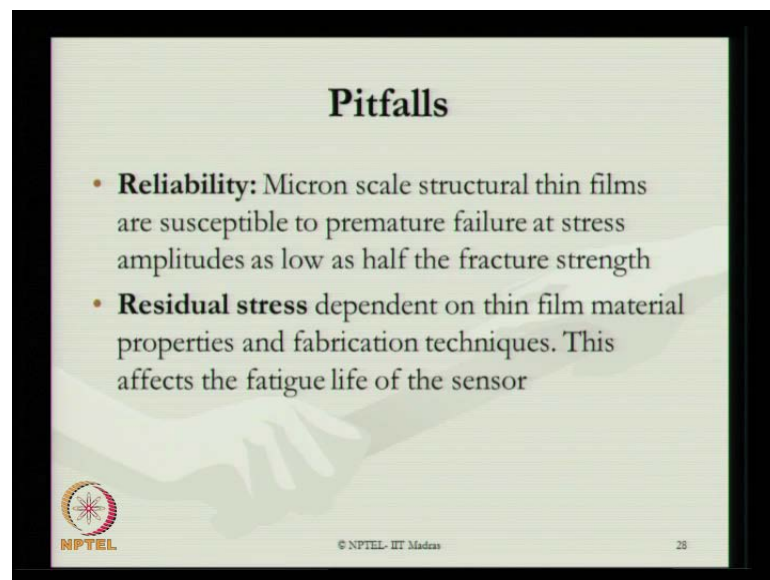
Different materials are used for fabrication. Choice of materials for fabrication is not based on electrical aspect, but all on the mechanical aspects like development and measurements of internal stress processing temperature and compatibility with other material with which they are have been used. The common material which have been used for manufacturing MEMS accelerometer are silicon and its substrates, because they are excellent mechanical strength and stress control strategies and we gone large elasticity limits. Various other materials are also used like polymers, glass, quartz crystal are also been used because of their uniqueness properties.

(Refer Slide Time: 20:00)



There are different techniques of fabrication, bulk micromachining, surface micromachining and deep reactive ion etching which is the very recent development in manufacturing and fabricating MEMS accelerometer, which is called dry technique.

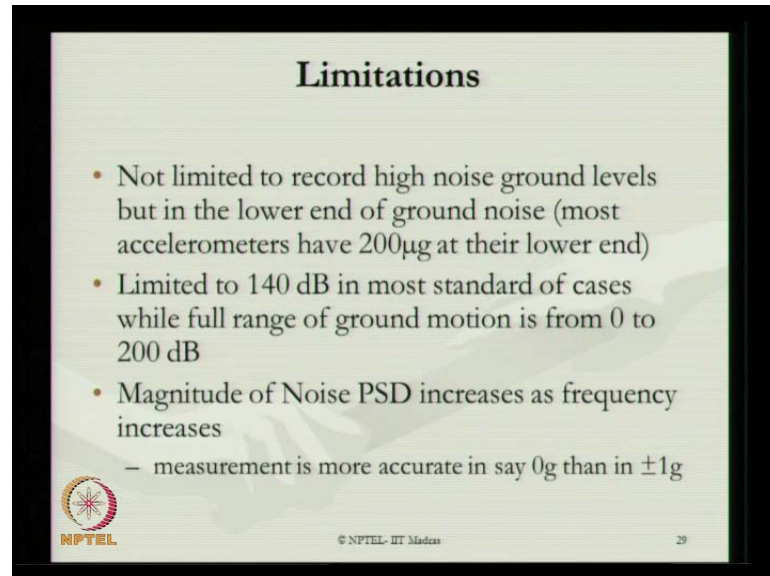
(Refer Slide Time: 20:15)



There are of course certain pitfalls in these using MEMS accelerometer. Reliability and residual stress developments are two segments which has got series pitfalls. Micron scale structural thin films are susceptible to premature failure, and therefore, reliability levels are lesser compared to the fracture strength. Residual stress dependence on thin film


material, properties and fabrication techniques, which also in important pitfalls using MEMS accelerometer.

(Refer Slide Time: 20:45)



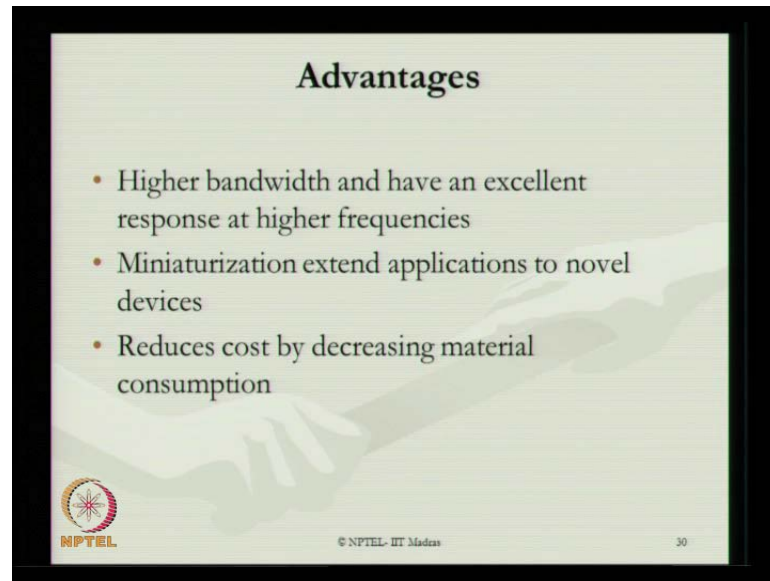
**Limitations**

- Not limited to record high noise ground levels but in the lower end of ground noise (most accelerometers have  $200\mu\text{g}$  at their lower end)
- Limited to 140 dB in most standard of cases while full range of ground motion is from 0 to 200 dB
- Magnitude of Noise PSD increases as frequency increases
  - measurement is more accurate in say 0g than in  $\pm 1\text{g}$

 © NPTEL- IIT Madras 29

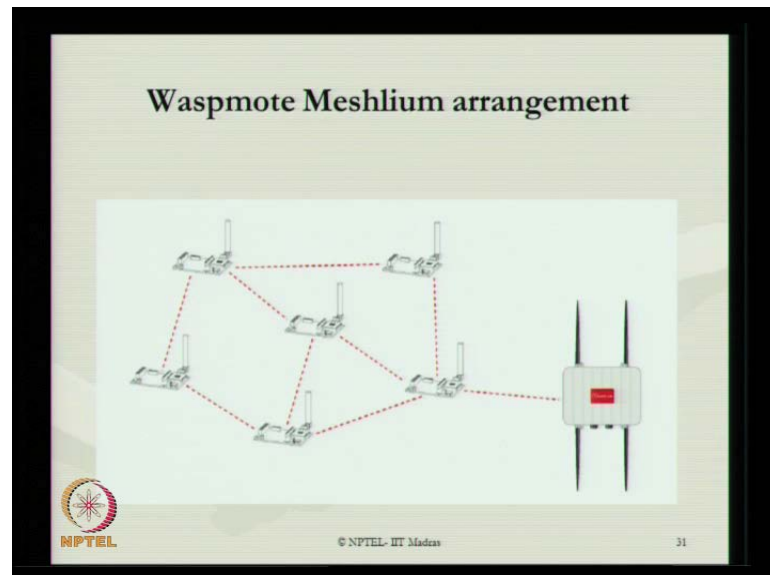
Of course, there are series limitations, not limited to the record high noise ground levels, but in the lower end of ground noise also there is a problem. They are limited to 140 decibel in most standard cases, while full range of ground motion is varying from 0 to 200 decibel. So, the magnitude of noise levels in terms of PSD increases as the frequency increases. Measurement is more accurate in the rays of 0 g less than in case of plus or minus 1 g.

(Refer Slide Time: 21:17)



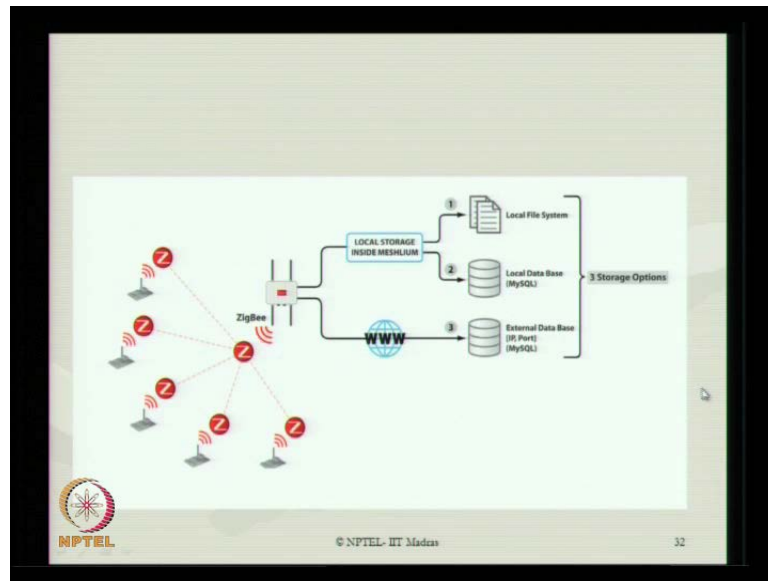
There are some advantages of these techniques, higher bandwidth and they have an excellent response at higher frequencies. They are very small in size, and they are extended application for novel devices. They are reduced cost by decreasing material consumption.

(Refer Slide Time: 21:35)



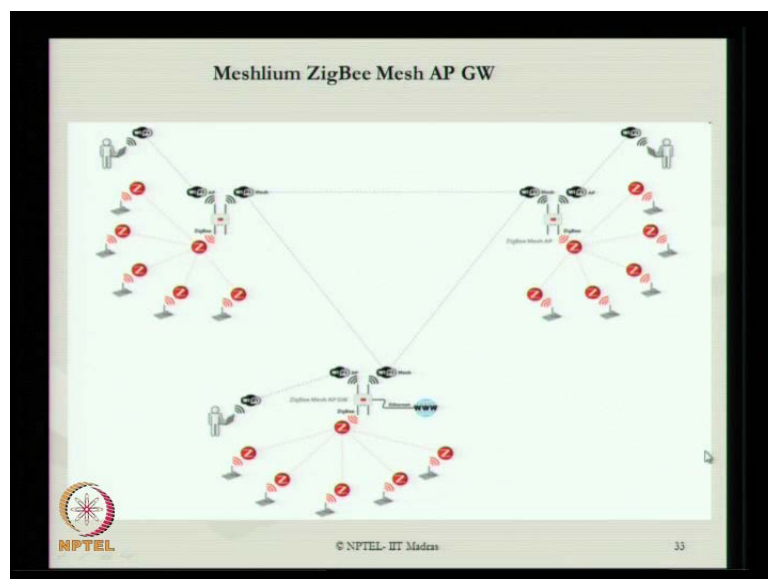
If we look at the waspote meshlium arrangement, the picture shows interestingly different waspote arrangement, which we called meshlium arrangement, which can be connected the central control console as you see in this picture.

(Refer Slide Time: 21:51)



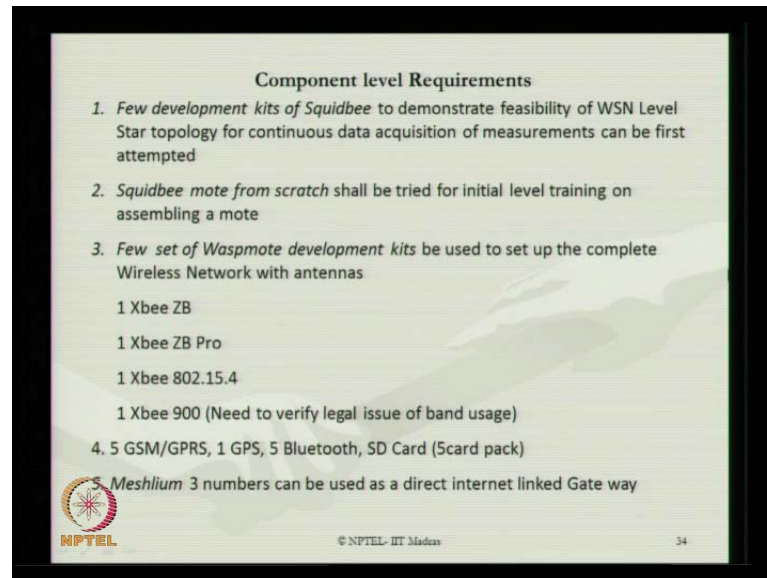
Now the interface of the gateway can be a zig bee gateway, it is a very common technique which is supported by libelium USA. The local storage inside the meshlium can be of two systems; one can be from the local file support system and can also have MySQL data base which can be used for local storage. Alternatively, one can use also internet which can create an external database, and therefore, we have three varieties of storage options whatever data collected from the central control console for further analysis of data, and this is connected to the network using what we called zig bee gateway.

(Refer Slide Time: 22:36)



The meshlium zig bee mesh, therefore, comprises of interesting three different configurations which can be then further network for wider area of networking for a different platform located in a specific region or in country.


(Refer Slide Time: 22:54)



**Component level Requirements**

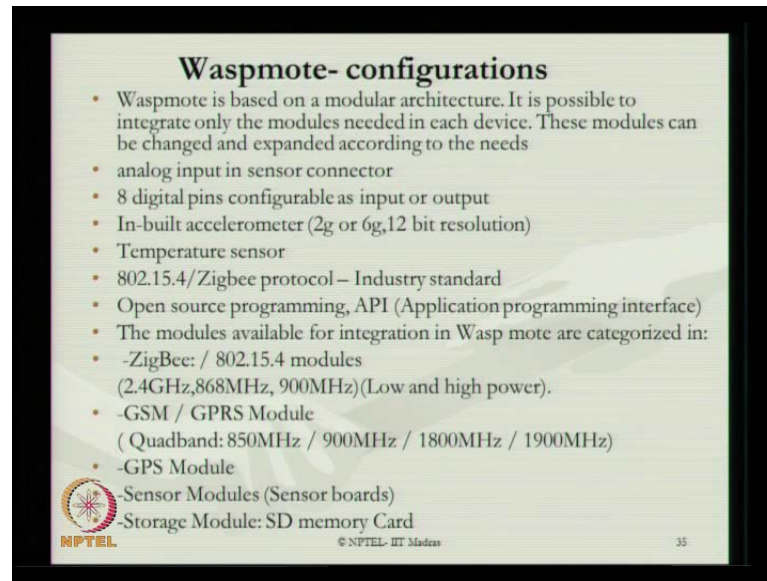
1. *Few development kits of Squidbee* to demonstrate feasibility of WSN Level Star topology for continuous data acquisition of measurements can be first attempted
2. *Squidbee mote from scratch* shall be tried for initial level training on assembling a mote
3. *Few set of Waspote development kits* be used to set up the complete Wireless Network with antennas
  - 1 Xbee ZB
  - 1 Xbee ZB Pro
  - 1 Xbee 802.15.4
  - 1 Xbee 900 (Need to verify legal issue of band usage)
4. 5 GSM/GPRS, 1 GPS, 5 Bluetooth, SD Card (5card pack)

5 Meshlium 3 numbers can be used as a direct internet linked Gate way

 © NPTEL- IIT Madras 34


So, then let us look at the component level requirements which are generally done for WSN networking. Few development kits of squid bee are to be done to demonstrate feasibility of wireless sensor networking, level star topology for continuous data acquisition that should be first attempted squid bee mote from scratch should be try for initial level training on assembling a mote. Few set of waspmote development kits are then to be used to set up the complete WN with antennas. This can comprise of 1 Xbee ZB, 1 z b pro, 1 802 15 4 configuration Xbee, and 1 Xbee with 900 which can need to verify the legal issues of band usage. I can also use 5 minimum GPRS, 1 GPS, 5 Bluetooth devices, and one standard SD card for a single assembling. Meshlium therefore, consists of three members which can be used as a direct inter link linked gateway which can connect three different systems architecture global.

(Refer Slide Time: 24:11)



**Wasmote- configurations**

- Wasmote is based on a modular architecture. It is possible to integrate only the modules needed in each device. These modules can be changed and expanded according to the needs
- analog input in sensor connector
- 8 digital pins configurable as input or output
- In-built accelerometer (2g or 6g, 12 bit resolution)
- Temperature sensor
- 802.15.4/Zigbee protocol – Industry standard
- Open source programming, API (Application programming interface)
- The modules available for integration in Wasp mote are categorized in:
  - -ZigBee: / 802.15.4 modules (2.4GHz, 868MHz, 900MHz) (Low and high power).
  - -GSM / GPRS Module (Quadband: 850MHz / 900MHz / 1800MHz / 1900MHz)
  - -GPS Module
  - -Sensor Modules (Sensor boards)
  - -Storage Module: SD memory Card

 © NPTEL- IIT Madras 35

Let us look at the waspmote configurations in detail. Wasmote is based on a modular architecture; it is therefore, possible to integrate only the modules in the device. These modules can then be changed and expanded according to the needs which is seen as one of the highest versatility and one of the great advantage have using waspmote configuration for wireless sensor networking. The analog input in the sensor connector, it is got 8 digital pins configurable as input or output depending upon what are using the device as, it is got in built accelerometer which is having the capacity varying from 2 G or 6 G which is having 12 bit resolution. It is also has the temperature sensor; it has a zig bee protocols with industrial standard is what open source programming which is supported by application programming interface. The modules available for the integration or categorized in zigbee, GPRS module which is having a quad band which has got also a GPS module which is having a sensor module which we called a sensor boards and off course it contains a storage module within SD memory card.



(Refer Slide Time: 25:28)



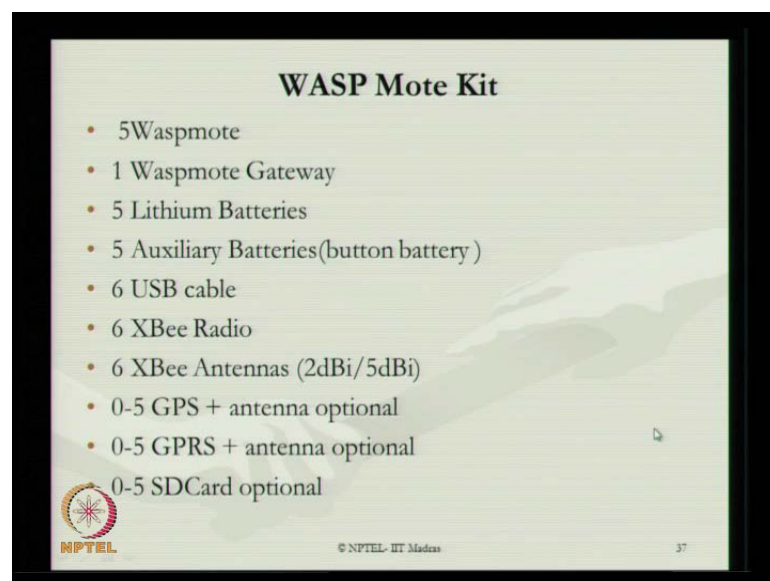
The slide titled "Wasp mote Specifications" lists the following details:

Microcontroller :	ATmega1281
Frequency	:8MHz
SRAM	: 8KB
EEPROM	:4KB
FLASH	:128KB
SD Card	:2GB
Weight	: 20gm
Dimensions	: 73.5x51x13mm
Temperature Range	:-20°C,+65°

The slide also features the NPTEL logo in the bottom left corner, the copyright notice "© NPTEL- IIT Madras" at the bottom center, and the slide number "36" in the bottom right corner.

Therefore, in summary the waspmote specification has a microcontroller which is AT mega 1281, it operates frequency of 8 mega hertz; the S ram about 8 kilo bytes whereas, EEPROM is about four kilo bytes. The flash memory about 128 KB and SD card about 2 GB. And the above all its weight only 20 grams and the dimensions are only about 73 by 51 by 13 millimeter it can sustains a temperature range from minus 20 to plus 65 degree Celsius.

(Refer Slide Time: 26:08)



The slide titled "WASP Mote Kit" lists the following components:

- 5Waspote
- 1 Waspote Gateway
- 5 Lithium Batteries
- 5 Auxiliary Batteries(button battery)
- 6 USB cable
- 6 XBee Radio
- 6 XBee Antennas (2dBi/5dBi)
- 0-5 GPS + antenna optional
- 0-5 GPRS + antenna optional
- 0-5 SDCard optional

The slide also features the NPTEL logo in the bottom left corner, the copyright notice "© NPTEL- IIT Madras" at the bottom center, and the slide number "37" in the bottom right corner.



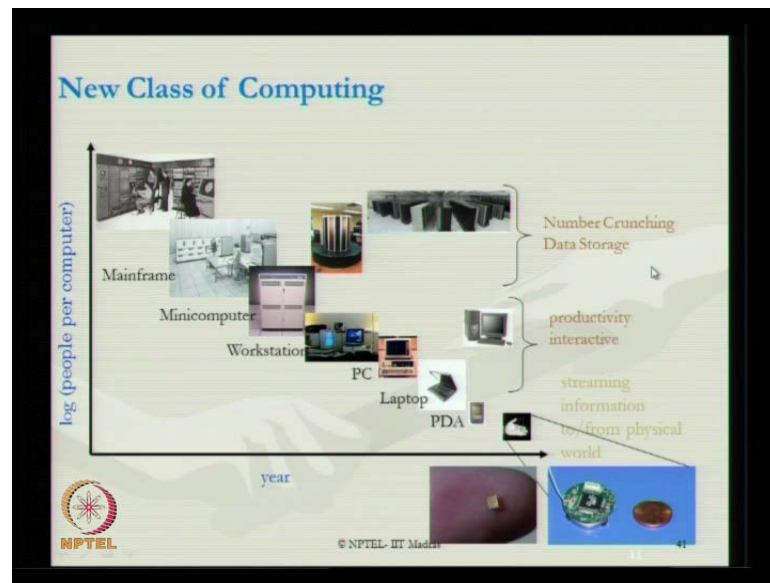
If we look at the meshlium specification which are adopted for WSN networking the processor consists of 500 mega hertz, and the power is essentially with watts the storage about varying from 8 GB to 32 GB the ram is about 256 MB. The power consumption varies from 270 to 450 milliamps. The maximum power current is required only 1.5 amperes; it can sustain a temperature range from minus 20 and plus 50 degree Celsius. It comes in a enclosure which is called specified as IP 67. It takes only 60 seconds to respond pinging over the Ethernet. The service start time is about ninety seconds. The whole Meshlium box weighs about 1.2 KG for the dimension of 200 and 10 by 175 by 50 millimeters. It is also have Wi-Fi enableity with Bluetooth and off course with GPRS configuration as shown in this slide.

(Refer Slide Time: 27:57)



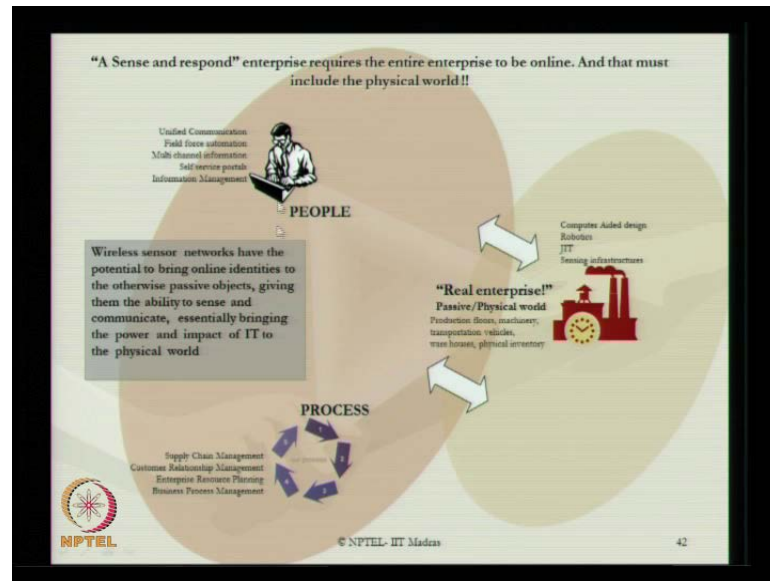
Now when you talk about open source programming, the configuration software which meshlium advises, if meshlium includes a management software on its own to configure all required parameters through interesting graphics user interface. All communication interfaces like Wi-Fi, ZigBee, GPRS, Bluetooth etcetera shall be used to manage the storage of data once they are received. The operating system generally preferable is Linux and the configuration software is an open ware a typical front end GUI is what you see here which has been advised by libelium as such.

(Refer Slide Time: 28:39)



Now let us look at the new class of computing. Once they receive the data from the network how do we analyze the data. If we look at people per computer what I called logging in configuration varying from US, it move from mainframe to now many computer to work stations to PCS and now to the laptop. And now we also something called PDA. So, the class of computing they started varying from the main frames to laptop and PDA's. Therefore, the chip order system architecture should be minimum possible as well as light as possible, which is sufficient enough to hold it in one form as you see in this photograph here. So, the interesting feature is I have a microchip which is very simple which can be hold in a thump of a human being. So, now, it is having a capability of recording data 24 into 7 continuously which can integrate minimum 5 waspmote configurations with meshlium linking. So, it is interactively productivity, the streaming information are all added advantages of new class of computing which required in the modern era.

(Refer Slide Time: 30:06)



Now let us look at interestingly a sense and respond enterprise that requires entire enterprise to be online, because I want the whole platform remain online, when I want assess health of the platform. So, let us say there are three elements, for example, the people, the process and off course the real physical world. A typical enterprise can be defined us the combination of these three the people, the process and off course what we defining of the real enterprise, which is the physical infrastructure that is core to what the business does. The unified communication, field force automation, multichannel information, self-service portals and information management are all related to the people. Whereas talk about process they have supply chain management, customer relationship, enterprise resource planning, and business process planning which all come as the process. There are all integrated together to the computer aided design robotics and sensing information and infrastructure what I say as real physical world. For these can be connected using wireless sensor networking that is very important that is the focus what we want to do the in the near future.

(Refer Slide Time: 31:28)

**Motes**

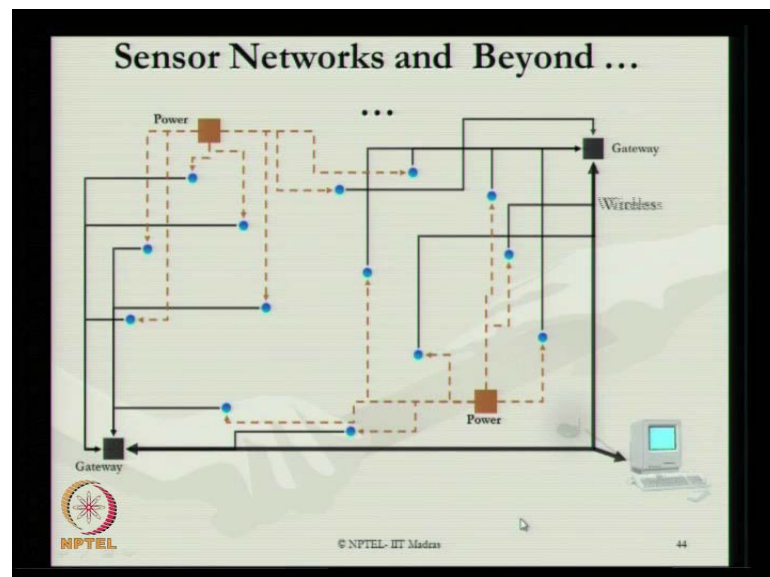
Diagram illustrating the Motes system architecture, showing a Sensor board connected to a Mote via an S1-Pin Expansion Connector. The Mote contains a Logger/Filter, Processor, Analog I/O, Digital I/O, and an IEEE 154-SP Transceiver. The Mote is connected to an Antenna and a Wireless Gateway. The system also includes Wired gateways and Wireless gateways.

Processor/Radio Board	MIP4000CA	Remarks
Processor Performance		
Program Flash Memory	128K bytes	
Microcontroller Serial Flash	1536 bytes	> 100,000 measurements
Configuration EEPROM	4K bytes	
Serial Communications	USART	8,247 characters/second
Analog to Digital Converter	10-bit ADC	8 channels, 0.5V input
Other interfaces	Digital PDIIC/JTAG	
Current Draw	8 mA	Active mode
	< 15 µA	Sleep mode
RF Transceiver		
Frequency Band	2400 MHz to 2483.5 MHz	On-board, programmable in 1 MHz steps
Transmit RF data rate	250 kbps	
RF power	0.1 dBm to 0 dBm	
Receive Sensitivity	-90 dBm (FSK) - 94 dBm (FSK)	
Adjustable channel spacing	47 dB	+ 5 MHz channel spacing
	30 dB	- 5 MHz channel spacing
Outdoor Range	75 m to 100 m	1/2 wave dipole antenna, LOS
Indoor Range	20 m to 30 m	1/2 wave dipole antenna
Current Draw	18.7 mA	Active mode
	11 mA	TX, 10 dBm
	18 mA	TX, 0 dBm
	17.4 mA	TX, 0 dBm
	30 µA	RF mode, voltage regulator on
	7 µA	Sleep mode, voltage regulator off
Electromechanical		
Battery	2x AA batteries	Attached pack
External Power	2.7V - 3.3V	Micro connector provided
User Interface	3 LEDs	Red, green and yellow
Size (W)	2.28 x 3.28 x 0.28	Including battery pack
Size (H)	100 x 100 x 7	Including battery pack
Weight (net)	0.7	Including battery
Weight (gross)	1.0	Including battery
Expansion Connector	81 pins	All major I/O signals

© NPTEL- IIT Madras 43

Now look at the motes which are used for system architecture there are different modes which are seen in the picture, sensor boards motes and the wireless gateways and wired gateways which are all forming the group of system architecture which can be used the configuration and a specification of these motes are available in this table.

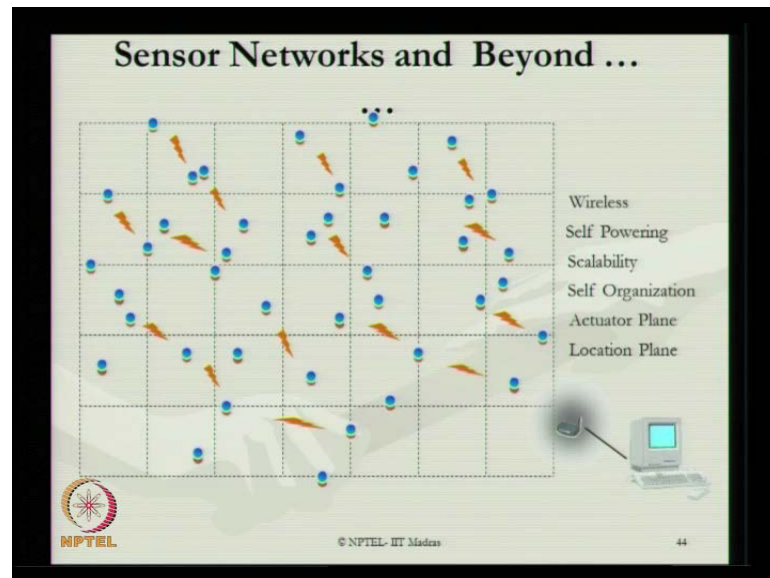
(Refer Slide Time: 31:53)



Now let us look at the sensor networking and an idea beyond this. Let say I want the power source at two locations, I got the gateway which is connecting one segment and

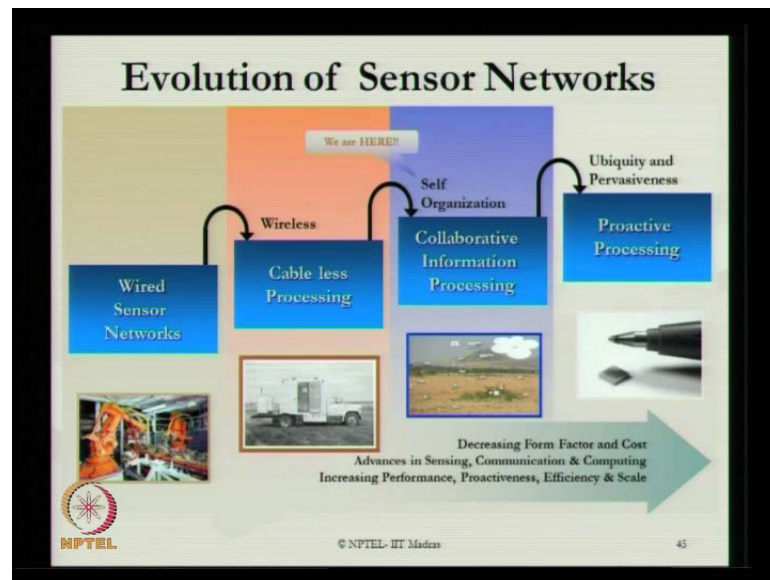
the other segment of the platform, which are connected ultimately for my central control console which can be a PC or it can be a system through internet.

(Refer Slide Time: 32:20)



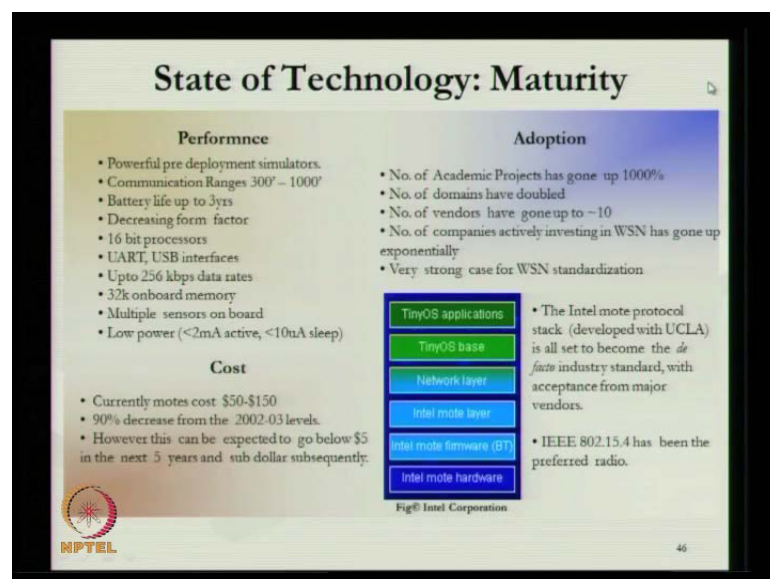
So, I can connect them using a wireless, remove all the wire connectivity and make a complete control console receiving the signal through the wireless configuration. I can make them self power, I can even remove batteries in these sensor units, and I can make them self power. Subsequently, I can improve the scalability, I can even make each sink subjected to different system architecture, where which they can receive signals from the adjacent units as well. I can also make them self organize, I can tune all of them, so that they all communicate successively in a chain and then they can be connected through a wasp mote network to my central control console what I call as self organization. I can also have an actuator plane; I can control them completely from a specific station which is connected using an wireless sensor networking. I can talk of the location plane where employee this central control console and do the control of all these data at one point of the time.

(Refer Slide Time: 33:30)



If you look at the evaluation of evolution of sensor networks, it is started with wired sensor network then people started using cable less processing what we called wireless. Then people are no moving to collaborative information processing which we called self-organization. Now in the present scenario, we are here whereas we should having an ability to make them proactive processing which the future networking of wireless sensor networking as applied to marine offshore structure .

(Refer Slide Time: 34:03)





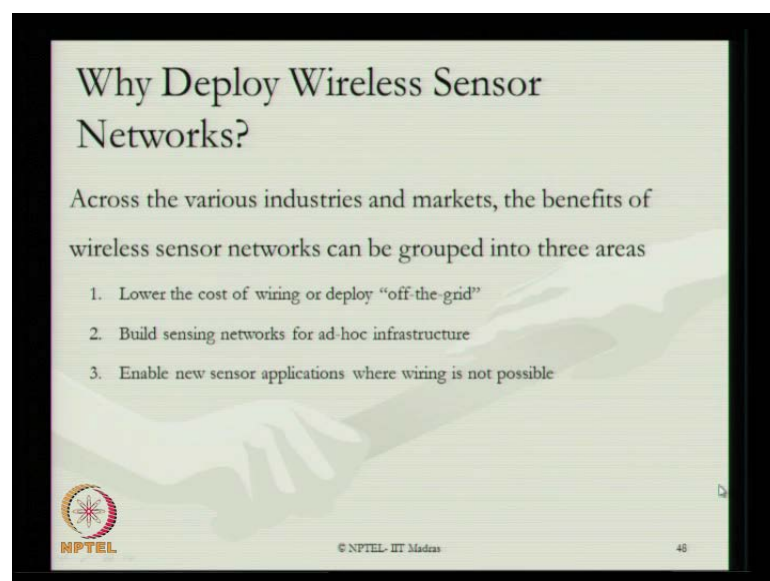
If we look at maturity state of our technology, look at the performance the cost and the adoption of these, they are not expensive in the initial stage and of course, a long run the benefit is very high.

(Refer Slide Time: 34:19)



They have been applied in different locations starting from buildings, mobile asset management, medical networking, security systems, offshore structure and industrial monitoring, environmental monitoring research in educational institutions as well.

(Refer Slide Time: 34:33)



Now the fundamental question comes why to deploy wireless sensor network after understanding so many advantages. Across the various industries and markets the benefit of WSN are grouped in three areas. Lower the cost of wiring or deploy off-the-grid; build sensing networks and ad-hoc-infrastructure; enable new sensor application where wiring is not possible that's very important.

(Refer Slide Time: 35:02)

The slide is titled "Benefits/Motivation" and lists the following points under "Lower cost of wiring":

- Retrofit of existing systems
- No power or IT infrastructure
- Intrinsically safe apps

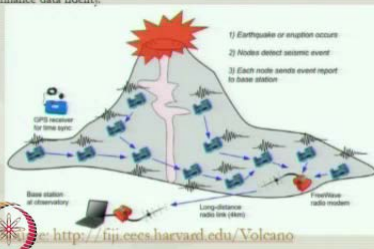
The slide includes two images: one of an industrial facility with large machinery and another of an offshore pipeline in a snowy, mountainous landscape. The NPTEL logo is in the bottom left, and the text "© NPTEL IIT Madras" and the number "49" are in the bottom right.

There are high benefits and motivation. Low cost of wiring because it can retrofit of existing system; no power or IT infrastructure; intrinsically safe application as you see in offshore pipelines is has been deploy the recent times.

(Refer Slide Time: 35:19)

### Harvard Volcano Monitoring Project



Deployed three wireless sensor networks on active volcanoes:  
Tungurahua volcano, Ecuador, in July 2004 served as a proof of concept and consisted of a small array of wireless nodes capturing continuous infrasound data.  
Reventador volcano, Ecuador, in July/August 2005 consisted of 16 nodes deployed over a 3 km aperture on the upper flanks of the volcano, and measured both seismic and infrasonic signals with high resolution (24 bits per channel at 100 Hz).  
Third deployment at Tungurahua in August 2007 tested the [Lance] utility-driven data collection system that we developed to enhance data fidelity.



1) Earthquake or eruption occurs  
2) Nodes detect seismic event  
3) Each node sends event report to base station

GPS receiver for time sync  
Base station or observatory  
Long-distance radio link (GPRS)  
Firehouse with nodes

<http://fiji.cecs.harvard.edu/Volcano>



Microphone cable  
Custom ASIC board  
Micro SD  
Seismometer cable  
Cell jammer  
Power cable

NPTEL © NPTEL- IIT Madras 50

I can give some interesting case examples where Harvard volcano monitoring project is done, deploying three-sensor network on active volcanoes. The Ecuador in July 2004 served as proof of concept and consisted of a small array of wireless nodes as you see in this picture and this is the system architecture which has been deployed in this specific example.

(Refer Slide Time: 35:46)

### Amrita University: Landslide Monitoring Project

Deployment Site, Anthoniar Colony, Munnar, Idukki, Kerala, India

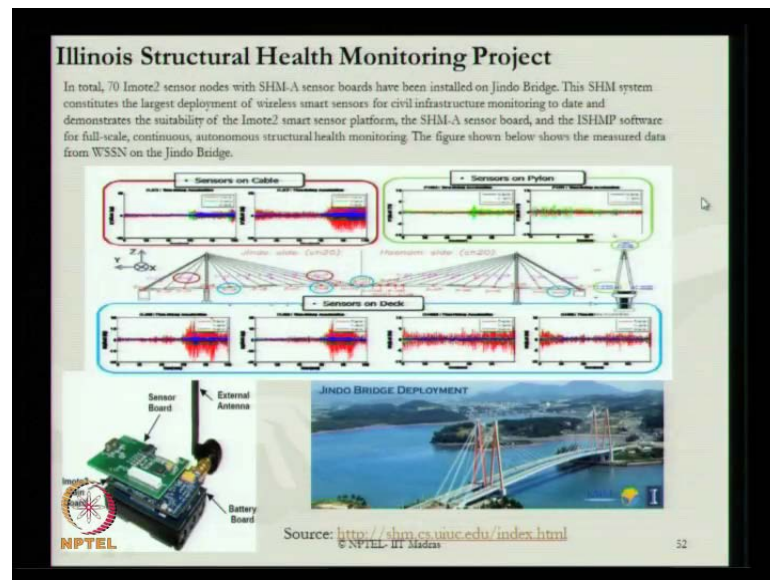


Source: [http://wmsoc.org/researchhighlights\\_reh\\_4.html](http://wmsoc.org/researchhighlights_reh_4.html)

NPTEL © NPTEL- IIT Madras 51

In Amrita university, the landslide-monitoring project is also carried out in Kerala using wireless sensor networking. You can see the source information as you see from here.

(Refer Slide Time: 35:58)



Illinois structural health monitoring project is also used this for developing health monitoring of Jindo bridge using structural health monitoring system. You can see on the left, a typical gateway which is housing a sensor board, external antenna, battery and Imote2, the main board is can be used for monitoring the Jindo bridge deployment in Illinois. The source is given in the website as you see in the bottom of the slide.

(Refer Slide Time: 36:31)



There are various benefit and motivation, which can be done. The new application where sensors have not been used or mobile equipments rapidly changing environment, they

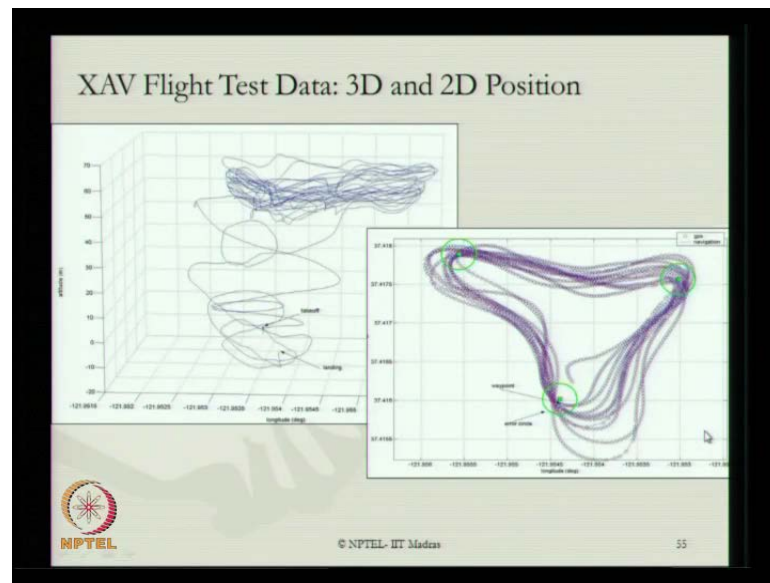
have been used underwater and power sensors and atmospheric monitoring, where wireless sensor networking has not been used intrinsic is a company in India located in Bangalore which works extensively on these kind of networking projects.

(Refer Slide Time: 36:57)



One can also use crossbow aerial vehicle, which is called XAV technique for really difficult location as you see in this picture. So, high gain Wi-Fi can receive from here, can communicate the ground station PC, one can use what we called RC transmitters are instated of that I can use what we called simply a crossbow aerial vehicle which can collect the data using any of advanced technique as you see in this picture here.

(Refer Slide Time: 37:27)



A typical flight data available for flight test data done on 3D and 2D positioning using an XAV flight is shown in this picture here.

(Refer Slide Time: 37:38)

### Application Domains

- Military applications
  - Tracking friendly forces, equipment and ammunition
  - Battlefield surveillance and intrusion detection
  - Reconnaissance activities
  - Battle damage assessment
  - Nuclear, biological and chemical attack detection and reconnaissance
  - Blind beam forming
- Environmental applications
  - Forest fire detection
  - Bio complexity mapping of the environment
  - Contaminant Transport
  - Weather monitoring
  - Precision agriculture
  - Seismic pattern studies
  - Galactic movements
  - Greenhouse Control Systems
- Health applications
  - Tracking and monitoring patients and doctors inside a hospital
  - Drug administration in hospitals
- Home applications
  - Home automation and smart environments
  - Structural Condition Assessment
- Projects in the Academia
  - P-wave monitoring
  - Smart Dust
- Other commercial applications
  - Environmental control in office buildings
  - Interactive museums
  - Managing inventory control
  - Supply Chain Management
  - Vehicle tracking and detection
  - Detecting and monitoring car thefts

The NPTEL logo is in the bottom left, and the text '© NPTEL- IIT Madras' and '56' are in the bottom right.

It got different application domains in military application, in environmental application, in health application, home application project in the academia and other commercial applications, we can use this methodology of wireless sensor networking in a larger interest.

(Refer Slide Time: 37:56)

### Other Significant Deployments

#### Contaminant Transport Monitoring

- Sited in greenhouse
- Applications
  - Measure soil & crop yields
  - Measure for stress, nutrient levels
  - One application for soil moisture & nutrient
  - Measuring water, soil, and air systems
- Field study of water uptake by transpiring plants in field

#### Wireless Systems for Environmental Monitoring

Creates a MICA family of wireless sensor networking hardware, software, and sensors as a popular solution for environmental monitoring. This article describes how MICA-based wireless sensor networks are configured and deployed for long-term field operation. Creates environmental sensor nodes are easy to deploy, self-manage, and report over a wireless and graphical software package. Software for these applications is made available from Crossbar's website and TinyOS distribution. All of the software components described in this application are now freely available for use with our sensors.

#### Feature Wise Mics in Controlled Environment Agriculture

Enables Wireless Mics in Agriculture. The MICA sensor network is used to monitor and control the growth of growing through sensors and reports using Controlled Environment Agriculture (CEA) techniques. The project was specifically designed to monitor the performance of a grower for water, lighting, air quality, and humidity for reducing plant stress and promoting growth. The project was designed to monitor the performance of a grower for water, lighting, air quality, and humidity for reducing plant stress and promoting growth. The project was designed to monitor the performance of a grower for water, lighting, air quality, and humidity for reducing plant stress and promoting growth.

#### Marine Micro-organism Monitoring

- Algal bloom (red, brown, green) impact
- Human life
- Fisheries (fisheries and tourism)
- Causes poorly understood, monthly fatalities
- Measurement of these phenomena can be complex and time consuming
- Sensor networks can help
- Monitor predict, mitigate

#### Industrial Security Using Wireless Mics Technology

Industrial security is a major and growing application for MICA. Creates a MICA family of wireless sensor networking. Utilizing a number of different potential sensor modalities. Shows an overview of security applications using these sensors. Shows an overview of security applications using these sensors. Shows an overview of security applications using these sensors. Shows an overview of security applications using these sensors.

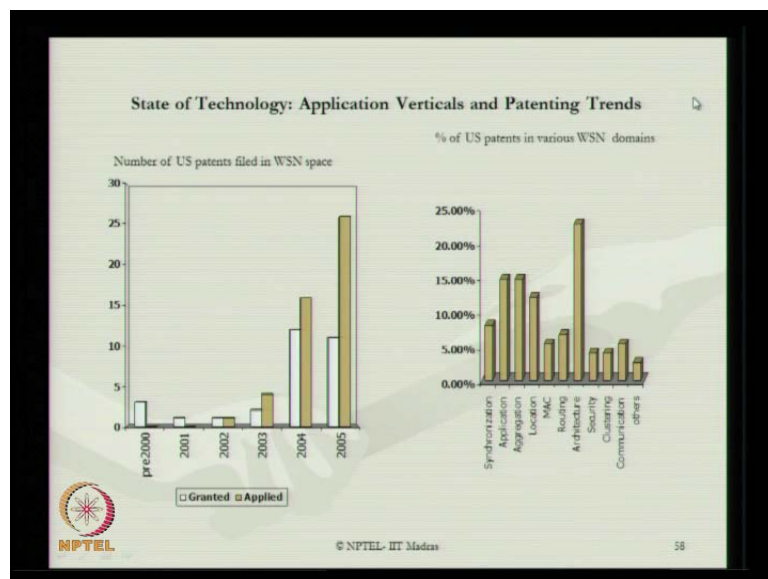
#### Asset Protection

- Real time response
- Varying escalation levels
- No IT infrastructure
- Mobile or temporary
- False alarms are costly
- RISK
- Easy to Deploy Simple

57

There are other significant deployments as seen in this picture here. It can be used for marine microorganism monitoring, can be used for industrial security, can be used for asset protection, can be used for controlled environment agriculture, can be also used for environmental monitoring, which is a very important task for in offshore structure and marine and coastal production system.

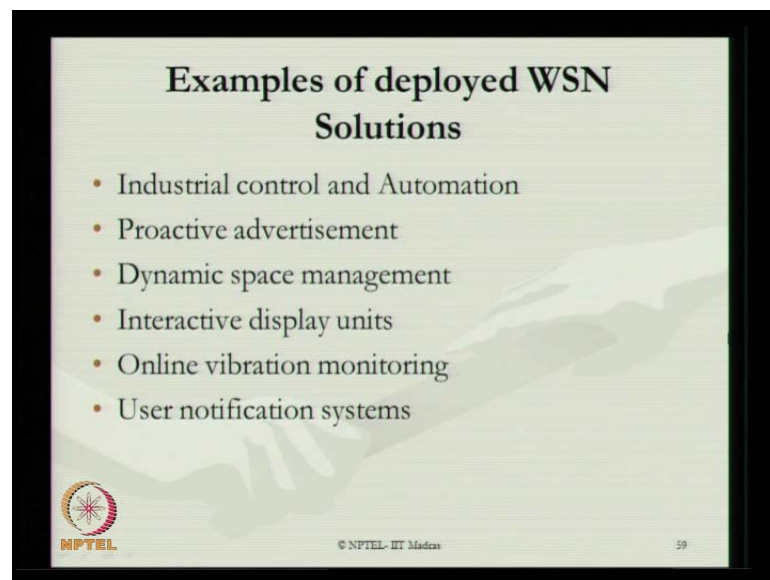
(Refer Slide Time: 38:19)



If we look at state of the technology in terms of patenting and research in US, the number of US patents filed in wireless sensor networking space is on the increasing

side. Whereas if you look at percent US patents in various wireless sensor-networking domain, you can see different segment in application, location, map, routing you see the maximum is done on our system architecture developed for WSN is closely about 25 percent.

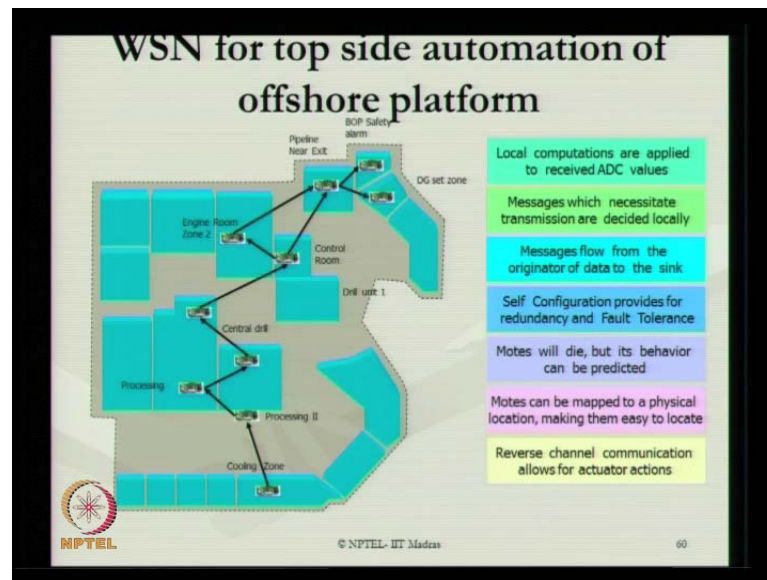
(Refer Slide Time: 38:52)



There are different examples where WSN is deployed for creating intelligent solution- Industrial control and automation, proactive advertisements, dynamic space management, interactive display units, online vibration monitoring and user notification systems.

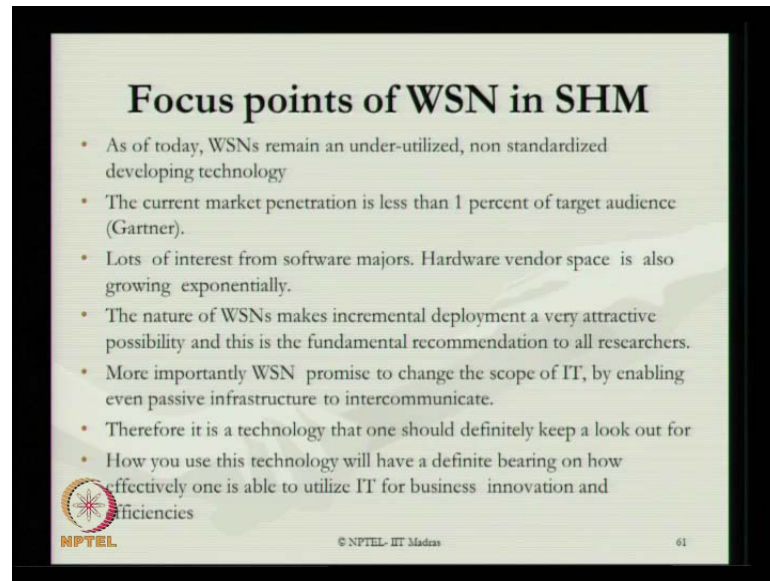


(Refer Slide Time: 39:10)



WSN for top side automation of offshore platform is a suggested model as you see in this picture here. I have got the BOP safety alarm here, pipeline near exit, DG set zone is what is marked here. The engine room zones here, the control room and the drilling units- the central drill unit here and the processing unit one and two and the cooling zone present here on the top side environment. Now local computation are applied to received the ADC value from different segments; once the pipeline engine room drill units and cooling zones are connected. Now by using WSN, the self-configuration provides for redundancy and fault tolerance is can improve safety. The motes will die; however, its behavior is off course can be predicted. The motes can be mapped to a physical location making them easy to locate where the actual failure is occurred. Once this can be done then reverse channel communication is possible, so that we can control the BOP safety alarm, and the control unit and the drilling segments from your cooling zones or from the central control station. Therefore, the operability and the safety can widely increase by applying WSN for top side automation than offshore platform.

(Refer Slide Time: 40:31)



**Focus points of WSN in SHM**

- As of today, WSNs remain an under-utilized, non standardized developing technology
- The current market penetration is less than 1 percent of target audience (Gartner).
- Lots of interest from software majors. Hardware vendor space is also growing exponentially.
- The nature of WSNs makes incremental deployment a very attractive possibility and this is the fundamental recommendation to all researchers.
- More importantly WSN promise to change the scope of IT, by enabling even passive infrastructure to intercommunicate.
- Therefore it is a technology that one should definitely keep a look out for
- How you use this technology will have a definite bearing on how effectively one is able to utilize IT for business innovation and efficiencies

NPTEL © NPTEL- IIT Madras 61

If you look at the focus points of WSN in SHM, as on today WSN remain as under utilized non- standardized developing technology. The current market penetration less than one percent; lots of interest are available for software majors hardware vendor space is also growing exponentially. The nature of WSNs makes incremental deployment a very attractive possibility and this is the fundamental recommendation to all researchers through this lecture. More importantly WSN promises to change the scope of IT, by enabling even passive infrastructure to intercommunicate. Therefore, it is a technology that one should definitely keep a look out for. How you use this technology will have a definite bearing on how effectively one is able utilized IT for business innovation and efficiencies. Thank you very much. So, this lecture has given you interestingly a broad idea of using wireless sensor networking as applicable to general construction industry and specifically to offshore industry as well.

Thank you.