Project	AtlantOS – 633211
Deliverable number	6.1
Deliverable title	Sensors and Instrumentation Roadmap
Description	Report including a ten year roadmap for strategic development of sensor and instrument technology for Integrated Atlantic Ocean Observing Systems and therefore global ocean observation.
Work Package number	6
Work Package title	Cross-cutting issues and emerging networks
Lead beneficiary	NERC
Lead author	Amy Pike
Contributors	See Author list
Submission data	31 March 2016

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 633211.

Sensors and Instrumentation Roadmap

Contents

Author list

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Glossary

Acronym	Definition
NOC	National Oceanography Centre
EC	European Commission
EU	European Union
AtlantOS	Horizon 2020 project to deliver an advanced framework for the development of an integrated Atlantic Ocean observing system
GEOSS	Global Earth observation system of systems
IP	Intellectual property
EuroGOOS	Euro global ocean observing system
GEO	Global Earth observation
TRL	Technology readiness level
UUV	Unmanned underwater vehicle
HEI	Higher education institution

Introduction

The international community is determined to integrate and improve ocean observing - not least in the Atlantic through the AtlantOS project. A deliverable of AtlantOS is this freely available ten-year roadmap for sensors and instrumentation.

The ambition for this roadmap is that it will constitute a tool from which the oceanographic community can learn of current and upcoming technology to better inform grant proposals, improve engagement with technology providers and help focus integrated effort on to the most important science questions.

To provide the best impact of the roadmap invitations to contribute were widely circulated to academia, private companies, research institutions and existing multilateral projects operating within oceanography. These sources were asked to provide details of what sensors and instrumentation are available, as well as a forecast to the availability and capability of future systems.

Other information such as product descriptions, flyers, datasheets or specification documents were also requested. If a release was subject to restrictions due to commercial conflicts contributors were still invited to consider supplying as much as possible. As a consequence the creation of the roadmap also constitutes a collection of more in-depth material for many of the sensors and instruments.

In the first instance information provided for the roadmap will be made available through the NOC and AtlantOS websites and GEOSS wiki. Co-hosting with platforms such as the EuroGOOS Technology Plan (http://eurogoos.eu/increasing-eurogoos-awareness/working-groups/technology-plan-working-group-tpwg/) and the GEO blue planet outputs (http://www.oceansandsociety.org/products/brochures.html) are to be explored.

Scope and purpose

This ten-year technology roadmap is for presently and soon to be available sensors and instrumentation for oceanographic research in and around the Atlantic Ocean.

The level of readiness is reported as Technology Readiness Levels (TRLs), definitions given in Appendix A. Whenever available, further parameters detailing the capabilities and specifications of submitted sensors and instrumentation are also made available.

The purpose of the roadmap can be summarised as:

"The provision of an open access technology roadmap for research centred in and around the Atlantic Ocean to both engage and improve collaboration and integrated effort from all stakeholders."

The stakeholders being researchers, industry, academia and other educational centres engaged in the development, deployment and analysis of sensor technology in and around the Atlantic Ocean.

Advantages to both contributors and users of this roadmap are:

- Greater awareness of technology for potential customers, collaborators, funders, reviewers and academics for oceanographic research in and around the Atlantic ocean
- Uplift in citations, prestige of work and outputs following increased collaboration
- Approaches from partners, end users and funders at appropriate points in the development cycle of upcoming technologies
- Increased likelihood that technology will be employed beyond immediate research need, including large scale ocean observation programmes
- Increased exposure to potential licensees and commercialisation partners, for which it is appropriate

It is important to note that this technology roadmap constitutes a snap shot in time and it is the intention of the authors to periodically bring the roadmap up to date throughout the AtlantOS project.

Methodology

Broad engagement with the oceanographic community was sought. This was principally through a widely circulated questionnaire that invited contributors to detail relevant sensors and instrumentation in the context of TRLs. This questionnaire was sent to every sector of the oceanographic community, including but not restricted to; academic centres, research institutes and industrial companies.

The delivery team directly consulted with databases from existing working relationships (e.g. SenseOcean project partners) but also coordinated with groups such as international strategic project offices, enterprise teams and through informal discussions at cross-discipline engagements, Figure 1.

The advantage of being part of a major consortium, the AtlantOS project itself, was also exploited. Partners within AtlantOS both contributed to the road map directly with the questionnaire but also highlighted existing consortiums to further engage with and raised the visibility of the roadmap at a number of international meetings.

The result was a comprehensive contact list of universities, research centres and industrial partners from around the globe, Appendix B. In total 144 separate addressees were contacted from a range of countries and sectors, Figure 2.

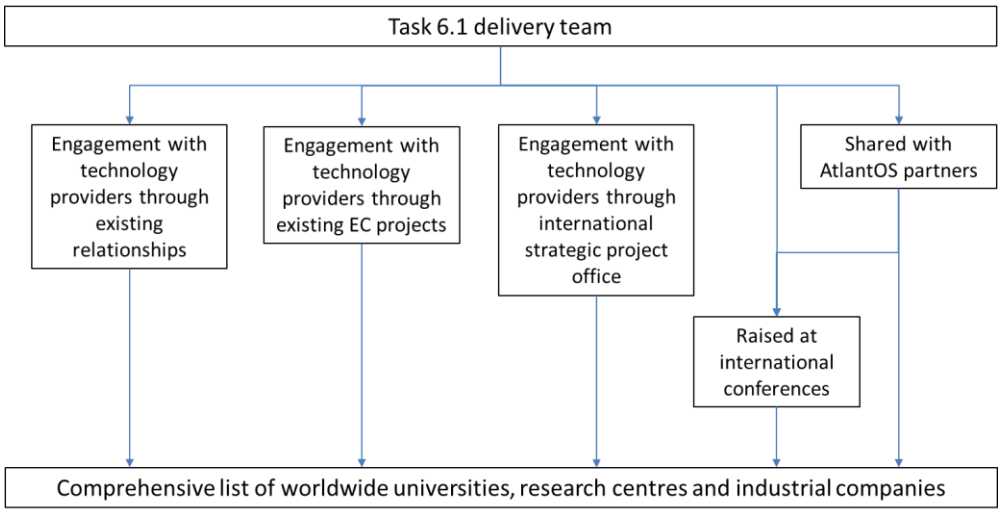
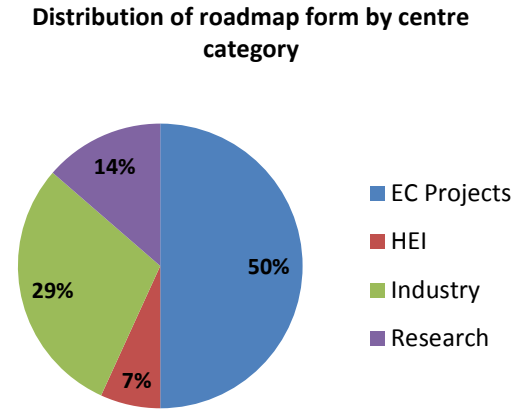


Figure 1 Diagram of the routes of engagement used to ensure representative source of contacts for roadmap



Centre category	N° contacted
EC projects	66
HEI	10
Industry	42
Research	18

Centre region	N° contacted
Africa	1
Americas	12
Asia	1
Europe	121
Pacific	1

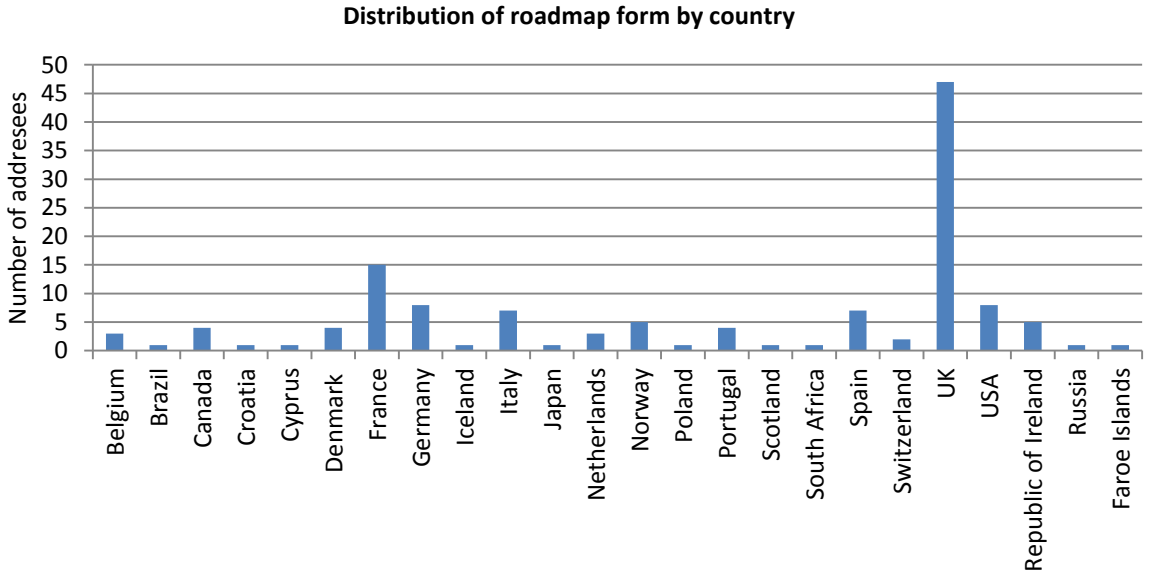


Figure 2 Summary of distribution of roadmap by centre category and region

Timeline

The first invitations for contributions to the technology roadmap were sent in January 2016, this was followed by a second invitation in February 2016. As collaborators returned responses suggestions for further engagement were also received, additional direct invitations were then made as appropriate.

The technology roadmap will be updated throughout the duration of the AtlantOS project, principally through the online version which is scheduled to go live by the end of 2016. It should be noted that this is a working resource and to maintain value further engagement from the community is welcome, encouraged and will be actively sought.

Technology roadmap

Presented here are the separate sensors and instruments that have been submitted to the roadmap along with their maturity, as described through TRLs. Table 1 gives the headings for the roadmap.

Additional information including links to specification sheets and application notes are included in Appendix C. An online version of the technology roadmap will be available by the end of 2016. The online version will contain embedded links to the additional material and will be periodically updated throughout the remainder of the AtlantOS project.

Table 1 Headings and definitions of technology roadmap

Roadmap heading	Definition and example
Company/institute	The name of the company or institute providing data, e.g. Geomar.
Sensor or instrument name	The name of the sensor or instrument.
Application/target/technology	Intended application of technology (e.g. ammonia) or type of technology (e.g. profiler).
TRL 1 - 9	'met' means TRL level passed, date indicates expected pass date for stated TRL (e.g. May - 16 which means May 2016). TRLs defined in Appendix A.
Operational demo	Can either be technology or full system demo (discretion of submission). 'complete' or date of expected pass date.
Commercial release	Can either be 'available' or date of expected release.
Notes	Blank space indicates information not yet available '-' indicates information purposely missed (e.g. skipping TRL level) * extra information in Appendix C and online roadmap

Company /institute	Sensor or instrument name	Application/target /technology	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9	Operational demo	Commercial release
Common Sense Project	Cefas Noise Sensor (pre production prototype)*	hydrophone	met	met	met	met	met	met	met	Jul-16		Jul-16	
Common Sense Project	SSU (Smart Sensor Unit)*	multiple parameters	met	met	met	met	met	met					
Common Sense Project	MK2 pCO2 Analyser (water)*	partial pressure CO2	met	met	met	met	met	met	met				
Common Sense Project	MK3 pCO2 Analyser (air)*	partial pressure CO2	met	met	met	met	met	met	met				
Common Sense Project	OceanPack AUMS*	autonomous underway measuring system	met	met	met	met	met	met	met				
Common Sense Project	OceanPack Subsea*	partial pressure CO2	met	met	met	met	met	met	met				
Common Sense Project	Microplastic sensor*	microplastics	met	met	met	met	Sep-16	Feb-17					
Common Sense Project	Nutrient Sensor*	nutrients	met	met	met	met	met						
Flydog Solutions LLC	Profiler buoy 'Mona'*	profiler	met	met	met	met	met	met	met	met	met		available
Flydog Solutions LLC	Submersed profiler 'Salla'*	profiler	met	met	met	met	met	met	met	met	May-16	complete	Jun-16
Geomar	HydroFIA TA*	total alkalinity	met	met	met	met	met	met	met	Jul-16	Dec-16	complete	available
Geomar	HydroFlash O2*	dissolved oxygen	met	met	met	met	met	met	met	met	Aug-16	complete	available
Geomar	HydroFlash CO2*	carbon dioxide	met	met	met	met	May-16	Jun-16	Sep-16	Dec-16	Dec-17	Jun-16	Dec-16
LOSEM University of Tuscia	TFLaP*	physical-chemical-biological parameters	met	met	met	met	met	met	met	met			
LOSEM University of Tuscia	Spectra (derived from TFLaP)*	physical-chemical-biological parameters	met	met	met	met	met	met	met	met			
National Oceanography Centre	Chemical Sensors: Nitrite	nitrite	met	met	met	met	met	met	met	met	Dec-17		
National Oceanography Centre	Chemical Sensors: Phosphate	phosphate	met	met	met	met	met	met	Apr-16	Aug-16	Feb-17		

Company /institute	Sensor or instrument name	Application/target /technology	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9	Operational demo	Commercial release
National Oceanography Centre	Chemical Sensors: Ammonia	ammonia	met	Jun-16	Aug-16	Nov-16							
National Oceanography Centre	Chemical Sensors: Silicate	silicate	met	met	met	met	Jun-16	Oct-16	Jan-17	Apr-17			
National Oceanography Centre	Chemical Sensors: DON	dissolved organic nitrogen	met	met	met	Jan-17	Feb-17	Feb-17	Apr-17	Jun-17	Sep-17		
National Oceanography Centre	Chemical Sensors: DOP	dissolved organic phosphorous	met	met	met	met	Sep-16	Sep-16	Nov-16	Jan-17	Mar-17		
National Oceanography Centre	Chemical Sensors: pH	pH	met	met	met	met	met	met	met	Dec-16	Nov-17		
National Oceanography Centre	Chemical Sensors: TA	total alkalinity	met	met	met	Jan-17	Jul-17	Dec-17	Jan-19	Jul-19			
National Oceanography Centre	Chemical Sensors: DIC	dissolved inorganic carbon	met	met	Jun-16	Jan-17	Jul-17	Dec-17	Jan-19	Jul-19			
National Oceanography Centre	Chemical Sensors: Fe	iron	met	met	met	met	met	met	Mar-17	May-17	Jul-17		
National Oceanography Centre	Chemical Sensors: Mn	manganese	met	met	met	met	met	Nov-16	Mar-17	May-17	Dec-17		
National Oceanography Centre	Chemical Sensors: O2	dissolved oxygen	met	met	met	met	met	met	met	Oct-16	Jun-17		
National Oceanography Centre	Chemical Sensors: pCO2	partial pressure CO2	Jan-17	Jan-18	Jan-19	Jan-20	Jan-21	Jul-21	Jan-22	Jan-23	Jan-24		
National Oceanography Centre	Chemical Sensors: CH4	methane	Aug-16	Jan-17	Jul-17	Jan-18	Jul-18	Jan-19	Jul-19				

Company /institute	Sensor or instrument name	Application/target /technology	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9	Operational demo	Commercial release
National Oceanography Centre	Chemical Sensors: Hydrocarbons	hydrocarbon	met	met	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17		
National Oceanography Centre	Chemical Sensors: Aptamer sensors	multiple parameters	met	met	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17		
National Oceanography Centre	Biology Sensors: Cytometer	multiple parameters	met	met	Jan-17	Jul-17							
National Oceanography Centre	Physical Sensors: T,C	temperature, conductivity	met	met	met	met	met	met	met	Oct-16	Jun-17		
NKE	SST & SSS sensor*	temperature, salinity											
NORTEK	Signature55 *	acoustic Doppler current profilers	met	met	met	met	met	met	met	met	met	complete	available
NORTEK	Signature250*	acoustic Doppler current profilers	met	met	met	met	met	met	met	met	met	complete	available
NORTEK	Signature500*	acoustic Doppler current profilers	met	met	met	met	met	met	met	met	met	complete	available
NORTEK	Signature1000*	acoustic Doppler current profilers	met	met	met	met	met	met	met	met	met	complete	available
NORTEK	Nortek DVL*	acoustic Doppler instrument	met	met	met	met	met	met	met	met	met	complete	available
Ocean Sonics	icListen Smart Hydrophone*	hydrophone	met	met	met	met	met	met	met	met	met	complete	available
Ocean Sonics	icListen RB9-ETH*	hydrophone	met	met	met	met	met	met	met	met	met	complete	available
Ocean Sonics	Digitial hydrohone array	hydrophone	met	met	met	met	met	met	met	met	met	complete	available
Ocean Sonics	icListen - generation four*	hydrophone	met	met	met								Dec-16
Plocan	A1- Low power multifunctional hydrophone	hydrophone	met	met	met	Jun-16	Oct-16	Nov-16				Jun-17	
Plocan	A2- Real time waveform streaming and preprocessing hydrophone array	hydrophone	met	met	met	Jun-16	Oct-16	Nov-16				Jun-17	

Company /institute	Sensor or instrument name	Application/target /technology	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9	Operational demo	Commercial release
SYSTEA	Micromac-1000*	multiple parameters	met	met	met	met	met	met	met	met	met	complete	available
SYSTEA	WIZ probe*	nutrients	met	met	met	met	met	met	met	met	met	complete	available
SYSTEA	µMac-Smart*	mutiple parameters	met	met	met	met	met	met	met	met	met	Sep-16	available
TELLabs	NAPEs platform	platform	met	-	-	Apr-16	-	-	May-17	-	-	Feb-17	Jan-20
TELLabs	Commonsense	multiple parameters	met	-	-	Apr-16	-	-	Feb-17	-	-	Dec-16	Jan-20
TELLabs	Aquawarn	multiple parameters	met	-	-	met	-	-	met	-	-	Apr-16	Nov-16
Vemco	VR2C*	cabled receiver	met	met	met	met	met	met	met	met	met		available
Vemco	VR2Tx*	cabled receiver and transmitter	met	met	met	met	met	met	met	met	met		available
Vemco	VR2AR*	acoustic release and receiver	met	met	met	met	met	met	met	met	met		available
Vemco	V13/V9P/TP/P*	temperature + depth tags	met	met	met	met	met	met	met	met	met		available
Vemco	V13AP/V9AP*	accelerometers	met	met	met	met	met	met	met	met	met		available
Vemco	DO-Tag	dissolved oxygen	met	met	met						Jun-18		Jan-17
Vemco	Predation Tag	predation	met	met	met						Jan-17		Jan-17

Discussion

From undertaking this first iteration of the technology roadmap a number of important observations have been made.

Responses and feedback

The proportional breakdown of sectors contacted does not match that of those that responded, Figure 2. For example, 29% of contacts and then 42% of respondents were from industry whilst 14% of contacts and 8% of respondents were from research centres. This is likely to be a consequence of the roadmap using TRLs to describe the maturity of systems. In many cases industrial companies will already consider technology readiness in this manner, making a contribution more attractive and therefore more likely.

It is expected that as this roadmap goes live and the benefits of having such a visible platform to promote and share innovations with the wider oceanographic community become more obvious those sectors which don't immediately report technology in the format required will start to engage with the roadmap in greater numbers.

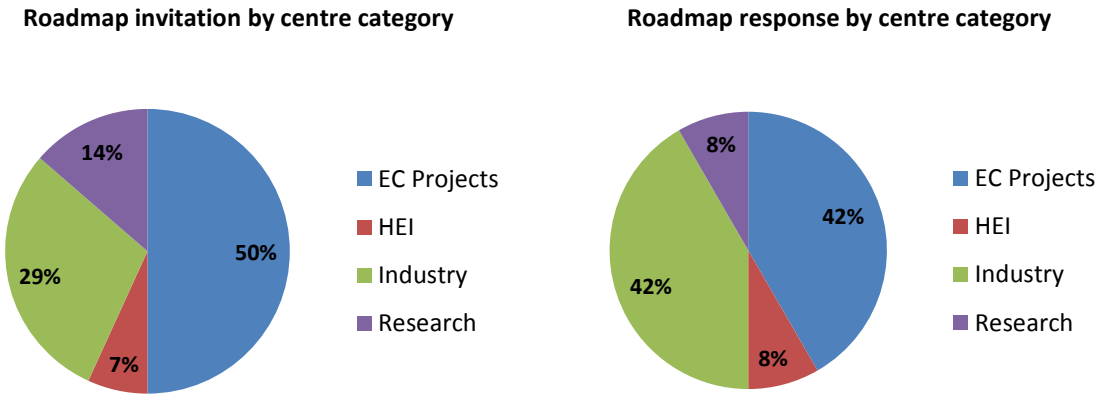


Figure 2 (left) Distribution of roadmap by centre category, shown earlier (right) Response from roadmap by centre category.

Encouragingly four responses to the technology roadmap were from centres other than those directly contacted, showing that the roadmap already has some visibility within the community. It is expected that such unprompted engagement will continue, enabling the roadmap to become more relevant and useful.

The delivery team have also been approached by the UK's Royal Navy who are seeking to create a similar technology roadmap. This is further evidence that the roadmap is obtaining a good visibility within the extended oceanographic community but also a demonstration of how unexpected and potentially productive collaborations could arise for those that have made submissions.

Strengths of this roadmap

This roadmap comprises a valuable resource of various sensors and instrumentation from principally Europe but also further afield. Once the roadmap is made available online the easy to access collection of specification sheets for the included technology is of undoubted use as existing information is better collated and enjoys greater visibility to the oceanographic community.

However, the principal benefit is to the oceanographic community as a whole. The scope of the AtlantOS project is centred in and around the Atlantic Ocean but the technology described within the roadmap will in most cases be available to any interested party around the world. Detailing not only what is available but also what will be available in the upcoming future enables more focussed and targeted research. This better allows the oceanographic community to answer vital scientific questions through timely engagement with technology providers.

The roadmap is also a demonstration of how the AtlantOS project is enabling closer communication and integration sought by the international community for oceanographic research.

Opportunities

The timeframe of a month in the first general call for contributions strongly favoured sectors that already consider technology development in the format requested for the ten-year roadmap. Also, a common response to the roadmap questionnaire was that groups were currently too busy to complete a full submission by the necessary deadline, now that the roadmap is available and will undergo periodic review this barrier to engagement is now removed.

A notable way in which engagement could be expanded is through making the questionnaire available in languages other than English. Whilst it is not expected that this is a major barrier for many of the larger contributors across Europe it is likely to have some impact for smaller centres and organisations. The UK was the most common location for the distribution of the roadmap principally because the delivery team could reach out to the smaller technology providers without modifying the questionnaire.

Bringing the format for submissions to be more in line with those of existing roadmaps for different goals (e.g. roadmap for UUVs, http://auvac.org/explore-database/simple-search) would also likely lead to greater engagement from the wider oceanographic community as submissions could be in the same format sent elsewhere. Under the initial scope of this roadmap such harmonisation was not accomplished but could be attempted in the future.

A final improvement would be the implementation of a live database that registered users could independently update. The resources required to implement such an advanced system were not available for this roadmap but future projects undertaking a similar aim are encouraged to explore such a system.

Conclusion

A multinational sensor and instrumentation roadmap has been created with submissions from industry, HEIs, EC funded projects and research institutes. To date the majority of contributions have been from within Europe.

Whilst the initial response has been modest there has been significant interest in the roadmaps development and the potential for growth in the future is high. All interested parties may not have been identified in the initial contact lists and it is hoped as visibility of this roadmap within the oceanographic community increases further contacts will be made. This process has already begun and is evident by late submissions from universities and companies which were not directly contacted by the task delivery team.

Some contacts, in particular those from industry, were wary of submitting to the roadmap owing to IP issues or the perceived workload in providing data for a large catalogue of sensors and instruments before the set deadline of this report. As this roadmap will now be periodically revised the self-imposed deadline has been removed as a barrier to submission. Hopefully, as the roadmap becomes more widely recognised contributions will become more attractive to all stakeholders.

The Sensor and Instrumentation Roadmap is now a living document that brings together an international community to enable better collaboration, integration and improving ocean observing. This roadmap should develop and become ever more relevant as visibility increases and further engagement is achieved. The online version of this roadmap will be updated throughout the AtlantOS project.

Appendix A

Technology readiness levels, adapted from NASA.

TRL	Description	Example / Notes
1	Basic principles of technology observed and reported	Evidence in the literature or from experiment indicates that a measurable response to the target parameter(s) is observed
2	Technology concept and or application formulated	Requirements of the application / market formally recorded, concept design(s) documented
3	Analytical and laboratory studies to validate analytical predictions	The analytical element (e.g. assay plus absorption cell) has been tested and performance evaluated vs design expectations
4	Component and / or basic sub-system technology valid in a lab environment	Benchtop system (e.g. labview control, benchtop pumps, simple chip) performance validated in the lab
5	Component and / or basic sub-system technology valid in a relevant environment	Components of the technology, or subsystems validated in a relevant environment (e.g. pressure pot, or dockside tests of elements of the system)
6	System / sub-system technology model or prototype demo in relevant environment	Prototype demonstrated in pressure pot or dockside
7	System technology prototype demonstrated in an operational environment	Prototype demonstrated in target deployment (e.g. in a river, mooring, glider etc.)
8	System technology qualified through test and demonstration	Performance in final environment validated through repeated testing and deployment
9	System technology qualified through successful mission operations	Technology has delivered data to science in the target environment on more than a handful of occasions

Appendix B

Contact List

Institution	Country (lead country if project)	Centre Type
ACRI-ST	France	EC Projects
Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC)	Spain	EC Projects
Albatros marine tech	Spain	Industry
Alfred Wegener Institut Helmnoltz Zentrum für Polar- und Meeresforschung	Germany	EC Projects
Alfred Wegener Institute	Germany	Research
Alma Mater Studiorum-Universita di Bologna (UNIBO)	Italy	EC Projects
Aquatec	UK	Industry
Atlas Electroniks	UK	Industry
Babcock	UK	Industry
Bae Systems	UK	Industry
BAS	UK	Research
Blue Lobster Ltd	UK	EC Projects
BMT Defence	UK	Industry
Boeing	UK	Industry
BRAAVOO	Switzerland	EC Projects
BRIDGES	France	EC Projects
Bristol University	UK	HEI
Bruncin	Croatia	EC Projects
CEFAS	UK	Research
Centro Euro Mediterraneo sui Cambiamenti Climatici S.c.a r.l. (CMCC)	Italy	EC Projects
Chelsea Technologies Group	UK	Industry
CLU Srl	Italy	EC Projects
CNRS	France	EC Projects
Collecte Localisation Satellites (CLS)	France	EC Projects
COMMON sense	Spain	EC Projects
Consorcio para el diseno, construccion, equip.y expl. de la plataforma ocean. De Canarias (PLOCAN)	Spain	EC Projects
CONTROS Systems & Solutions GmbH	Germany	EC Projects
Council for Scientific and Industrial Research (CSIR)	South Africa	EC Projects
Cranfield technology uni	UK	HEI
Daithi O'Murchu Marine Research Station Ltd.	Republic of Ireland	EC Projects
Dalhousie University	Canada	EC Projects
Danmarks Meteorologiske Institut	Denmark	EC Projects
Danmarks Tekniske Universitet (DTU)	Denmark	EC Projects
DCU	Republic of Ireland	Research
DE&S	UK	Industry
Develogic GmbH	Germany	EC Projects
DSTL	UK	Industry
EIG Eumetnet	Belgium	EC Projects
ENVIGUARD	Germany	EC Projects
ETT S.p.A. - Electronic TechNology Team	Italy	EC Projects

Institution	Country (lead country if project)	Centre Type
Euro Argo ERIC	France	EC Projects
European Centre for Medium-Range Weather Forecasts (ECMWF)	UK	EC Projects
European Global Ocean Observing System (EUROGOOS)	Belgium	EC Projects
Flydog Solutions LLC *(new response, not on original contact list)*	Estonia	Industry
Fraser Nash	UK	Industry
Geomar	Germany	Research
Havstovan	Faroe Islands	EC Projects
Hydroptic	France	Industry
Idronaut	Italy	Industry
Ifremer	France	Research
IMR	Norway	Research
Institut de Recherche pour le Dévelop., Lab. d'Etudes en Géoph. Et Océanog. Spatiales (IRD)	France	EC Projects
Institute of Electrical and Electronics Engineers Inc (IEEE)	France	EC Projects
Institute of Oceanology Polish Academy of Sciences (IO PAS)	Poland	EC Projects
Instituto Español de Oceanografía (IEO)	Spain	EC Projects
Interdisciplinary Centre for Marine and Environmental Research (CIIMAR)	Portugal	EC Projects
International Council for the Exploration of the Sea (ICES)	Denmark	EC Projects
Ko-Ichi Nakamura	Japan	Research
Kongsberg	Norway	Industry
Konsortium Deutsche Meeresforschung e.V. (KDM)	Denmark	EC Projects
Lockheed Martin	UK	Industry
Los Gatos, Batelle	USA	Industry
LOSEM University of Tuscia *(new response, not on original contact list)*	Italy	HEI
MARIABOX	Cyprus	EC Projects
Marine Institute	Republic of Ireland	Research
Marine Institute	Republic of Ireland	EC Projects
MARIS B.V.	Netherlands	EC Projects
Marlin-Yug Ltd.	Russia	EC Projects
MBA	UK	Research
MEOPAR Incorporated	Canada	EC Projects
Mercator Ocean	France	EC Projects
Met Office	UK	EC Projects
Meteo France	France	EC Projects
Ministério da Ciência, TecNologia e INovação (MCTI)	Brazil	EC Projects
National Oceanic and Atmospheric Administration	USA	EC Projects
NERC	UK	EC Projects
NEXOS	Spain	EC Projects
NIOZ	Netherlands	Research
NKE	France	EC Projects
Norsk Institutt for Vannforskning (NIVA)	Norway	EC Projects
Nortek	Italy	Industry
Ocean Sonics *(new response, not on original contact list)*	Canada	Industry
OSIL	UK	Industry

Institution	Country (lead country if project)	Centre Type
Oxford University	UK	EC Projects
Planet Ocean	UK	Industry
PML	UK	Research
PML	UK	EC Projects
Qinetiq	UK	Industry
RBR	Canada	Industry
RIBOCON GMBH	Germany	EC Projects
RN	UK	Industry
Robert Gordon Institute	UK	HEI
Rolls Royce	UK	Industry
RS Aqua Ltd	UK	Industry
SAHFOS	UK	Research
SAMS	Scotland	Research
Satlantic	Canada	Industry
SCHEMA	Switzerland	EC Projects
SEA Ltd	UK	Industry
Seabird Scientific	USA	Industry
SEA-ON-A-CHIP	Spain	EC Projects
Seascape Consultants Ltd (EMODNET Secretariat)	UK	EC Projects
Sonardyne	UK	Industry
Star Oddi	Iceland	Industry
Stichting Koninklijk Nederlands Instituut Voor Zeeonderzoek (NIOZ)	Netherlands	EC Projects
STS defence	UK	Industry
Systea	Italy	Industry
Teledyne RDI	USA	Industry
Teledyne Webb	USA	Industry
TELLABS	Republic of Ireland	EC Projects
Thalis	UK	Industry
UEA	UK	HEI
UIB	Norway	Research
UK Hydrographic Office	UK	Industry
Ultra Electronics	UK	Industry
uni do porto (UPORTO)	Portugal	Research
United Nations Educational, Scientific and Cultural Organization - UNESCO IOC	France	EC Projects
Universidade do Algarve (UALG)	Portugal	EC Projects
Universitaet Bremen (MARUM)	Germany	EC Projects
Universite Pierre et Marie Curie (UPMC)	France	EC Projects
University Bergen Norway (UIB)	Norway	EC Projects
University of Bangor	UK	HEI
University of Cambridge	UK	HEI
University of Exeter	UK	EC Projects
University of Hull	UK	HEI
University of Liverpool	UK	HEI

Institution	Country (lead country if project)	Centre Type
University of Plymouth	UK	EC Projects
University of Southampton	UK	HEI
University of the Azores (IMAR)	Portugal	EC Projects
Valeport	UK	Industry
Vemco *(new response, not on original contact list)*	Canada	Industry
Villefranche Oceanographic Laboratory (LOV)	France	Research
VLIZ	Belgium	Research
WetLabs	USA	Industry
Woods Hole Oceanographic Institution	USA	EC Projects
Xylem	USA	Industry

Appendix C

The additional information from submissions to the roadmap is collected here; heading descriptions are given in Table 2. Please note, only submissions that included extra information to that already provided (previously highlighted by an *, as defined in Table 1) are compiled here.

Table 2 Headings and definitions of additional information from technology roadmap

Roadmap heading	Definition and example
Company/institute	The name of the company or institute providing data, e.g. Geomar.
Sensor or instrument name	The name of the sensor or instrument.
Application/target/technology	Intended application of technology (e.g. ammonia) or type of technology (e.g. profiler).
Links to or filename of specification/datasheet	Either weblink, notes on specification or notification that documents to be available with online version.
Filename or link to application notes or additional information	Either weblink, additional notes or notification of documents to be available with online version.

Company /institute	Sensor or instrument name	Application/target /technology	Links to or filename of specification/datasheet	Filename or link to application notes or additional information
Common Sense Project	Cefas Noise Sensor (pre production prototype)	hydrophone	To meet requirements of MSFD D11.2 Surveillance indicator to monitor trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz centre frequency. Freq range 10Hz - 10kHz. Sampling : 25kHz (up to 50kHz). Summary @ 1/3 octave bands 63Hz and 125Hz. Sensitivity : 50-150 dB re 1 µPa. Voltage : 24v. Endurance : TBA Weight in air / water : TBA Signal Interface : RS232	
Common Sense Project	SSU (Smart Sensor Unit)	multiple parameters		Sensor control, data logger and data transmission. Prototype test soon.
Common Sense Project	MK2 pCO2 Analyser (water)	partial pressure CO2	http://subctech.eu/empemco2_monitoring/pco2_analyzer/	http://subctech.eu/Datasheets/Environmental/OceanPack%20pCO2%20Analyzer/SpecSheet_Subctech_OceanPack-pCO2-MK-2_ENG.pdf
Common Sense Project	MK3 pCO2 Analyser (air)	partial pressure CO2	http://subctech.eu/empemco2_monitoring/pco2_top-box/	http://subctech.eu/Datasheets/Environmental/OceanPack%20pCO2%20Analyzer/SpecSheet_Subctech_OceanPack-pCO2_Sea-Air-Exchange_ENG.pdf
Common Sense Project	OceanPack AUMS	autonomous underway measuring system	http://subctech.eu/sensor_systems/oceanpack_aums/	http://subctech.eu/Datasheets/Environmental/OceanPack%20pCO2%20Analyzer/Flyer-OceanPack-Family_4-pages_2015-0.pdf
Common Sense Project	OceanPack Subsea	partial pressure CO2	http://subctech.eu/empemco2_monitoring/pco2_buoy/	http://subctech.eu/Datasheets/Environmental/OceanPack%22pCO2%20BUOY/SpecSheet_Subctech_OceanPack-pCO2-Buoy_ENG.pdf

Company /institute	Sensor or instrument name	Application/target /technology	Links to or filename of specification/datasheet	Filename or link to application notes or additional information
Common Sense Project	Microplastic sensor	microplastics		In development: Optical device with processing system, to monitor trends in microplastics concentration: Sampling system; optical device; fluorescence detection; image processing
Common Sense Project	Nutrient Sensor	nutrients	http://www.commonsenseproject.eu/2014-02-21-11-34-56/commonsensenews/1397-new-common-sense-progress-update-2015-factsheet-now-available	
Flydog Solutions LLC	Profiler buoy 'Mona'	profiler	http://www.flydogmarine.com/products/profiler-buoy/	Files available with online roadmap
Flydog Solutions LLC	Submersed profiler 'Salla'	profiler	http://www.flydogmarine.com/products/submersed-profiler/	Files available with online roadmap
Geomar	HydroFIA TA	total alkalinity	http://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/F39F9536AC620A95C1257EDC0048B162?OpenDocument	
Geomar	HydroFlash O2	dissolved oxygen	http://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/2052B2A42B415092C1257EDD00269390?OpenDocument	
LOSEM University of Tuscia	TFLaP	physical-chemical-biological parameters	Files available with online roadmap	
LOSEM University of Tuscia	Spectra (derived from TFLaP)	physical-chemical-biological parameters	Files available with online roadmap	
NKE	SST & SSS sensor	temperature, salinity	Files available with online roadmap.	SST & SSS sensor for SVP-BS (drifters measuring SST, pressure, and SSS).
NORTEK	Signature55	acoustic Doppler current profilers	http://www.nortek-as.com/lib/brochures/signature55-brochure	http://www.nortek-as.com/en/products/current-profilers/signature55
NORTEK	Signature250	acoustic Doppler current profilers	http://www.nortek-as.com/lib/brochures/signature250-datasheet	http://www.nortek-as.com/en/products/current-profilers/signature250

Company /institute	Sensor or instrument name	Application/target /technology	Links to or filename of specification/datasheet	Filename or link to application notes or additional information
NORTEK	Signature500	acoustic Doppler current profilers	http://www.nortek-as.com/lib/brochures/signature1000-500-brochure	http://www.nortek-as.com/en/products/current-profilers/signature1000-signature500-en
NORTEK	Signature1000	acoustic Doppler current profilers	http://www.nortek-as.com/lib/brochures/signature1000-500-brochure	http://www.nortek-as.com/en/products/current-profilers/signature1000-signature500-en
NORTEK	Nortek DVL	acoustic Doppler instrument	http://www.nortek-as.com/en/products/dvl/standard-dvl	http://www.nortek-as.com/lib/data-sheets/nortek-dvl-datasheet-1
Ocean Sonics	icListen Smart Hydrophone	hydrophone	http://oceansonics.com/wp-content/uploads/Ocean-Sonics-icListen-Specs-Web.pdf	http://oceansonics.com/wp-content/uploads/3in1-icListen-Brochure.pdf
Ocean Sonics	icListen RB9-ETH	hydrophone	http://oceansonics.com/wp-content/uploads/Ocean_Sonics_R_Type.pdf	http://oceansonics.com/wp-content/uploads/Ocean-Sonics-icListen-Specs-Web.pdf
Ocean Sonics	icListen - generation four	hydrophone	Smaller and lower power than previous generations	
SYSTEA	Micromac-1000	multiple parameters	http://www.systea.it/PDF/Mic1000-05-E.pdf	http://www.systea.it/Papers/Micromac/Grunwald2007_A%20novel%20time-series%20station%20in%20the%20Wadden%20Sea%20(NW%20Germany).pdf
SYSTEA	WIZ probe	nutrients	http://www.systea.it/PDF/WIZ-04E.pdf	http://www.systea.it/Papers/In-situ/Instrumentation%20for%20continuous%20monitoring%20of%20nutrients%20in%20marine%20environments%20(final).pdf
SYSTEA	µMac-Smart	mutiple parameters	http://www.systea.it/PDF/uMAC_SMART-01E%20rev_0.pdf	
TELLabs	NAPEs platform	platform		www.napes.eu
TELLabs	Commonsense	multiple parameters		www.commonsenseproject.eu/
TELLabs	Aquawarn	multiple parameters		www.aquawarn.com

Company /institute	Sensor or instrument name	Application/target /technology	Links to or filename of specification/datasheet	Filename or link to application notes or additional information
Vemco	VR2C	cabled receiver	http://vemco.com/products/vr2c-cabled-receiver/	Acoustic receivers
Vemco	VR2Tx	cabled receiver and transmitter	http://vemco.com/products/vr2tx-transceiver/	Acoustic receivers
Vemco	VR2AR	acoustic release and receiver	http://vemco.com/products/vr2ar-acoustic-release-and-transceiver/	Acoustic receivers
Vemco	V13/V9P/TP/P	temperature + depth tags	http://vemco.com/products/v9tp-to-v16tp-temperature-depth-tags/	Acoustic transmitters with depth and temperature sensors
Vemco	V13AP/V9AP	accelerometers	http://vemco.com/products/v9ap-v13ap-accelerometer/	Acoustic transmitters with depth and acceleration
Vemco	DO-Tag	dissolved oxygen	Files available with online roadmap	Acoustic transmitter with depth, temp and dissolved oxygen
Vemco	Predation Tag	predation	Files available with online roadmap	Measures the occurance of a predation event upon a tagged fish