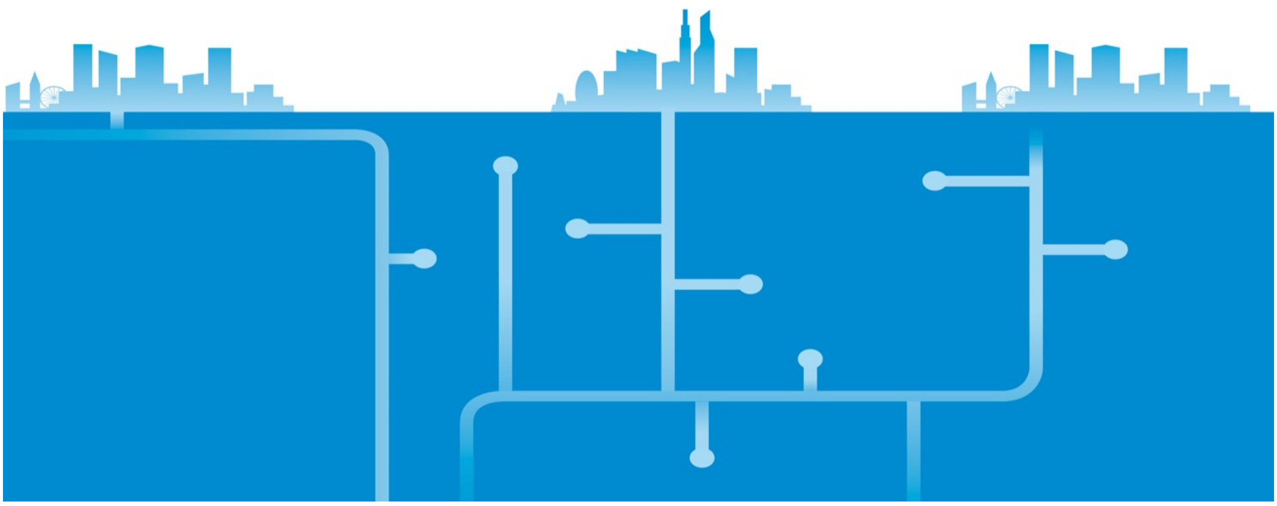
ITU-WMO-UNESCO IOC
Joint Task Force

Functional requirements of
“green” submarine cable systems

Joint Task Force to investigate the potential of using submarine telecommunication cables for ocean and climate monitoring and disaster warning



Functional requirements of “green” submarine cable systems

Summary

The purpose of these functional requirements is to identify the capabilities and features of fiber optic submarine cable systems equipped with sensors to measure temperature, absolute pressure, and three axis acceleration at regular intervals along the entire length of the cables.

Forward

Three UN specialized agencies **(International Telecommunication Union (ITU), World Meteorological Organization (WMO) and Intergovernmental Oceanographic Commission (IOC) of UNESCO)** have jointly proposed the development of mini-observatories on trans-ocean submarine cables to measure key ocean seafloor observables, with the concept and applications being developed further through a **Joint Task Force (JTF)**. The latter was established in 2012 with a wide membership including scientists, engineers, cable owners and operators, regulators and legal experts.

The JTF initiative addresses two main needs: **a) increased reliability and integrity of the global tsunami warning network, and b) sustained climate-quality data from the sparsely observed deep oceans**. Deployment of seismic and pressure sensors is directed at the first of these. Pressure and temperature measurements support the second need. The extent and impact of damage from tsunamis and earthquakes is a major societal issue for coastal communities throughout the world. Ocean temperature is a critical variable, particularly regarding climate change, sea level rise and ecosystem stress. These aspects of the health and status of marine environments could be monitored globally in real-time through a new generation of ocean mini-observatories hosted on telecommunication cables. Measurements provided by these systems will increase our understanding of the planet and its ecosystems on decadal time scales, hence the term “green” submarine cable systems.

The requirements presented here are developed in conjunction with the scientific community and represent a realistic appraisal of end user needs. Commercial, legal, and public outreach efforts are to be addressed in the appropriate forums and are not considered here.

Notes included in brackets are intended to aid in the review and discussion of this document. It is expected they will be removed from the final version of this specification. Additional working papers may be developed around specific topics to provide a more thorough interpretation of these requirements.

Purpose

The objectives of this functional requirements document are to:

- Provide baseline requirements that will facilitate continued discussion and iteration of requirements for ocean observations utilizing optical fiber submarine telecommunications cables
- Provide a discussion paper to promote standardization
- Maintain contact between interested parties

- Encourage system suppliers, i.e. those who directly design, develop, and manufacture fully integrated submarine cable systems or critical components of submarine cable systems, to allocate modest resources to early development stages
- Allow system suppliers to consider suitability of existing product lines
- Encourage the science community to develop a consensus regarding sensor requirements within practical limits
- Establish realistic goals
- Establish credibility needed to solicit more substantial resources from governments, NGOs, and industry
- Permit further investigation of suitable sensor technologies, power feeding arrangements and communications methods
- Permit system owners, including telecommunications carriers, consortia, and governments, to understand the functional and operational objectives of green systems
- Permit system suppliers to begin to consider how such sensors could be deployed and supported on their cable systems
- Generate a working document that can be revised as requirements develop with feedback from industry, telecommunications companies, national governments, regulating agencies and scientists
- Provide a baseline specification for a trial or demonstration system

Intellectual Property Rights

ITU draws attention to the possibility that the practice or implementation of these functional requirements may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the functional requirements development process.

Contents

1 Scope

These functional requirements apply to optical fiber submarine cable systems equipped with a temperature sensor, absolute pressure gauge (APG) and three-axis accelerometer. The purpose of these requirements is to identify the minimum capabilities of such systems to ensure that collected data is robust, valid, and scientifically useful. These functional requirements specify functionality and not the method of attaining such functionality. The method of providing this functionality is left to the system suppliers, whose development and prototyping capabilities are best equipped to implement innovative solutions. In particular, in the event a system is specified to be supplied with sensors, the system suppliers will offer power and communications systems for the sensors that best suit each supplier's specific technology.

2 Standardization

The objective of standardization is to provide the same quality of data regardless of supplier. End users expect consistent, traceable and defensible data. Standardizing the instrument performance and possibly the data formats is intended to achieve this result. Implementation details such as the size of the mechanical housing, circuit board operation, power delivery and control and communications protocol must be designed such that they have no impact on the quality of the data gathered and no effort is made to standardize these at this time. Should it prove, following assessment, that implementation details have an impact on the quality of the data, it may be necessary to standardize further aspects of the system.

3 References

The following ITU-T Recommendations contain definitions and background information that apply to these requirements.

ITU-T G.971 Recommendation ITU-T G.971 (07/2010), General features of optical fiber submarine cable systems.

ITU-T G.972 Recommendation ITU-T G.972 (09/2011), Definition of terms relevant to optical fiber submarine cable systems.

4 Definitions

4.1 Terms defined elsewhere

These requirements use the terms defined in ITU-T G.972.

4.2 Additional terms

client: The user of the science subsystem or a data processing system belonging to the user. For clarity, the Client lies outside the scope of the submarine cable system. (Note: client is used here in the context of "client-server" systems and not in the context of an organization or entity which is accessing the data.)

green system: A fiber optic submarine cable system equipped with sensors to measure temperature, pressure, and three axis motion at regular intervals along the entire length of the cable.

science subsystem: Those components of the optical fiber submarine cable system, including both submerged plant and terminal equipment, whose sole purpose is the collection of scientific data.

sensors: Elements of the science subsystem that measure physical properties of the environment.

system owner: The owner of the telecommunications system to which sensors are to be added, or more generally, owners of submarine telecommunications systems.

system supplier: The designer and manufacturer of the telecommunications system to which sensors are to be added, or more generally, the submarine telecommunications system supply industry. Note that submarine telecommunications systems are generally built under EPC (engineer, procure, construct) type contracts.

5 Acronyms and abbreviations

This document uses the following abbreviations and acronyms:

APG	Absolute Pressure Gauge
ASCII	American Standard Code for Information Exchange
CMIP	Common Management Information Protocol
CORBA	Common Object Request Broker Architecture
FITS	Failures in Time (1E9 hours)
IOC	Intergovernmental Oceanographic Commission
IP	Internet Protocol
ITU	International Telecommunications Union
ITU-T	International Telecommunications Union Telecommunications Standardization Sector
JTF	Joint Task Force
MAC	Media Access Control
NGO	Non-Governmental Organization
NTTS	Nominal Transient Tensile Strength
OADM	Optical Add Drop Multiplex
QA	Quality Assurance
ROADM	Reconfigurable Optical Add Drop Multiplex
SNMP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
UNESCO	United Nations Educational, Scientific and Cultural Organization
UTC	Universal Time Coordinates
UTS	Ultimate Tensile Strength
WMO	World Meteorological Organization
XML	Extensible Markup Language

6 Conventions

Use of the words “shall” or “must” indicates a mandatory requirement.

Use of the word “should” indicates an optional requirement that is desirable.

Use of the word “may” indicates an option or method to be used at the suppliers’ discretion.

Use of the word “will” indicates a requirement that is assumed to be fulfilled outside the scope of these functional requirements.

Note that some sections include both a mandatory minimum requirement indicated with “shall” and a more stringent requirement indicated with the word “should.” In this case, the higher level of performance is advantageous, but not absolutely required.

7 Representative system

For the purposes of discussion and estimation of engineering parameters, it is useful to define a representative system. The representative system consists of:

- A system in the predesign or early design stage
- 5,000km cable
- 100 sensor locations or one set of sensors per repeater, whichever is less
- 2 terminal stations

These functional requirements are developed based on a standard system. It is anticipated that they will apply without modification to shorter systems, and to most longer systems. These functional requirements may require modifications such as an increase sensor spacing or longer polling times to accommodate some very long systems. Generally, these requirements shall apply to optical fiber submarine cable systems irrespective of actual length.

The maximum operating depth is assumed to be 8,000m which is the typical maximum operating depth of submarine telecommunications repeaters. This limitation would preclude installation of sensors in some deep ocean trenches. Where submarine systems have to cross these trenches, they are normally designed to avoid placing repeaters in the trench. Should one or more technical solutions proposed by the system suppliers to support sensors not include proximity of the sensors to the repeaters, it may be possible to increase the maximum operating depth of the sensor package.

These requirements consider only new build commercial optical fiber submarine cable systems.

These requirements do not preclude the use of branches, spurs, fixed OADM or ROADM. To the extent feasible, branch cables should be equipped with sensors spaced at regular intervals along the cable.

[Note: it is assumed the sensors will either be integrated into each repeater body or hosted adjacent to each repeater body. Alternative approaches to the support of sensors, such as incorporating sensor housings separate from the repeaters have been proposed by some system suppliers, and are not precluded by these requirements. As stated above, the technology for support for sensors, including implementation details, power and communications, is left to the system suppliers. It is likely that system suppliers will propose use of existing industry standard components, such as Universal Joints and repeaters. Development of a sensor package that

could be integrated into <u>any</u> cable system, independent of the system supplier, would also be of interest.

An essential aspect of green systems is for sensors to be placed at regular intervals across an ocean body. Sensors must be incorporated at many points along the cable, at least once per repeater section. This requirement differentiates green systems from shared use systems that may support multiple applications including science nodes, offshore platforms, buoys, and shore station – shore station communications. Shared use systems use a telecommunications system as a platform for "regional" instrument arrays. Shared use systems will typically have less than twelve science nodes and will support much higher power and bandwidth to those nodes than are needed for a green system. Generally, sensor nodes for shared use systems will more closely resemble the nodes on regional cabled observatories such as NEPTUNE Canada and the Regional Scale Network of the Ocean Observing Initiative than the instrument sets supported by green systems.]

8 Sensor performance

8.1 General

Sensor performance requirements shall be met after taking into account:

- variations arising from the measurement circuitry
- the aging of any measurement circuit components
- realistic positioning accuracy
- realistic orientation variation
- environmental variations, including depth, ambient temperature, and seabed conditions.

8.2 Temperature sensor

Temperature sensors shall have the performance parameters given in Table 1:

Table 1: Temperature Sensor Parameters

Range:	-5.0 to +35ºC
Initial accuracy:	±0.001ºC
Stability:	0.002ºC / year
Sampling rate:	0.1 Hz
Sample resolution:	24 bits

[Note: It is anticipated that the temperature sensor must be remote from any equipment that produces heat, including the repeater. The required separation distance is a matter for further study but is expected to be on the order of a few tens of meters.]

8.3 Absolute pressure gauge

Absolute pressure sensors shall have the performance parameters given in Table 2:

Table 2: Pressure Sensor Parameters

Range	0 to 73MPa (0 to 7,000m)
Overpressure tolerance	84MPa (8,000m)

Accuracy	±1mm relative to recent measurements 0.01% of full range absolute
Maximum allowable drift after a settling-in period	0.2 dbar / year
Accuracy after drift correction	
Hysteresis	≤ ±0.005% of full scale
Repeatability	≤ ±0.005% of full scale
Sampling rate:	20 Hz
Noise Floor	0.14 Pa^2/Hz
Sample resolution:	32 bits
Temperature sensor sampling rate:	20 Hz
Temperature sensor resolution:	24 bits

[Note: Pressure sensors are typically compensated for local temperature variations and therefore would not need to be located away from the repeater. However, as with the temperature sensor, this is a matter for further study.]

8.4 Accelerometer

Accelerometers shall have the performance parameters given in Table 3:

Table 3: Acceleration Sensor Parameters

Configuration:	3-Axis
Response	0.1 to 200Hz
Resonance frequency	>2,000Hz
Full scale range:	±1.5g where g is 9.806 m/s^2
Noise:	≤ 2ng / √Hz
Amplitude response	±1% across frequency range
Linearity	±1% of full scale
Cross-axis sensitivity	<1%
Sampling rate:	200Hz
Sample resolution	24 bit

The orientation of the 3-component system shall have one axis aligned in the direction of the cable itself (and consistently oriented for all sensors). For instance, for east-west cables, all sensors should have one axis pointing either toward the eastward or westward direction.

9 Features of a green cable

9.1 Power requirements

The science subsystem shall support a power load of 350mW to be allocated among the sensors. Table 4 provides a preliminary power allocation. This power load shall be available to the instruments and does not include any power conversion losses or power required to deliver data between instruments and shore stations.

The science subsystem shall provide additional power as required to support data sampling and communications functions.

Table 4: Sensor power use

Sensor	Power Consumption
Temperature (seawater)	275mW
Pressure	100mW
Temperature (pressure sensor)	Included in Pressure
Acceleration	70mW (<22mW per axis)

9.2 Clock synchronization

The science subsystem shall be capable of recording the UTC at which data is collected with an accuracy of ±100.µsec. For clarity, the time of interest is the time at which an event is detected by the sensor, not the time at which data reaches a data processing facility.

The science subsystem should be capable of recording the UTC at which data is collected with an accuracy of ±1µsec.

[Notes: The maximum propagation velocity of phenomena of interest is estimated to be 15m/ms (upper limit for P-waves). The positional uncertainty associated with the timing accuracy is therefore less than 1.5m. Other phenomena, including tsunamis in the deep ocean (<0.3m/ms), move more slowly. The geographic location of the sensor will have an uncertainty of tens of meters. This assumes that positional accuracy is the primary concern and that no other applications are intended.

If feasible, ±1µsec accuracy is the desired objective.]

It is anticipated that each supplier will develop a method of clock synchronization that best suits their system design. Depending on the design of the data transmission system, it may be possible to meet the ±100.µsec requirement within shore station equipment only. Where this is the case, care must be taken to ensure constant transmission delay from the sensors to the shore station equipment.]

9.3 Data transmission rates

The science subsystem shall support a sensor rate of 15.5Kb/s as shown in Table 5. Additional data, including network addresses or other identifiers, time stamps, error checking, packetization overhead and other overhead, must be included in a functional system. The additional data rate necessary will depend on the specific implementation. A minimum aggregate data rate of 30Kb/s per sensor location is suggested, although higher rates may be necessary.

Table 5: Raw Data Rates

Sensor	Sampling Rate	Sampling Resolution	Quantity per location	Bandwidth
Temperature (seawater)	0.1Hz	24 bit	1	<10b/s
Pressure	20Hz	32 bit	1	640b/s
Temperature (pressure sensor)	20Hz	24 bit	1	24b/s
Acceleration	200Hz	24 bit	3	14,400b/s

9.4 Data sampling rates

Data sampling rates shall be as indicated in Table 5.

[Note: The sampling rate is the frequency at which data are collected from the sensors. The polling rate is the frequency at which data are sent to the shore stations. Multiple samples may be sent in one data packet, thus the polling rate may be lower than the sampling rate.]

9.5 Latency

The science subsystem shall transmit data to the shore stations with no more than 100msec latency.

9.6 Communications

There are no specific requirements regarding the communications method employed by the system supplier to transfer data from the sensors to the shore station. While the lack of specific requirements makes integration of a standard sensor package across systems challenging, it is considered that, at this stage, the system suppliers should not be limited in the type of technology to be implemented.

Communications within the shore station and between the science subsystem and end users shall utilize industry standard technologies.

[Note: It is anticipated that each supplier will develop a communications method to be used on the submarine cable after taking into account the total number of sensors and anticipated bandwidth. Further specificity of communications protocol and methods is not desirable, due to the difference in system designs between the suppliers and the likely evolution of communications protocols over a ten to twenty year period.]

9.7 Performance

The presence of a science subsystem shall have no net impact on the telecommunications performance of an optical fiber submarine cable system. Any allocation to the system power budget as a result of the science subsystem shall be clearly identified and the system performance measured only after taking this into account.

[Note: This covers the general case in which the science subsystem has some impact on the performance budget. This may or may not be the case. If, for example, the science subsystem uses independent fibers or out-of-band wavelengths, then it may be unnecessary to make an allocation in the system performance budget.]

9.8 Availability

The addition of the science subsystem shall have negligible impact on the availability of telecommunications channels.

[Note: Availability is generally determined by the terminal station equipment. Interaction between the science subsystem and other terminal station equipment should be extremely limited, if it exists at all. A suggested limit would be no more than 0.0005% decrease in availability as a result of adding the science subsystem.]

9.9 Reliability

The probability of a failure which results in the inability to transfer data from more than one location in the representative system over ten years shall be less than 5%.

Failure of a data processor / communications module at a single sensor location shall not prevent communication with other sensor locations.

[Note: It is assumed here that the data processor / communications module is transferring data from locations further along the cable. Where this is the case, the failure of one communications module has limited impact because the system can continue to poll the remaining sensors by polling from both ends of the cable. However, if two modules fail, the sensors between the two failure points will be unreachable; this situation is undesirable and should be limited to a very low probability of occurrence. Therefore, the reliability of the data processor / communications module must be much greater than the sensor. If all sensors at a location fail, the data processor / communications module must still be capable of passing data from other locations.

Some system designs may choose a different approach, in which case the reliability of the data processor / communications module may be reduced accordingly.]

No more than 10% of sensors should fail or exceed their specified accuracy over a ten year period.

[Note: Individual sensors will be somewhat less reliable and some failures can be tolerated because of the large number of sensors deployed.]

9.10 Design life and expected ship repairs

The design life of the science subsystem shall be ten years or greater.

The addition of the science subsystem shall have no impact on the system design life.

The science subsystem shall be designed such that failures in the science subsystem do not impact the telecommunications system, or at a minimum only impact the telecommunications system in extremely unlikely circumstances.

Failures in the science subsystem shall not require intervention.

Users shall not be led to expect repairs to the science subsystem during the system life.

The science subsystem shall add no more than 1% expected ship repairs to the representative system over the system design life.

[Notes: "Expected ship repairs" is a statistical measure of the reliability of submarine cable systems which states the probability of a failure which requires replacement of any portion of the underwater plant to restore service over some period, usually the system design life or 25 years.

The science subsystem may or may not have the same design life as the overall system. For example, it may be acceptable for sensors to go out of calibration after ten years, perhaps on the assumption that another cable will have been placed on the same route before then. The system must continue to meet its communications performance requirements for its entire design life.

It is assumed that failed sensors or science subsystem components will not be repaired unless necessary to restore telecommunications functions (as opposed to science instrument communications functions). Thus, failure of any sensor, data processor, or communications module does not result in a ship repair.

The science subsystem must share the power feed path and as a result additional components will be introduced into the power feed path. Because failure of these components could disrupt power feeding, some impact on the expected ship repair number will be inevitable. The science subsystem may share other components within the repeater that may be less reliable as a result. The impact of these changes must be kept within limits acceptable to the system owner.

For clarity, it is expected that the allowed increase in ship repairs will be allocated entirely to the power supply components, because these are the only elements of the science subsystem that could impact operation of the telecommunications system.]

9.11 Environmental requirements

The science subsystem shall meet the same environmental requirements as the overall system both during transport and installation and during operation, including specifications for mechanical shock, thermal extremes, thermal shock, and electromagnetic interference.

Sensors shall be suitable for all expected seabed conditions. Sensors shall allow burial, self-burial, or surface laid placement of the submarine cable system.

Sensors shall operate over the temperature range from –5ºC to +35ºC.

[Notes: Environmental requirements vary slightly from system to system depending on location and other factors.

There can be no assurances regarding the impact of installation conditions on sensor performance. Burial depths can range from 0.3. to 4 meters, with 0.6 to 1.0 meters being typical; this may affect pressure and short term temperature measurements. Cables and repeaters in the deep ocean tend to self bury in soft sediments which may affect coupling of seismic and pressure waves to the sensors. Special operations to improve sensor performance should not be anticipated.]

9.12 Mechanical

Pressure housings shall be suitable for depths up to 8,000m (84 MPa), including a safety factor.

[Note : f could be set at 1.5 according to the rules on deep submergence vehicles in order to allow such submersibles to participate to cross calibration exercises.[1]

f could be set at 1.2, according to less conservative rules used in oceanography[2] *for metallic housings.]*

Pressure seals on submerged plant shall be designed to seal against Hydrogen migration for the design life of 25 years.

Pressure seals for sensors, and for cables to sensors, shall be compatible with the seals used by the submarine cable system, and be similarly qualified.

Submerged plant housing materials shall be corrosion resistant, or protected from corrosion. Materials shall be compatible, and not create corrosion in adjacent materials. Housing materials shall be uniform, and not subject to local corrosion such as crevice corrosion.

Material selection for sensors shall take into account the materials used in the adjacent repeater housing, and be compatible with them.

Sensors and related electronics shall be isolated from the housings. No grounding to the housing, even reference grounding, is permitted.

---

[1] ANSI/ASME PVHO 1 – Safety standards for pressure vessels for human occupancy.
[2] AFNOR ad hoc standardisation commission - « Milieu marin - Matériels immergés - Essais en environnement et recommandations » - AFNOR NF X 10-812 -February **2013** , http://www.boutique.afnor.org/norme/nf-x10-812/milieu-marin-materiels-immerges-essais-en-environnement-et-recommandations/article/807713/fa178382. ISSN 0335-3931.

The system design shall ensure that sensor measurements are not affected by the system itself. In particular, temperature sensor accuracy shall not be impacted by heat dissipation from the system.

[Note: In practice, this implies that a temperature rise due to heat dissipation must be less than 0.001ºC at the location of the temperature sensor. Thermal modeling may be needed to demonstrate this requirement is met. The feasibility of this requirement has not been studied.]

9.13 Deployment

The science subsystem shall be compatible with all conventional system installation methods including, but not limited to, cable transport, cable and repeater storage on vessels, linear cable engines, four meter sheaves, plough burial, ROV burial and jetting.

All submerged science subsystem components shall be designed to withstand the rigors of installation from the deck of a vessel in the type of weather that may be encountered in winter in the world's oceans.

All submerged science subsystem components shall be designed for deployment through cable engines, over capstan wheels and along cable ways, chutes and over stern ways. To meet this requirement the exterior of all submerged plant shall be clean of protrusions and extremely robust.

Each assembly shall be tested to significant impact and vibration, including a 40 × force of gravity impact test. Cable housing entries shall be protected by substantial cable bend restrictors that are designed to accommodate loads that exceed the cable breaking strength. The cable and repeaters are designed for the tension and snatch loads that occur during deployment of repeaters in bad weather.

Science subsystem components shall not degrade the tensile properties of the cable to less than 90% of its UTS.

Submerged science subsystem components shall withstand a shock of up to 40g without permanent damage.

All deployable science subsystem components shall be able to pass over a 3m diameter sheave when subject to a tension equal to the NTTS of the connected cable. [Note: This performance requirement is intentionally less than the diameter of sheaves typically encountered on working vessels to ensure the system can tolerate worst case conditions.]

Submerged science subsystem components shall work in any seabed conditions, including buried, either by plough or by natural sedimentation, in suspension off the seabed in areas where the seabed has more relief than anticipated, or, where the seabed is jagged, when laying across protrusions.

9.14 Geographic position and orientation

It shall be possible to determine, by cable lay calculation or other means, the geographic location of 95% of sensor sets to within ±100.m.

It shall be possible to determine, by cable lay calculation or other means, the heading of the cable for each sensor set to with ±0.5º.

The supplier shall demonstrate the accuracy of their method of determining location and heading through field trials and analysis.

[Notes: Factors affecting the positional accuracy of repeater locations include ship's position, water depth, cable slack, the cable's drag coefficient, and the effect of currents. These must be monitored during the cable laying operation and, through the use of appropriate models, used to determine each repeater's location on the seabed. Further measures, such as post-lay inspection or the use of acoustic beacons can increase this accuracy, but will impact the cost of system installation. An allowance is made for 5% of repeaters installed in areas of high current or difficult conditions having a greater tolerance.

It is assumed the repeater body containing the sensor set is aligned to the cable Route Position List and that the heading of the cable can be determined with reasonable accuracy.]

9.15 Recovery and repair

The science subsystem shall have no impact on the ability to recover and repair the submarine cable system.

[Notes: A variety of vessels and methods may be used to recover and repair the system over its lifetime. Since it is impossible to anticipate in advance what these might be, there must be absolutely no special requirements or considerations needed as a result of the science subsystem.

Added weight of science subsystem must be taken into account during system design to ensure changes to recovery conditions are within acceptable limits. The impact, if any, is expected to be small.

It must be assumed that any impact on the science system as a result of the repair operation will not be rectified. For example, repeaters may be re-laid in different positions or at different orientations with no attempt made to replicate the original installation conditions.]

9.16 System operation

The science subsystem shall have no impact on operation of the submarine cable system, including supervisory performance, element management or network management.

The science subsystem should require minimal intervention from cable station personnel.

[Note: Operation of the science subsystem is a topic that should be more fully addressed elsewhere. The science subsystem will include terminal station equipment that will need maintenance, repair, and possibly replacement over the operating life of the system.]

9.17 Fault isolation

The science subsystem shall be fault tolerant. The failure of a single sensor shall have no impact on the performance of other sensors. The failure of the science subsystem components at a single location shall not prevent data being gathered from other locations.

[Note: It should be possible to poll the sensors from both ends of the cable. If multiple sensor packages fail, then the sensor packages between the two failed units may be unreachable.]

The science subsystem should utilize a unique hardware address for each sensor.

[Note: this is to ensure data integrity and traceability.]

9.18 Quality assurance

Supplier shall be responsible or the Quality Assurance (QA) of the science subsystem.

Supplier shall operate an effective method of QA during the design, development, qualification, manufacture, installation and testing of the science subsystem.

10 Metadata

10.1 Time stamp

The science subsystem shall be capable of recording the UTC at which data is collected with an accuracy of ±100.µsec. For clarity, the time of interest is the time at which an event is detected by the sensor, not the time at which data reaches a data processing facility. However, depending upon the communications technology, it may be possible to time stamp the data at the shore station by allowing for the transmission time.

10.2 Geographic position and orientation

The science subsystem shall be capable of reporting the geographic location of any sensor, as determined during the cable lay, and an estimate of the accuracy of that location.

The science subsystem shall be capable of reporting the heading of the cable at each sensor set as determined during the cable lay. One sensor axis shall be aligned with this orientation.

[Notes: This information may be gathered at the time of installation and stored for future reference. The definition of science subsystem includes shore based data processing equipment which can be used to store this information and respond to queries. It is <u>not</u> intended that this information be gathered by or stored in the submerged plant.

The orientation of the other two axes will be determined through analysis of background noise detected by the accelerometers. This analysis will be performed by the client and lies outside the scope of the system.]

10.3 Calibration coefficients

The science subsystem shall be able to report the calibration coefficients of all sensors, as set prior to deployment or as calculated after deployment.

[Note: As above, it is assumed that calibration coefficients are collected and stored during manufacture and commissioning and simply need to be available for retrieval. It is not intended that these be adjusted or re-measured after installation.]

10.4 Sensor status

The science subsystem shall be able to report the current status of each sensor, e.g. normal operation, faulty, failed, off-line.

The science subsystem should be able to report values of interest regarding each sensor including, at a minimum, device model, serial number, manufacture date, installation date, and. calibration history. This information may be collected prior to or during installation and commissioning.

[Note: Again, this information must be collected and stored during manufacturing and be available for retrieval. It is not intended that this information be stored in the wet plant.]

10.5 Alarm management

The science subsystem shall be able to issue alarms generated in the shore station or data processing facility when a fault or failure is detected.

[Note: Shore based equipment should be used to detect anomalous responses from the wet plant.]

10.6 Performance management

The science subsystem should be capable of performing data integrity checks such as packet loss ratios and reporting this data.

10.7 Configuration management

The science subsystem should not require configuration management, but may include facilities to allow system extension, additional cable segments, etc. to be added in a straightforward manner.

11 Data presentation

The science subsystem shall provide an open and fully documented interface to the client for transfer of sensor data and metadata.

The science subsystem should make use of standard interfaces and protocols such as TCP/IP over Ethernet for the transfer of sensor data and metadata using one or more of the following methods which are listed in order of preference.

Data shall be reported in natural units, i.e. ºC for temperature, m/s^2 for acceleration, and Pa for pressure.

Raw data shall also be retained and reported. This includes counts from analog-to-digital converters and intermediate values such as frequency measurements from the pressure sensors.

The data format shall be as simple and universal as possible and compatible with future computer architectures and formats.

[Notes: It is not the intent to specify a single data exchange protocol for all green systems. Each supplier should furnish an interface that allows for rapid development of the necessary communications interface on the client. It is essential that such interfaces be well documented.

The supplier may provide adaptation in the terminal station equipment. If the supplier chooses to use a proprietary method of communication between the sensors and terminal station equipment, then this adaptation will be mandatory.

Other data exchange methods, including CORBA, CMIP, SNMP should be avoided unless a valid case can be made to justify the cost and complexity.]

Five methods are considered for transfer of data between the science subsystem and client. The science subsystem may provide one or more of these methods. Methods are listed in order from least to most desirable:

11.1 Data streaming

Data is streamed from each sensor without error checking and with no capability for retransmission. The client is responsible for capturing and storing all data, and data collection systems should be designed to be fully redundant such that a system failure is extremely unlikely. Data that is not captured by the data collection system is lost. Individual sensors must be identified by means of IP address and port, MAC address, or similar.

[Note: this method is undesirable due to the high potential for data loss and should not be implemented unless some limitation prevents the other methods from being utilized.]

11.2 Polling

The client sends a data request to each sensor. The sensor returns the most recent data collected. Error checking and retransmission may be provided. Sensors may store data for some time period, allowing data to be recovered if lost in transmission. If the sensor's storage period is exceeded, then data that was not collected is overwritten and lost. Individual sensors must be identified by means of IP address and port, MAC address, or similar.

11.3 Text file repository

The science subsystem gathers data (through streaming, polling, another method, or combinations thereof) and stores it as ASCII text files. The client may access this information by reading the text files. Metadata indicating the meaning of each element in the file shall also be provided.

11.4 Database query

The science system gathers data (through streaming, polling, another method, or combinations thereof) and stores it in an SQL database. The client may access this data by issuing queries to the database.

11.5 XML data exchange

The science system gathers data (through streaming, polling, another method, or combinations thereof) and stores it. The client may access this data through an XML data exchange protocol such as SOAP.

12 Annex: Implementation Aspects

[Note: Only those aspects that diverge from Recommendation ITU-T G.971.]

12.1 Sensor calibration

Sensors shall be calibrated to recognized standards in a manner that is traceable and repeatable prior to deployment.

Care must be taken to ensure sensor calibration is not invalidated during system assembly, transport, or installation.

12.2 Engineering data collection

Various engineering data, including but not limited to sensor pedigree, sensor calibration coefficients, and sensor geographic positions must be gathered and retained.

12.3 Science subsystem commissioning

Commissioning tests of the science subsystem shall be performed to ensure the science subsystem meets its performance requirements. This work may be performed in parallel or immediately after routine system commissioning.