A New Open Cabled Infrastructure in Medsea

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***Abstract*—Recently the ANTARES Neutrino telescope's Infrastructure in the deep Mediterranean Sea, has been extended by a Secondary Junction Box. The main emphasis has been to provide basic power and communications capability for new scientific cabled observatories. This new infrastructure provides unprecedented amounts of power and two-way bandwidth to access and control instrument networks in the oceans. This new development allows cabled observatory to connect the seafloor to the Internet via real-time, two-way high-speed communications. This design gives researchers new capabilities beyond the reach of traditional oceanography. Ocean scientists can run deep-water experiments from labs and universities anywhere around the world. Three different underwater observatories are already been connected at this Secondary Junction Box.**

This paper presents this new Infrastructure which has been deployed by the R/V Pourquoi Pas? and connected by the IFREMER's ROV VICTOR6000. After a technical description of the system, we detailled an overview of the complete deployment at sea.

I. INTRODUCTION

Traditionally, ocean scientists have relied on infrequent ship cruises or space-based satellites to carry out their research. Underwater cabled networks and the ocean observatories offer now a new and exciting approach to ocean science. Recently the ANTARES Neutrino telescope's Infrastructure in the deep Mediterranean Sea, has been extended by a Secondary Junction Box (BJS) (Fig.1). The main emphasis has been to provide basic power and communications capability at new scientific cabled observatories. IFREMER, in partnership with CNRS Centre de Physique des Particules de Marseille (CPPM), Geosciences Azur laboratory and l'INSU, also with the initial funding provided by the Provence Alpes Cote d'Azur (PACA) French region, has developed a Secondary Junction Box. The idea is to take the opportunity of the ANTARES site infrastructure to install this BJS, to provide additional connections for deep sea experimentations. This BJS has been connected in November 2010, by 2500m water depth, through a 400m electro-optical interlink at the main *Antares* junction box, which is located at 2500m deep in the Mediterranean Sea, 42 km offshore from Toulon (France). The shore station is installed in the control room at La Seyne sur mer (France) (Fig.2).

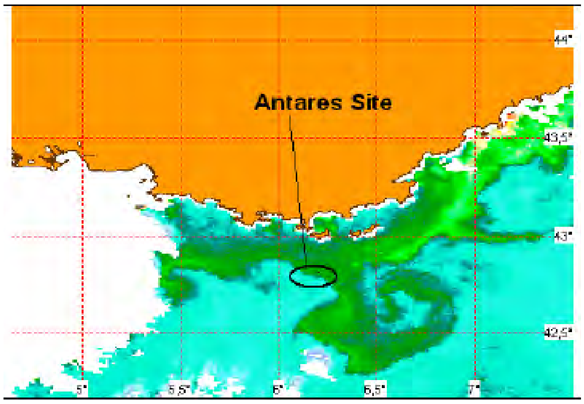


Figure 1. ANTARES Site location

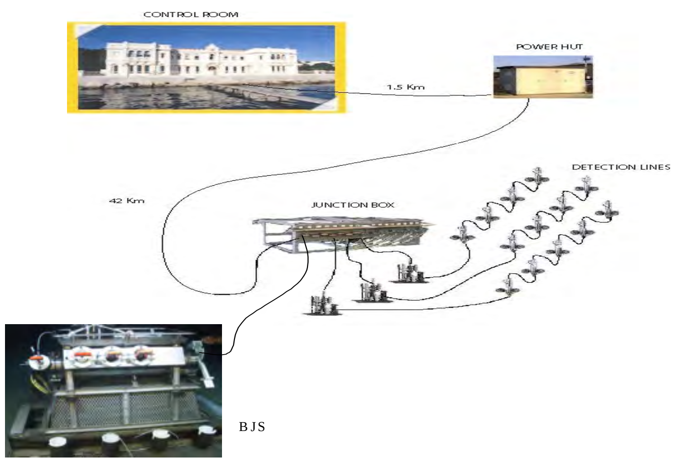


Figure 2. BJS and ANTARES Telescope overview

This new junction Box will focus on providing research and development services to two primary sectors:

- Underwater engineering research, including the development of innovative ocean technologies, such as: new concept of deep sea sensor network (project DEEPSEANET) built from fiber optic micro cable and battery operated IP access mode, new economic wet-mateable economic connector design, new high accuracy synchronisation system.
- Interdisciplinaries Marine sciences; it provides a facility for marine scientist to design and test unique instrumentation, particularly for application on cabled ocean observatories; this include experiments in the area of studies of active seismic regions, acoustics for cetacean monitoring.

II. BJS System overview

The submarine cable, which connects the ANTARES neutrino telescope to the shore, is a conventional telecommunication cable. This 42km long cable is equipped with 48 single-mode fibers and one conductor. Power is delivered from shore in AC at 3700V, the sea water providing the return path for the current. At its undersea end, the cable is terminated by the main junction box which is equipped with 16 wet-mateable connectors and performs the following vital operations:

- it transforms the power received from the shore down to 500VAC, by means of 16 independent secondaries, individually protected by breakers.
- It splits the fibers of the cable coming from shore so as to serve the different lines of the telescope

Each wet-mateable connector of the main junction box delivers 4 single mode fibers and 500VAC on 2 electrical conductors. The BJS is connected on one of this wet-mateable ODI connector.

The main aim of the BJS is to provide internet communication interfaces between the scientific equipment and shore. This equipment offers 7 wet-mateable ports for the users, allowing the transmit of data and the power supply for the scientific equipments connected. One is a new Ifremer design of economic optical expanded beam connector and is used to connect by means of only one single mode fiber, the first node of the new network *DeepSeaNet* prototype. Three ODI connectors deliver 100Mb/s on Cu, and VDSL2 for extended long range applications. Another one is a specific Ifremer design wet-mateable connector called CDC and is used for delivering 100Mb/s on Cu . Two ODI optical connectors are integrated for transmit data and clock on two optical fibers.

On principle, the BJS delivers 1kW, only 400VDC on its wet-mateable outputs and Ethernet 100Mb/s. The low voltage power supplies (48V,12V or 5VDC) for scientific sensors and RS232, RS422 or RS485 are generated on the scientific instrumentation modules as the MII (Interface Instrumentation Module) developed by the DT-INSU. This MII is directly connected on shore with scientific sensors.

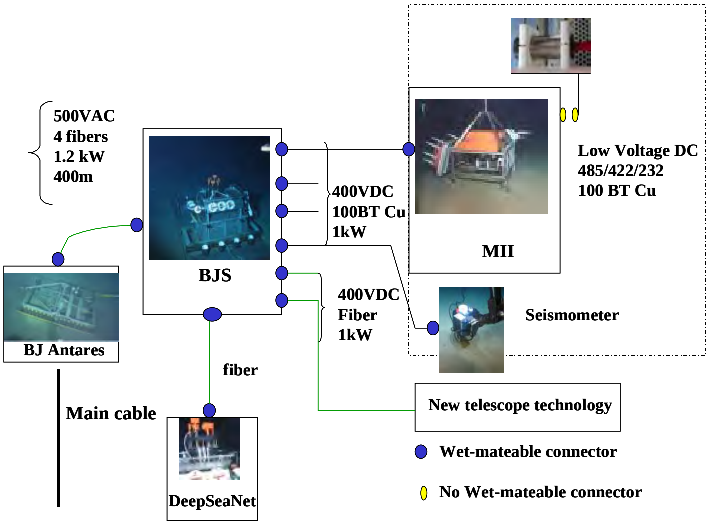


Figure 3. BJS system overview

All the BJS has been designed with the requirement for a high level of reliability and for a 20 years life expectancy. Although the concept is simple, the physical system is much more complex.
All the BJS electronic is integrated in a specific titanium housing 350 mm diameter and 1400 mm length (an old one reused for this application), the output connectors have been integrated on the cylinder three on each side.

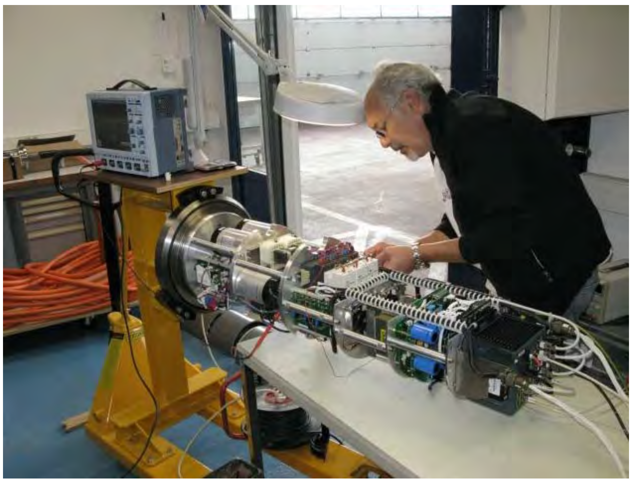


Figure 4. BJS Electronic Integration

All the design and integration have been achieved by *Ifremer* at *La Seyne s/mer* (Fig.4).

III. Power generation

The main design features of BJS power system are to provide 400VDC with 1kW full power. It is also to insure a total protection of the power supply input, whatever fault is present on the output. This scientific and technology test bed must be completely transparent for the *Antares* telescope. This requirement means a high accuracy of monitoring of the current delivers and of the leakage and ground faults detection on the outputs. This means also, that the power system has to be autonomous with enough intelligence to be able to switch off in very short time (and always faster than the *Antares* BJ breakers), all the individually outputs and in generally all the power generation circuits.

For that purpose, 3 current hall sensors, which react straightly on the regulation interrupter, have been integrated. At the

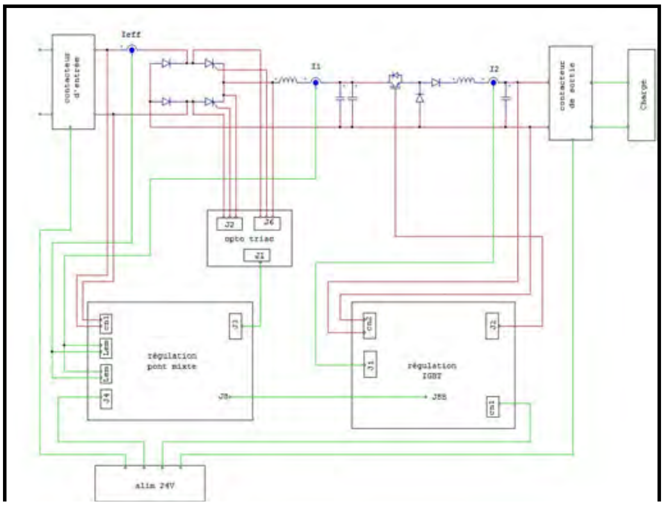
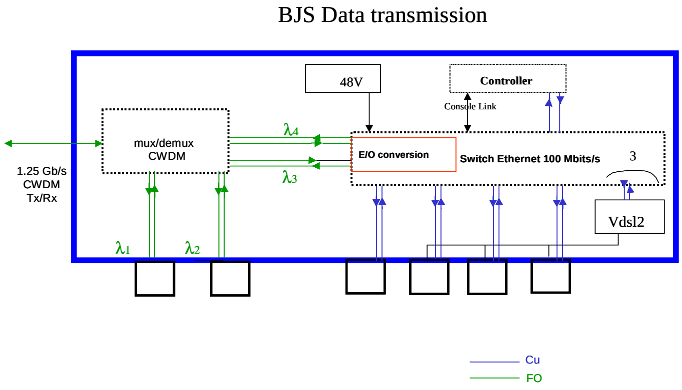


Figure 5. Power generation overview

input, a rectifier bridge built with diodes and triacs, allows a controlled slow slope on the input filter capacitor. That principle reduces the inrush current when closing the switches, thus eliminating the need for current limiting resistances at startup. Generally the power supply has been designed for a very compact sizing, compatible with the integration in the housing. This design is very compact and allows 75% efficiency for all AC/DC conversion (Fig.5).

IV. DATA TRANSMISSION

Only one 9/125µm single-mode fiber is used for the bidirectional data transmission. This network is mainly composed of passive devices for maximum reliability. Among the 4 optical fibers deliver on the connectors, two are dedicated to Antares master clock for the future experiment of a km3-scale apparatus. Another one is dedicated to DeepSeaNet node. A Coarse Wavelength Division Multiplexing (CWDM) system is used for data transmission in order to merge several 100Mb/s Ethernet on a single optical fiber, using different laser wavelengths. Passive CWDM filter distribute 8 λ CWDM from 1470 ηm to 1610 ηm. Four are used by the Ethernet switch for



a complete redundancy and increasing the reliability. This equipment provides eight 100Mb/s full duplex Ethernet.

Figure 6. Data transmission

Four ports are directly wired on the output connectors. One link is dedicated to the controller embedded in the BJS. Three are used by VDSL2 modem, for extending the distance with scientific instrumentation, with of course lower data rate. The embedded *IE3000 Cisco* switch, with its compact size, its 24V power supply, and its ability to transmit very accurate Precise Time Protocol (PTP, IEEE1453) is particularly well adapted for this application (Fig.6).

The controller, based on ARM with a light embedded Linux, controls in complete autonomy all the system. It is always powered and can restart on alarm, the switch and the power generation. This equipment can be control on surface by a single navigator connected to the embedded web browser (Fig.7). The surface operator can check in real time all the data (as currents, voltages, state of outputs) and command the start-up of the regulation and the switching of each output individually, every second.

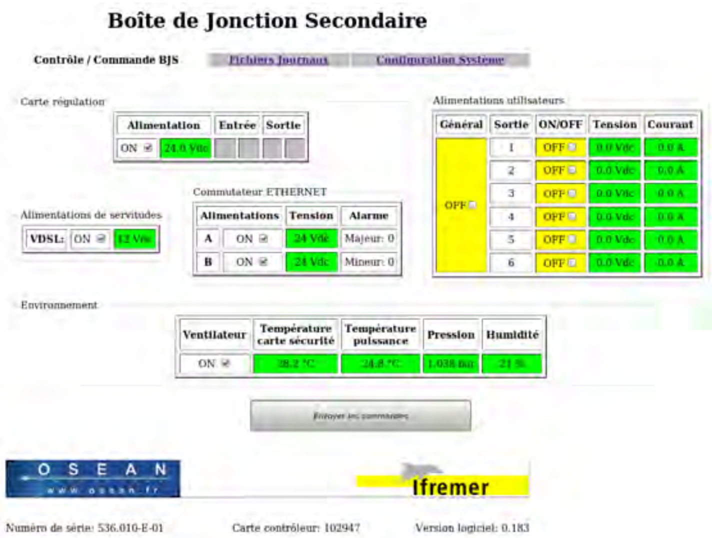


Figure 7. Real Time Control Interface

All the control data refreshed every second, are logged on SD card and are accessible immediately on the web interface. On shore station, the network architecture is completely symmetrical, concerning the switch and the passive CWDM filter. A set of PCs run the applications of the scientific sensors. A server route the BJS data network on the IP public network. By this way, every scientist can have access to all the sea sensors data, in real time in the lab. Users will be able to access the system from anywhere in the world and interact with their instruments as if it were on their work bench. One of the key requirements is that users can interact with their instrument using their own software without any major configuration changes. To enable this, each instrument attached to the BJS is on its own virtual LAN. The user will be provided with an account for accessing the system, which will allow them to access their instrument as if it were locally, connected (Fig.8).

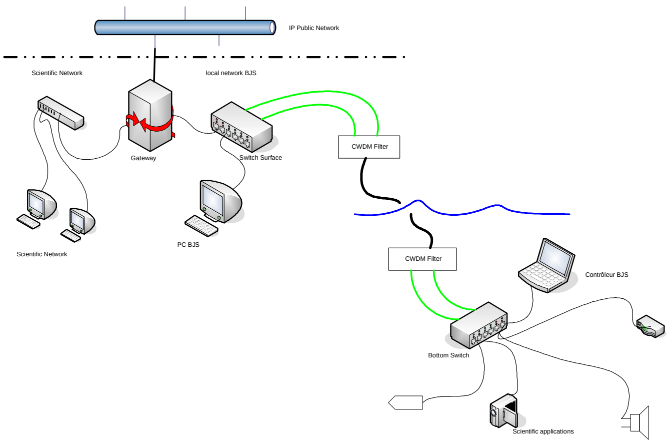


Figure 8. Shore station network architecture

V. DEEPSEANET PROTOTYPE.

Deep Sea Net is a new concept of a deep sea sensor network built from one optic fiber micro cable and battery operated IP access nodes. This innovative approach permits to build extend and maintain future sensor networks at very competitive prices.

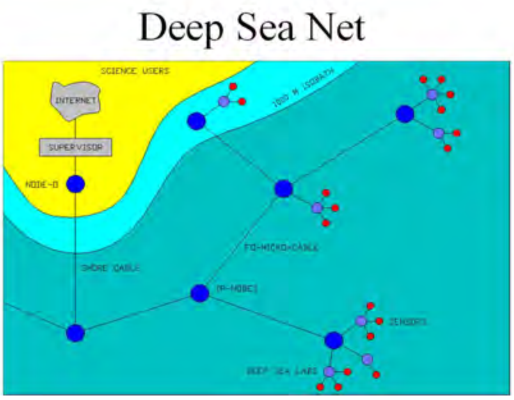


Figure 9. Deep Sea Net topography

The first Deep Sea Net IP-node has been deployed during the TEXREX cruise on a dedicated fiber through the BJS (Fig.9). This node is connected to the shore node by a 42km single optical fiber. The optical wake-up principle and the new economic wet-mateable connector have been validated. This network, easy to install can be deployed by non specialized sea-operating company, providing IP connection every 40 km. Each node is equipped with batteries and wet-mateable connectors for geophysic sensors, but could be open to other sensors (Fig.10).

All the system is now fully operational and others segments of 40km will be deployed during the next ROV Victor6000 operation .

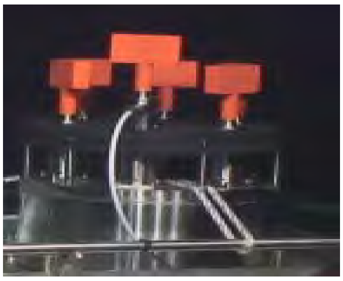


Figure 10. Deepseanet First Node

VI. DEPLOYMENT OF THE INFRASTRUCTURE AT SEA

For the deployment of the BJS electronic titanium housing, an heavy sled has been built, which is laid down on the seabed. On this sled, two platforms have been mounted on each side, allowing the ROV Victor 6000 to stay stable, during the connexions operations, with the two manipulator arms. For guiding the wet-mateable plugs, guide systems have been installed around each wet-mateable connectors. The BJS has been designed as recoverable module and is locked up on the sled with a prism case. (Fig.11)

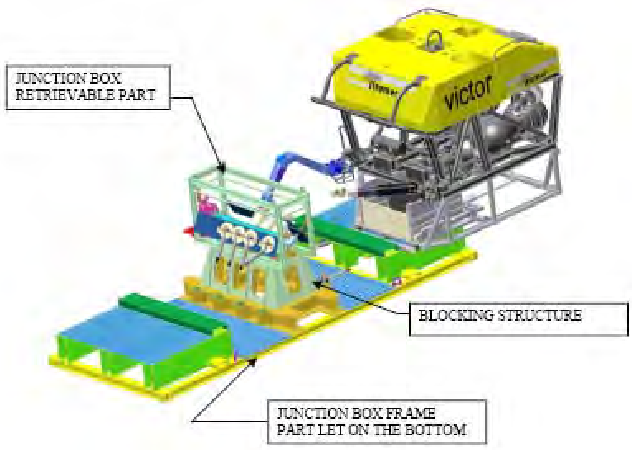


Figure 11. sled overview

The BJS has been deployed during the TEXREX cruise in November 2010 on the Research Vessel *PourquoiPas?*, with the Ifremer ROV *Victor6000*. After navigating by fixes from a network of sea-bed acoustic transponders deployed around the ANTARES site, and then staying in place with its GPS dynamical positioning system, the R/V *PourquoiPas?* has deployed electro-optical interlink and equipments.

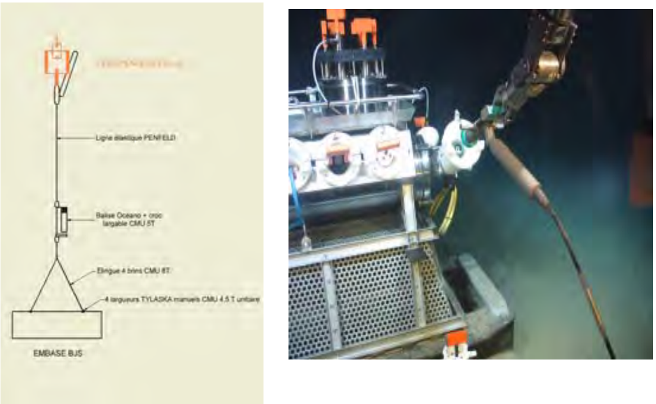


Figure 12. Deployement and connection of the BJS

All the deployment to seabed and positioning over site need to operate with adequate accuracy. The whole BJS system, including scientific modules, has been laid down on the bottom with cable, flotation and acoustic release system. Underwater interlink cables are used for connecting the BJS to the main *Antares* junction box and to the scientific equipments MII and seismometer (Fig.12). The installation and the connection of these cables is made by means of the *Victor 6000* (Fif.13).

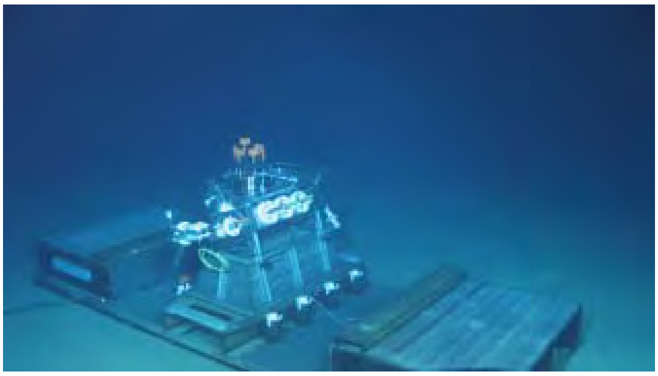


Figure 13. BJS at 2500m depth

VII. Scientific Results

During the same *Texrex* cruise different scientific modules have been connected to the BJS on the sea bed at 2500m, and are now delivering real time data. Generic oceanographic sensors have been deployed on the MII (developed by DT-INSU) for monitoring in real time of key oceanographic parameters as: temperature, salinity, current velocity and direction, pressure, oxygen concentration and a camera for measuring bioluminescence on the site (Fig.14).

Figure 14. MII module

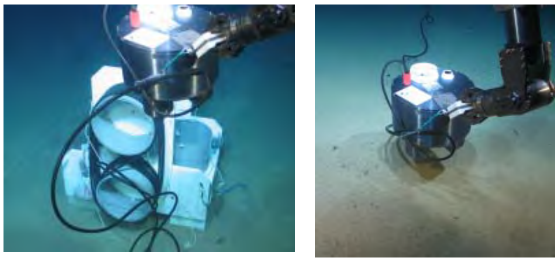


Figure 15. Seismometer module

A multiparameter seismometer module for sea floor motion observation proposed by *Geosciences Azur* and integrated by *Guralp System* has been also connected on the BJS to respond to both operational and scientific goals (Fig.15). The module is composed of a very broad band (0.0028 at 50Hz**)** seismometer, an accelerometer, 2 tiltmeters, a differential pressure gauge and an absolute pressure sensor *Paroscientific*. A bell was placed over the seismometer to prevent noise from bottom currents.

Few days after the connection, on 9th November, the instrument recorded an uncommon magnitude 4 seismic event between Toulon and Corsica; the available data contributed to a better location of this event (Fig.16).

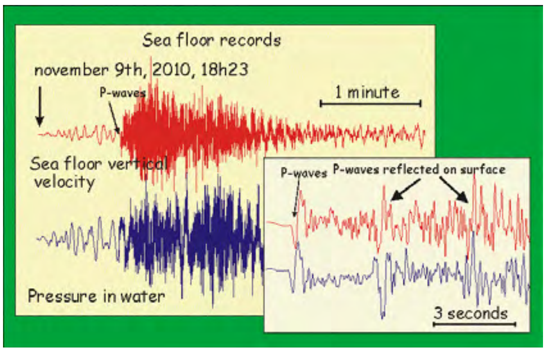


Figure 16. Seismometer data

VIII. CONCLUSION

This new infrastructure has been developed in a very short time by IFREMER, in partnership with DT-INSU, CPPM and Geosciences Azur. It has been deployed at 2500m in the Mediterranean Sea in November 2010 and is now fully operational, with scientific modules already connected, providing real time data.

This new infrastructure installed on the ANTARES site presents all the capabilities for European demonstration mission with real time data acquisition, in order to test new developed instruments and observatory technologies

ACKNOWLEDGMENT

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