



D.3.1– Technology Readiness Level Report

IFREMER

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THE OCEAN OF TOMORROW



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Deliverable 3.1 – Technology Readiness Level Report

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Abstract

Proposed as a reference since the submission of NeXOS, the Technological Readiness Level (TRL) is generally implemented as a metrics for the improvement of technologies (e.g. sensor systems but also related platforms and software). A common definition, and a common methodology of determination of the TRL is discussed, proposed and exemplified here with the validation of four products: one sensor (Recopesca temperature turbidity), one software (Seadataview), one platform (ARVOR CM) and one component (SnO2 antifouling protection). This defines a method that will be then applied for each of the NeXOS sensor systems, in relation with functional analysis report, market study, reliability study, and as a tool for NeXOS Scientific and technical management (TOC) and evaluation. The template of TRL estimate will be made available in the internal NeXOS intranet web pages under WP3 working section. TRL analysis results will be provided in D.3.2 (Functional analysis report – M12).

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1. NeXOS TASK 3.1 FROM THE DESCRIPTION OF WORK

Objectives

Evaluate the technological maturity of sensor systems

Description of Work

Associated Task 3.1. Engineering specifications and technological maturity; Leader: IFREMER; Duration: M6-M12

The target specifications developed as part of WP 1 will determine the required performance in precision, deployment duration etc of the new sensors. The Technology Readiness Level (TRL) will be evaluated for each of the NeXOS sensor systems, leading to basic engineering specifications so that performance can be demonstrated within the duration of the project. The TRL study will use remote interviews and meetings among the NeXOS consortium (including referenced providers) and related projects (EuroARGO, EMSO/ESONET, JERICO, GROOM, etc). It will be based on common practice for sensor choice and enhancement and will critically review the limits and achievements of existing sensors within the market. In parallel to WP5, 6 and 7, this task will perform functional analysis for several multi-sensor architectures and integration scenarios (including multiparameter probe, junction boxes, profilers and gliders as well as new concepts). The analysis will address the following questions:

Is it possible to integrate additional sensors into the NeXOS sensor package?

- what is the feasibility of self calibration and/or self biofouling control?
- can pre-processing and modifications to sampling procedure be applied locally?
- How the RAMS strategy can contribute to the production of more reliable and cost-efficient sensors ?

D3.1) TRL report: The Technology Readiness Level will be evaluated for each of the NeXOS sensor systems, leading to basic engineering specifications so that performance can be demonstrated within the duration of the project. This deliverable will justify part of the work done in task 3.1 [M6]

Inputs needed and reference documents

Deliverable D.1.3: Project implementation plan

Other references: see [1-5]

2. INTRODUCTION

In its initial documents of submission, NEXOS has presented the Technological Readiness Level as a conceptual tool for the support of sensor development and a major indicator for the follow-up of the project (See Table 1 and Figure 1 hereunder). The concept of Technology Readiness Level (TRL) was developed by NASA and ESA for space systems and has recently introduced in ocean observation to identify the stages that a technology needs to pass in order to bridge the gap between research and development and production/operations.

TABLE 2.1 TRL DEFINITION IN NEXOS SUBMISSION DOCUMENT AND DoW.

Level	Description
TRL 1	Basic principles of technology observed and reported
TRL 2	Technology concept and/or application formulated
TRL 3	Analytical and laboratory studies to validate analytical predictions
TRL 4	Component and/or basic sub-system technology valid in lab environment
TRL 5	Component and/or basic sub-system technology valid in relevant environment
TRL 6	System/sub-system technology model or prototype demo in relevant environment
TRL 7	System technology prototype demo in an operational environment
TRL 8	System technology qualified through test and demonstration
TRL 9	System technology qualified through successful mission operations

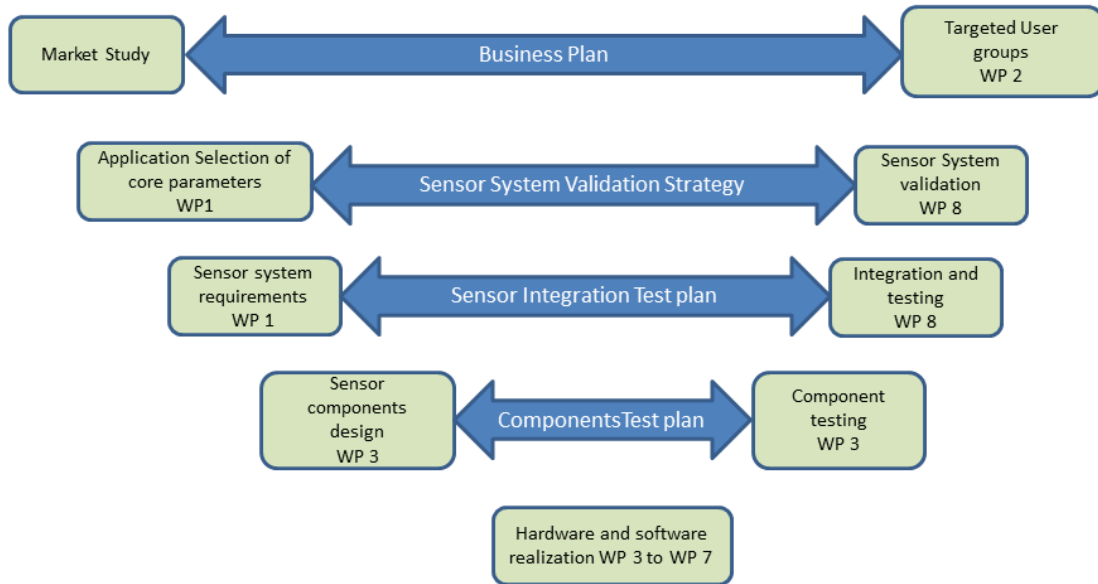


FIGURE 2.1: THE V-DIAGRAM DESCRIBING THE STEPS IN THE DEVELOPMENT PROCESS

This V-shape diagram is describing the process of development of NeXOS, linking the specification, the innovation and the validation activities. The TRL estimates as presented in this report will be a major tool to issue a metrics for the increase of maturity achieved by the project throughout the V-shape process.

3. FINDING THE NeXOS APPROACH AMONG TECHNOLOGY READINESS LEVEL DEFINITIONS

Short history and field of application of TRL

Technology Readiness Levels (TRL's) were invented by NASA after the first failures in the Apollo program. After a few years it was promoted through a paper titled "NASA technology push towards future space mission systems" (Saden, et. al., 1989) [6]. It initially included 7 levels and was increased to 9 later on. It was understood after a while as an interesting way to address the limits of the technology, reliability and the associated risks. In a troubleshooting process, reasons may for example come from lack of maturity of the technology of one component. Readiness level assignment was typically left to the technology developer. When the UK Department of Defense was requested to use NASA's TRL process in 2002, they started to refine the methods. Other large institutions proposed variations, adapted to their field. TRL has been adopted internationally with the use of TRL's at NATO (with specific definitions), ESA, CNES, in Canada, the UK, and Japan. An ISO TRL Working Group (WG) has started to work from an initiative of the British Standards Institute.

In the field of ocean instrumentation, a few actors started to introduce TRL approach in Europe [10], [11]. It was introduced in strategic discussions at national level in the U.K. (Gwynn Griffith NOC) and in France [12].

TABLE 3.1 NASA CURRENT TRL DEFINITION

Definition Of Technology Readiness Levels

TRL 1 Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.

TRL 2 Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.

TRL 3 Analytical and experimental critical function and/or characteristic proof-of-concept: Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.

TRL 4 Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.

TRL 5 System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.

TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.

TRL 7 System prototyping demonstration in an operational environment (ground or space): System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.

TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space): End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.

TRL 9 Actual system "mission proven" through successful mission operations (ground or space): Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

The European Commission, in the Horizon 2020 general annexes G requires to refer to:

TABLE 3.2 EUROPEAN COMMISSION – HORIZON 2020 – TRL LIST

<p style="text-align: center;"><i>HORIZON 2020 – WORK PROGRAMME 2014-2015</i></p> <p style="text-align: center;">General Annexes</p> <p style="text-align: center;">G. Technology readiness levels (TRL)</p> <p>Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:</p> <ul style="list-style-type: none"> • TRL 1 – basic principles observed • TRL 2 – technology concept formulated • TRL 3 – experimental proof of concept • TRL 4 – technology validated in lab • TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies) • TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies) • TRL 7 – system prototype demonstration in operational environment • TRL 8 – system complete and qualified • TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

This is in complete agreement with the NeXOS definition, although less detailed.

In another document available on the internet¹, the EC also describes these levels as follows:

TRL 0: Idea. Unproven concept, no testing has been performed.

TRL 1: Basic research. Principles postulated and observed but no experimental proof available.

TRL 2: Technology formulation. Concept and application have been formulated.

TRL 3: Applied research. First laboratory tests completed; proof of concept.

TRL 4: Small scale prototype built in a laboratory environment ("ugly" prototype).

TRL 5: Large scale prototype tested in intended environment.

TRL 6: Prototype system tested in intended environment close to expected performance.

TRL 7: Demonstration system operating in operational environment at pre-commercial scale.

¹http://ec.europa.eu/research/conferences/2013/energy_infoday/pdf/session_3_summary_of_the_calls_open_in_2014_-_philippe_schild.pdf

TRL 8: First of a kind commercial system. Manufacturing issues solved.

TRL 9: Full commercial application, technology available for consumers.

a) Simplified or extended TRL scales?

The French project Captiven supported by Agence Nationale pour la Recherche is aiming at stimulating instrumentation for the environment developed by SMEs and research institutes. The choice was made to simplify the TRL scale in order to keep a limited number of categories.

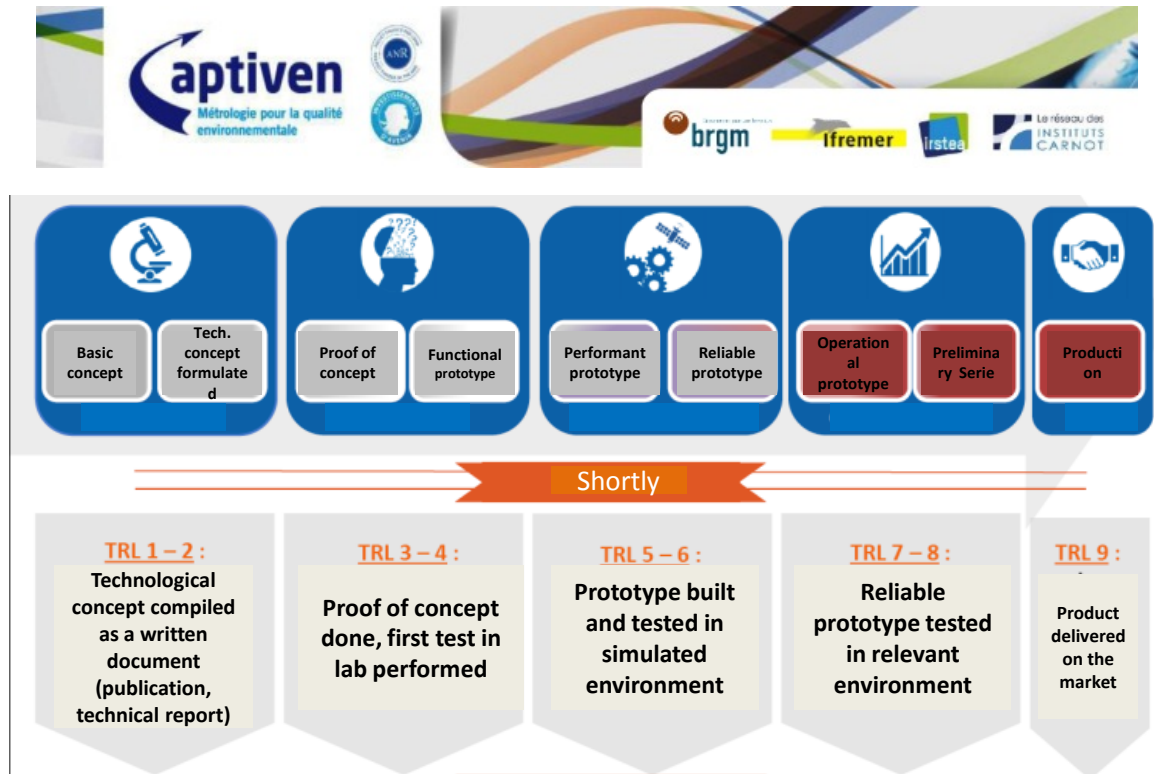


FIGURE 3.1: TRL APPROACH IN CAPTIVEN PROJECT

This approach is useful when we need to present rough estimates of TRL and include them in brochures for a large public. But it does not disseminate the actual difficulties in development and is quite insufficient to introduce a discussion between parties. It could be a means for NeXOS for general market assessment but is in contradiction to the will to follow the advances with a metrics.

A contrasting approach was introduced by NATO, where more detailed descriptions were provided and a TRL0 was even added when adopting the TRL scale.

TRL0: Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and /or observable facts with only a general notion of military applications or military products in mind. Many levels of scientific activity are included here but share the attribute that the technology readiness is not yet achieved.

TRL0 is obviously out of the scope of NeXOS.

For NeXOS, the end of development, corresponding to TRL 6 to 9 (depending on initial levels and objectives for each sensor) needs more attention than the early stage. This is presented in § 4 c)

b) Components, sub-systems or systems?

In Nexos we address several integration levels: sensor systems, platforms, instrumentation systems, interfaces, systems of systems.

We intend to use TRL in priority for the components of the project corresponding to a sensor or sensor component deliverable in a Task, to be tested, validated and demonstrated on a platform mentioned in a scenario or used for validation in WP8 or demonstration in WP9.

Estimate of TRL can be envisaged for the discussion on opportunities in market analysis, comparison of solutions, reliability studies, etc. TRL of components or systems will then be performed.

4. NeXOS TRL QUESTIONNAIRE

a) Description and calculation TRL 1 to TRL 6

A questionnaire made available by nysesda R&D for free use on the internet is proposed for the determination of TRL1 to TRL6. It uses a definition very similar to the TRL definitions of the NeXOS DoW. The only difference comes from the TRL 3 where the questionnaire proposes the “proof of concept” as key word, a concept broadly used by original TRL 3 definitions.

Once the 7 tables have been filled-in by answering a series of yes or no questions, a synthetic TRL evaluation between 1 and 6 is calculated, highlighting the weak point.

OVERALL SUMMARY OF TECHNOLOGY READINESS		
1-1)	Have the basic technology processes and principles been observed and reported?	<input type="radio"/> YES <input checked="" type="radio"/> NO
1-2)	Has an equipment and process concept been formulated?	<input type="radio"/> YES <input checked="" type="radio"/> NO
1-3)	Has equipment and process analysis and proof of concept been demonstrated in a simulated environment?	<input type="radio"/> YES <input checked="" type="radio"/> NO
1-4)	Has laboratory-scale testing of similar equipment systems been completed in a simulated environment?	<input type="radio"/> YES <input checked="" type="radio"/> NO
1-5)	Has bench-scale equipment/process testing been demonstrated in a relevant environment?	<input type="radio"/> YES <input checked="" type="radio"/> NO
1-6)	Has prototypical engineering scale equipment/process testing been demonstrated in relevant environment, incl. testing safety functions?	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.1: OVERALL SUMMARY OF TECHNOLOGY READINESS

MARKET AND CUSTOMER NEEDS		
2-1)	Know who cares about the technology (customer, funding source, etc.) (5)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-2)	Customer identified and expressed interest in the application (1,10)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-3)	Customer representative identified to work with development team and participates in requirements generation (11,12)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-4)	Overall system requirements for end user's application known and documented; performance metrics measuring reqt's established (6,7,8)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-5)	Requirements definition with performance thresholds and objectives established for final design (19)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-6)	Operating environment for final commercial system is known (4)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-7)	Analysis of project timing ensures technology will be available when required (13)	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.2: MARKET AND CUSTOMER NEEDS

DESIGN/DEVELOPMENT		
3-1)	Physical laws and assumptions used in new technologies defined (2)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-2)	Research hypothesis formulated (7)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-3)	Know who would perform research and where it would be done (9)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-4)	Theoretical or empirical design solution identified with basic elements of technology and initial analysis of major functions included (5,6,11,13)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-5)	Potential system/components identified, performance predictions made for each; modeling/simulation only to verify physical properties (2,9,12)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-6)	Qualitative idea of risk areas such as cost, schedule, performance (22)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-7)	Know what output devices are available, capabilities and limitations of researchers and research facilities, and required experiments (17,19,21)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-8)	Preliminary strategy to obtain TRL Level 6 developed (18)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-9)	Preliminary system performance characteristics and measures identified and estimated (6)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-10)	Science known to extent that mathematical and/or computer models and simulations are possible (5)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-11)	Risk areas identified in general terms and risk mitigation strategies identified (24,25)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-12)	Design techniques identified/developed; sources of key components for lab testing identified (15,21)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-13)	Analysis of present state of the art shows technology fills a need (23)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-14)	Scalable prototypes produced (bigger than lab scale) (15)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-15)	Conceptual design developed and documented (16)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-16)	Initial cost drivers identified (19)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-17)	Formal risk management program initiated (21)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-18)	Preliminary design engineering begins and prototypes of components created (4,7)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-19)	Detailed design drawings completed to support engineering-scale system; ability to acquire all components for final prototype (18,22)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-20)	Preliminary cost estimates of commercial product prepared	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-21)	Performance baseline including total project cost, schedule, and scope completed (6)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-22)	Engineering-scale system is high-fidelity functional prototype of operational system (22)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-23)	More precise cost estimates prepared for system	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-24)	Operating limits for components determined (7)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-25)	System design specs are complete and ready for detailed design (20)	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.3: DESIGN/DEVELOPMENT

INTEGRATION	
4-1) Individual parts of the technology work (no real attempt at integration) (16)	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-2) Paper studies indicate that system components should work together (16)	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-3) Modeling and simulation used to simulate some components and interfaces; analysis completed to establish component compatability (5,12)	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-4) Available components assembled into lab scale system; integration studies have begun (10,20)	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-5) System interface issues and requirements known and relationships between major system and sub-systems understood on a lab scale with component	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-6) Integration of modules/functions demonstrated in lab/bench-scale environment (21)	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-7) At engineering scale, relationships between system and subsystems understood and component integration demonstrated (1,11)	<input type="radio"/> YES <input checked="" type="radio"/> NO
4-8) Preliminary design drawings for final system complete (3)	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.4: INTEGRATION

TESTING AND VALIDATION	
5-1) Paper studies confirm basic principles; basic characterization data exists (3,4)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-2) Initial scientific observations reported in journals/conference proceedings/technical reports (5,8)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-3) Paper studies show application is feasible and components of technology have been partially characterized (3,8)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-4) Rigorous analytical studies confirm basic principles; analytical results reported in scientific journals/conference technical reports (14,15)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-5) Predictions of elements of technology capability validated by analytical studies, lab experiments, and modeling and simulation (3,7,10)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-6) Lab experiments verify and fully demonstrate feasibility, but not yet at system components level (8, 9,22)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-7) Individual components and subsystems composed of multiple components tested in lab (3,4)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-8) Lab experiments in a controlled environment show components work together and demonstrate basic functionality in simulated environment (11,14,18)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-9) Requirements for technology verification established and include testing and validation of safety functions (5)	<input type="radio"/> YES <input checked="" type="radio"/> NO
5-10) Lab-scale tests using prototype completed and results validate the design; ready for test in relevant environment; lab environment for testing modified to approximate operational environment (9,11,16,27,32)	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.5: TESTING AND VALIDATION

ENVIRONMENTAL AND SAFETY		
6-1)	Key process and safety requirements and associated hazards have begun to be identified (2,14)	<input type="radio"/> YES <input checked="" type="radio"/> NO
6-2)	Key process variables fully identified, preliminary hazard evaluations completed/documented; safety control strategies being explored (1,31)	<input type="radio"/> YES <input checked="" type="radio"/> NO
6-3)	Range of all relevant physical and chemical properties determined to the extent possible (24)	<input type="radio"/> YES <input checked="" type="radio"/> NO
6-4)	Limits for process variables, parameters & safety controls defined; integration demos done incl. testing/validating safety functions (24,31)	<input type="radio"/> YES <input checked="" type="radio"/> NO
6-5)	Finalization of required hazardous material forms; identification of system/component level safety controls (26)	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.6: ENVIRONMENTAL AND SAFETY

MANUFACTURING AND SCALE UP		
7-1)	Scaling studies have been started (19)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-2)	Current manufacturability concepts assessed (20)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-3)	Equipment scale-up relationships understood/accounted for in technology development; scaling designs completed (17,23)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-4)	Key manufacturing processes identified and assessed in lab; mitigation strategies identified to address manuf/producibility shortfalls (22,24,27)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-5)	Lab to engineering scale scale-up issues understood and resolved (30)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-6)	Manufacturing processes to make components that are new are validated via demonstration in the lab (8)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-7)	Manufacturing techniques have been defined to the point where largest problems are defined (10)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-8)	Engineering to full-scale scale-up issues understood and resolved (29)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-9)	Critical manufacturing processes have been prototyped and scaling issues that remain are identified and understood (12,16)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-10)	Process and tooling are mature to support fabrication of system and components; at least one product demo has been completed (27,33)	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.7: MANUFACTURING AND SCALE UP

PON 2458 - Technology Readiness Calculator - Results

TRL Calculator Results				
TRL	Questions Answered "Yes"	% Complete	Progress Towards Level	
1)	0 of 7	0%		
2)	0 of 10	0%		
3)	0 of 13	0%		
4)	0 of 13	0%		
5)	0 of 13	0%		
6)	0 of 15	0%		


Detailed Results									
By Question Section					By Technology Readiness Level				
1. General	1-1)	No	4-1)	No	TRL 1	1-1)	No	1-4)	No
	1-2)	No	4-2)	No		2-1)	No	2-4)	No
	1-3)	No	4-3)	No		3-1)	No	3-14)	No
	1-4)	No	4-4)	No		3-2)	No	3-15)	No
	1-5)	No	4-5)	No		3-3)	No	3-16)	No
	1-6)	No	4-6)	No		5-1)	No	3-17)	No
2. Market Need	2-1)	No	4-7)	No	TRL 2	5-2)	No	4-3)	No
	2-2)	No	4-8)	No		1-2)	No	4-4)	No
	2-3)	No	5. Testing and Validation	5-1)		2-2)	No	5-7)	No
	2-4)	No		5-2)		3-4)	No	5-8)	No
	2-5)	No		5-3)		3-5)	No	6-2)	No
	2-6)	No		5-4)		3-6)	No	7-3)	No
	2-7)	No		5-5)		3-7)	No	7-4)	No
3. Design & Development	3-1)	No	6. Safety	5-6)	TRL 3	3-8)	No	1-5)	No
	3-2)	No		5-7)		4-1)	No	2-5)	No
	3-3)	No		5-8)		5-3)	No	3-18)	No
	3-4)	No		5-9)		5-4)	No	3-19)	No
	3-5)	No		5-10)		1-3)	No	3-20)	No
	3-6)	No	7. Manufacturing & Scale	6-1)	TRL 4	2-3)	No	4-5)	No
	3-7)	No		6-2)		3-9)	No	4-6)	No
	3-8)	No		6-3)		3-10)	No	6-3)	No
	3-9)	No		6-4)		3-11)	No	7-5)	No
	3-10)	No		6-5)		3-12)	No	7-6)	No
	3-11)	No		7-1)	TRL 5	3-13)	No	7-7)	No
	3-12)	No		7-2)		4-2)	No	1-6)	No
	3-13)	No		7-3)		5-5)	No	2-6)	No
	3-14)	No		7-4)		5-6)	No	2-7)	No
	3-15)	No		7-5)		6-1)	No	3-21)	No
	3-16)	No		7-6)		7-1)	No	3-22)	No
	3-17)	No		7-7)		7-2)	No	3-23)	No
	3-18)	No		7-8)				3-24)	No
	3-19)	No		7-9)				3-25)	No
	3-20)	No		7-10)				4-7)	No
	3-21)	No			TRL 6			4-8)	No
	3-22)	No						6-4)	No
	3-23)	No						6-5)	No
	3-24)	No						7-8)	No
	3-25)	No						7-9)	No

FIGURE 4.8: SYNTHETIC TABLE CALCULATED BY THE EXCEL SHEET

b) Next steps from TRL 7 to TRL 9

A continuation of the questionnaire, proceeding TRL by TRL is proposed for the 3 next levels once

TRL6 is achieved.




Technology Readiness Calculator TRL7 issues

SYSTEM TECHNOLOGY PROTOTYPE DEMO IN AN OPERATIONAL ENVIRONMENT	
VII-1) Pressure tests with safety coefficient	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-2) Temperature, vibration and other environment tests	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-3) Interface with platform is validated	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-4) Functional tests in simulated environment	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-5) Functional tests at sea (short or shallow)	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-6) Prototypical engineering scale equipment/process demonstrated in various environment conditions and various functional configurations, incl. testing safety functions?	<input type="radio"/> YES <input checked="" type="radio"/> NO

Applicant Name:

Comments


FIGURE 4.9: TECHNOLOGY READINESS CALCULATOR TRL7 ISSUES



Technology Readiness Calculator TRL8 issues

SYSTEM TECHNOLOGY QUALIFIED THROUGH TEST AND DEMONSTRATION	
VIII-1) Tested in all environmental conditions	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-2) Manufacturing issues solved for several products	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-3) Several demonstrations performed	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-4) Operated by one end user at least	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-5) Commercial system available	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-6) Manufacturing and user documentation established	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.10: TECHNOLOGY READINESS CALCULATOR TRL8 ISSUES



Technology Readiness Calculator TRL9 issues

SYSTEM TECHNOLOGY QUALIFIED THROUGH SUCCESSFUL MISSION OPERATION	
IX-1) Experience in a full range of operating conditions	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-2) Manufacturing performed for several contracts	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-3) Operation by several end users	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-4) Functional tests in simulated environment	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-5) Several commercial contracts	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-6) User group and/or FAQ and/or report/publication by user	<input type="radio"/> YES <input checked="" type="radio"/> NO

FIGURE 4.11: TECHNOLOGY READINESS CALCULATOR TRL9 ISSUES

c) Various uses/market according to equipment (9+)

Being at the forefront of innovation and high-tech, the inventor of TRL at NASA or the promoters inside the weapon systems of NATO considered the proof in operation stage as a final one. In other industrial fields, several hierarchies may be found. A TRL 9 recognized in one field (home kitchen) may not be sufficient for another commercial application such as the kitchen of a restaurant.

Oceanography was started by Navy engineers and the references of readiness were military. Since the end of the 80s, a new generation of instruments was able to promote more cost-efficient technical solutions. NeXOS ambition is to proceed in this direction in order to “improve the temporal and spatial coverage, resolution and quality of marine observations”. Our NeXOS TRL9 is the ultimate fulfilment of the cost efficiency and reliability objectives of the project.

Nevertheless, some industries are not satisfied with the oceanography references in term of robustness, size and capital base of the provider, security specifications... In this case, NEXOS TRL 9 “System technology qualified through successful mission operations” may not be sufficient to ensure the H2020 TRL 9 “Full commercial application”. It is probably because an industrial field will not recognize qualification capacities of “mission operations” that are not from the same industrial field.

For the sake of this report and further uses in these special cases of reliability (WP3) and market studies (WP2) in NEXOS, we will mention a 9+ level with a reference to the specific market.

TRL9+ OIL AND GAS

TRL9+ DEFENCE

TRL9+ FISHERY

TRL9+ MARINE RENEWABLE ENERGIES

d) Methodology of use: interview and/or working sessions with specialists

The questionnaire will be answered through an interview with the task leads for project products developments.

5. KEY COMPONENTS FOR TRL ESTIMATE FOR THE TASK 3.1

The TRL of the following components will be evaluated during Task 3.1. Those in red are used as reference for the present deliverable.

Optical sensor systems

NEXOS WP5 starting products

(FRANATECH)

(TRIOS)

(HZG)

(NIVA)

Other projects

CHEMINI (EXOCET-D/*Ifremer*) for comparison purpose

Passive acoustics sensor systems

NEXOS A1 and A2 for NeXOS WP6

Ecosystem approach to fisheries management sensor systems (EAF)

RECOPECA oxygen, fluorescence (e.g. chlorophyll-a initially identified in DoW) and turbidity (tentative) sensors.

Sensor anti-fouling

Chlorination system (NEXOS WP3 starting product/*nke, Ifremer*). This component is an important issue (NeXOS WP3).

Sensor interface interoperability

UPC/smart sensor interface and 52N/SWE integrated implementation

6. RESULTS PER EQUIPMENT**1. Optical sensor systems**

To be determined.

2. Passive acoustics sensor systems

To be determined.

3. Ecosystem approach to fisheries management sensor systems (EAF)

RECOPECA oxygen, fluorescence and (tentative) turbidity (NEXOS WP7 starting product/nke)

The level is strictly TRL 5. Solving weaknesses in performance baselines will bring it to TRL8. Solving the severity level of shock test issue in addition would bring it to TRL9.

4. Sensor anti-fouling

Chlorination system (NEXOS WP3 intended product/nke, *lfremer*)

The level is TRL2. Next topics to address are risk mitigation strategy and pressure tests. Proofs of achievement are advanced up to TRL7 questions concerning environment constraints but results are lacking for producibility issues and the validation of low impact of by-products.

5. Sensor interface interoperability and software

Level is to be determined. In general and especially the page 5 of the questionnaire, the simulations, lab experiments and modelling are not criteria suited for software.

7. SYNTHETIC VIEW**a. Limits of the exercise**

The TRL analysis with a simple questionnaire is not a complete study. Functional analysis, reliability analysis, etc. will bring additional input.

b. Trends

We can see from the first cases that some issues such as safety, client involvement and risk analysis are less often treated at an early stage than for instance environmental tests.

We will have to see during the next months if these tendencies are confirmed.

c. Special cases

The TRL analysis performed on software reveals that many questions are easily achieved because developers are used to apply Quality Assurance methods to produce software codes. Some questions are also not suited for certain types of products such as software. Despite these caveats, overall the method of TRL assessment is able to reveal lacks and the estimate of TRL is reasonable with respect to the general progress of the development.

8. DISCUSSION ON THE NEXOS OBJECTIVES IN TERMS OF INCREASED READINESS

The V-diagram (**Error! Reference source not found.**) shows the series of steps of development in NeXOS. It is suggested to use TRL at several stages:

- ❖ Initial evaluation of the state of the art inside the NeXOS consortium as most of the developments start after feasibility assessment and aim at increasing TRL. This must be estimated by the developers and be considered as a way to express their individual objectives during the Project duration.

- ❖ Objectives for NeXOS developments as expressed by the DoW and revised through sensor requirements workshops can be presented in terms of TRL increase.
- ❖ Some items in the questionnaire show weak points. If they concern reliability they may be solved with the help of WP3 and WP4. If they concern simulated environment, they may be solved with contribution of WP3. If they concern validation, they are in the scope of WP8. If they concern demonstration, they are in the scope of WP9. If they concern market or relations to clients, they may be addressed by WP2 and/or WP1. A plan to solve weak points would help the developer.

9. CONCLUSIONS

The template of TRL estimate will be made available on the internal NeXOS intranet web pages under WP3 working section.

The basis of a metrics for NeXOS technological development using TRL has been established.

The final validation of the method used for TRL will be continued during the second part of Task 3.1:

It will be applied to the 7 sensor systems of NeXOS.

It will be compared with the market maturity to be addressed by the market study in Work package 2 (D2.1 Market Assessment)

It will be used by the engineering specifications (D3.2) to establish the target of TRL increase for each product.

What NeXOS participants need to know before TRL increase assessment of Task 3.5 is performed (due month 39):

- ❖ The TRL estimate is done on declarative principles. It is neither binding the interviewer nor the developer who is interviewed, neither legally nor morally.
- ❖ The TRL figures will not be published outside the NeXOS consortium without acceptance of the developer. If a more strict confidentiality is required by private partner, the request will be submitted to the NeXOS TOC.
- ❖ One of the more interesting outcome for the TRL estimate exercise is to identify the issues which have not been solved (sometimes simply forgotten). By solving them, one or often more TRL levels can be earned.

The 2nd Ordinary Project meeting on April 1st 2014 supported the idea to use the present document as a basis to promote a common TRL estimation between the 4 “intercooperation projects” (NeXOS, SenseOcean, Commonsense, Schema).

10. REFERENCES

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11. APPENDIX 1: Example of initial TRL of Recopesca temperature – turbidity probe.

PON 2458 - Technology Readiness Calculator - Results

TRL Calculator Results			
TRL	Questions Answered "Yes"	% Complete	Progress Towards Level
1)	7 of 7	100%	<div></div>
2)	10 of 10	100%	<div></div>
3)	13 of 13	100%	<div></div>
4)	13 of 13	100%	<div></div>
5)	13 of 13	100%	<div></div>
6)	14 of 15	93%	<div></div>

Detailed Results									
By Question Section					By Technology Readiness Level				
1. General	1-1)	Yes	4. Integration	4-1)	Yes	TRL 1	1-4)	Yes	TRL 4
	1-2)	Yes		4-2)	Yes		2-4)	Yes	
	1-3)	Yes		4-3)	Yes		3-14)	Yes	
	1-4)	Yes		4-4)	Yes		3-15)	Yes	
	1-5)	Yes		4-5)	Yes		3-16)	Yes	
	1-6)	Yes		4-6)	Yes		3-17)	Yes	
2. Market Need	2-1)	Yes		4-7)	Yes	TRL 2	4-3)	Yes	
	2-2)	Yes	5. Testing and Validation	4-8)	Yes		4-4)	Yes	
	2-3)	Yes		5-1)	Yes		5-7)	Yes	
	2-4)	Yes		5-2)	Yes		5-8)	Yes	
	2-5)	Yes		5-3)	Yes		6-2)	Yes	
	2-6)	Yes		5-4)	Yes		7-3)	Yes	
3. Design & Development	2-7)	Yes		5-5)	Yes	TRL 3	7-4)	Yes	
	3-1)	Yes		5-6)	Yes		1-5)	Yes	TRL 5
	3-2)	Yes	6. Safety	5-7)	Yes		2-5)	Yes	
	3-3)	Yes		5-8)	Yes		3-18)	Yes	
	3-4)	Yes		5-9)	Yes		3-19)	Yes	
	3-5)	Yes		5-10)	Yes		3-20)	Yes	
	3-6)	Yes		6-1)	Yes	TRL 6	4-5)	Yes	
	3-7)	Yes	7. Manufacturing & Scale	6-2)	Yes		4-6)	Yes	
	3-8)	Yes		6-3)	Yes		6-3)	Yes	
	3-9)	Yes		6-4)	Yes		7-5)	Yes	
	3-10)	Yes		6-5)	Yes		7-6)	Yes	
	3-11)	Yes		7-1)	Yes		7-7)	Yes	
	3-12)	Yes		7-2)	Yes	TRL 3	1-6)	Yes	TRL 6
	3-13)	Yes		7-3)	Yes		2-6)	Yes	
	3-14)	Yes		7-4)	Yes		2-7)	Yes	
	3-15)	Yes		7-5)	Yes		3-21)	No	
	3-16)	Yes		7-6)	Yes		3-22)	Yes	
	3-17)	Yes		7-7)	Yes		3-23)	Yes	
	3-18)	Yes		7-8)	Yes		3-24)	Yes	
	3-19)	Yes		7-9)	Yes		3-25)	Yes	
	3-20)	Yes		7-10)	Yes		4-7)	Yes	
	3-21)	No					4-8)	Yes	
	3-22)	Yes					6-4)	Yes	
	3-23)	Yes					6-5)	Yes	
	3-24)	Yes					7-8)	Yes	
	3-25)	Yes					7-9)	Yes	
							7-10)	Yes	



Technology Readiness Calculator TRL7 issues

SYSTEM TECHNOLOGY PROTOTYPE DEMO IN AN OPERATIONAL ENVIRONMENT	
VII-1) Pressure tests with safety coefficient	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-2) Temperature, vibration and other environment tests	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-3) Interface with platform is validated	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-4) Functional tests in simulated environment	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-5) Functional tests at sea (short or shallow)	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-6) Prototypical engineering scale equipment/process demonstrated in various environment conditions and various functional configurations, incl. testing safety functions?	<input checked="" type="radio"/> YES <input type="radio"/> NO

Applicant Name:

Ifremer and nke

Comments

The condition of use are very difficult due to shocks on the fishing vessels. Limitation of measurement near the sea floor prevent from use on board benthic trawlers.

Technology Readiness Calculator TRL8 issues

SYSTEM TECHNOLOGY QUALIFIED THROUGH TEST AND DEMONSTRATION	
VIII-1) Tested in all environmental conditions	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-2) Manufacturing issues solved for several products	<input checked="" type="radio"/> YES <input type="radio"/> NO
VIII-3) Several demonstrations performed	<input checked="" type="radio"/> YES <input type="radio"/> NO
VIII-4) Operated by one end used at least	<input checked="" type="radio"/> YES <input type="radio"/> NO
VIII-5) Commercial system available	<input checked="" type="radio"/> YES <input type="radio"/> NO
VIII-6) Manufacturing and user documentation established	<input checked="" type="radio"/> YES <input type="radio"/> NO

Applicant Name:

Ifremer and nke

Comments

Shock tests performed are the standard ones.

SYSTEM TECHNOLOGY QUALIFIED THROUGH SUCCESSFULL MISSION OPERATION	
IX-1) Experience in a full range of operating conditions	<input checked="" type="radio"/> YES <input type="radio"/> NO
IX-2) Manufacturing performed for several contracts	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-3) Operation by several end users	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-4) Functional tests in simulated environment	<input checked="" type="radio"/> YES <input type="radio"/> NO
IX-5) Several commercial contracts	<input type="radio"/> YES <input checked="" type="radio"/> NO
IX-6) User group and/or FAQ and/or report/publication by user	<input type="radio"/> YES <input checked="" type="radio"/> NO

Applicant Name:
Ifremer and nke

Comments
<p>Unlike the other Recopesca probes used by several clients , the Temperature-Pressure-Turbidity have been operated by several shipsbut only through one contract with regional operational oceanography project Previmer.</p>



Technology Readiness Calculator TRL9+ (not official, for the sake of NeXOS only)

SYSTEM TECHNOLOGY ACCEPTED IN A DEMANDING MARKET	
1) Oil and gas	<input type="radio"/> YES <input checked="" type="radio"/> NO
2) Fisheries	<input checked="" type="radio"/> YES <input type="radio"/> NO
3) Defense	<input type="radio"/> YES <input checked="" type="radio"/> NO
4) Marine Renewables	<input type="radio"/> YES <input checked="" type="radio"/> NO
5)	<input type="radio"/> YES <input checked="" type="radio"/> NO
6) Other	<input type="radio"/> YES <input checked="" type="radio"/> NO

Applicant Name:
Ifremer and nke

Comments
<p>Targeted industry is fishery. Other Recopesca components are already accepted. Temperature pressure turbidity is under evaluation still.</p>

12. APPENDIX 2: Example of Initial TRL of antifouling SnO2

Technology Readiness Calculator (Page 1 of 7)

OVERALL SUMMARY OF TECHNOLOGY READINESS		
1-1)	Have the basic technology processes and principles been observed and reported?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-2)	Has an equipment and process concept been formulated?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-3)	Has equipment and process analysis and proof of concept been demonstrated in a simulated environment?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-4)	Has laboratory-scale testing of similar equipment systems been completed in a simulated environment?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-5)	Has bench-scale equipment/process testing been demonstrated in a relevant environment?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-6)	Has prototypical engineering scale equipment/process testing been demonstrated in relevant environment, incl. testing safety functions?	<input type="radio"/> YES <input checked="" type="radio"/> NO

Applicant Name:
NEXOS ANTIFOULING SNO2

Technology Readiness Calculator (Page 2 of 7)

MARKET AND CUSTOMER NEEDS		
2-1)	Know who cares about the technology (customer, funding source, etc.) (6)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-2)	Customer identified and expressed interest in the application (1,10)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-3)	Customer representative identified to work with development team and participates in requirements generation (11,12)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-4)	Overall system requirements for end user's application known and documented; performance metrics measuring reqt's established (6,7,8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-5)	Requirements definition with performance thresholds and objectives established for final design (19)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-6)	Operating environment for final commercial system is known (4)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-7)	Analysis of project timing ensures technology will be available when required (13)	<input checked="" type="radio"/> YES <input type="radio"/> NO

Technology Readiness Calculator (Page 3 of 7)

DESIGN/DEVELOPMENT	
3-1) Physical laws and assumptions used in new technologies defined (2)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-2) Research hypothesis formulated (7)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-3) Know who would perform research and where it would be done (9)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-4) Theoretical or empirical design solution identified with basic elements of technology and initial analysis of major functions included (5,6,11,13)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-5) Potential system/components identified, performance predictions made for each; modeling/simulation only to verify physical properties (2,9,12)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-6) Qualitative idea of risk areas such as cost, schedule, performance (22)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-7) Know what output devices are available, capabilities and limitations of researchers and research facilities, and required experiments (17,19,21)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-8) Preliminary strategy to obtain TRL Level 6 developed (18)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-9) Preliminary system performance characteristics and measures identified and estimated (6)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-10) Science known to extent that mathematical and/or computer models and simulations are possible (5)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-11) Risk areas identified in general terms and risk mitigation strategies identified (24,25)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-12) Design techniques identified/developed; sources of key components for lab testing identified (15,21)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-13) Analysis of present state of the art shows technology fills a need (23)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-14) Scalable prototypes produced (bigger than lab scale) (15)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-15) Conceptual design developed and documented (16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-16) Initial cost drivers identified (19)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-17) Formal risk management program initiated (21)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-18) Preliminary design engineering begins and prototypes of components created (4,7)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-19) Detailed design drawings completed to support engineering-scale system; ability to acquire all components for final prototype (18,22)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-20) Preliminary cost estimates of commercial product prepared	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-21) Performance baseline including total project cost, schedule, and scope completed (6)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-22) Engineering-scale system is high-fidelity functional prototype of operational system (22)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-23) More precise cost estimates prepared for system	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-24) Operating limits for components determined (7)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-25) System design specs are complete and ready for detailed design (20)	<input checked="" type="radio"/> YES <input type="radio"/> NO
Comments	
NEXOS ANTIFOULING SNO2 - COST ESTIMATES ARE NOT YET FULLY ADDRESSED	

Technology Readiness Calculator (Page 4 of 7)

INTEGRATION	
4-1) Individual parts of the technology work (no real attempt at integration) (16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-2) Paper studies indicate that system components should work together (16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-3) Modeling and simulation used to simulate some components and interfaces; analysis completed to establish component compatability (5,12)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-4) Available components assembled into lab scale system; integration studies have begun (10,20)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-5) System interface issues and requirements known and relationships between major system and sub-systems understood on a lab scale with component	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-6) Integration of modules/functions demonstrated in lab/bench-scale environment (21)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-7) At engineering scale, relationships between system and subsystems understood and component integration demonstrated (1,11)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-8) Preliminary design drawings for final system complete (3)	<input type="radio"/> YES <input checked="" type="radio"/> NO

Technology Readiness Calculator (Page 5 of 7)

TESTING AND VALIDATION	
5-1) Paper studies confirm basic principles; basic characterization data exists (3,4)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-2) Initial scientific observations reported in journals/conference proceedings/technical reports (5,8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-3) Paper studies show application is feasible and components of technology have been partially characterized (3,8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-4) Rigorous analytical studies confirm basic principles; analytical results reported in scientific journals/conference technical reports (14,15)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-5) Predictions of elements of technology capability validated by analytical studies, lab experiments, and modeling and simulation (3,7,10)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-6) Lab experiments verify and fully demonstrate feasibility, but not yet at system components level (8, 9,22)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-7) Individual components and subsystems composed of multiple components tested in lab (3,4)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-8) Lab experiments in a controlled environment show components work together and demonstrate basic functionality in simulated environment (11,14,18)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-9) Requirements for technology verification established and include testing and validation of safety functions (5)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-10) Lab-scale tests using prototype completed and results validate the design; ready for test in relevant environment; lab environment for testing modified to approximate operational environment (9,11,16,27,32)	<input checked="" type="radio"/> YES <input type="radio"/> NO

Technology Readiness Calculator (Page 6 of 7)

ENVIRONMENTAL AND SAFETY		
6-1)	Key process and safety requirements and associated hazards have begun to be identified (2,14)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-2)	Key process variables fully identified, preliminary hazard evaluations completed/documentated; safety control strategies being explored (1,31)	<input type="radio"/> YES <input checked="" type="radio"/> NO
6-3)	Range of all relevant physical and chemical properties determined to the extent possible (24)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-4)	Limits for process variables, parameters & safety controls defined; integration demos done incl. testing/validating safety functions (24,31)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-5)	Finalization of required hazardous material forms; identification of system/component level safety controls (26)	<input type="radio"/> YES <input checked="" type="radio"/> NO

Comments
AN HSE EVALUATION IS NEEDED FOR CHEMICALS PRODUCED DURING THE ELECTROCHEMICAL REACTIONS

MANUFACTURING AND SCALE UP	
7-1) Scaling studies have been started (19)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-2) Current manufacturability concepts assessed (20)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-3) Equipment scale-up relationships understood/accounted for in technology development; scaling designs completed (17,23)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-4) Key manufacturing processes identified and assessed in lab; mitigation strategies identified to address manuf/productibility shortfalls (22,24,27)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-5) Lab to engineering scale scale-up issues understood and resolved (30)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-6) Manufacturing processes to make components that are new are validated via demonstration in the lab (8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-7) Manufacturing techniques have been defined to the point where largest problems are defined (10)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-8) Engineering to full-scale scale-up issues understood and resolved (29)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-9) Critical manufacturing processes have been prototyped and scaling issues that remain are identified and understood (12,16)	<input type="radio"/> YES <input checked="" type="radio"/> NO
7-10) Process and tooling are mature to support fabrication of system and components; at least one product demo has been completed (27,33)	<input type="radio"/> YES <input checked="" type="radio"/> NO
Comments	
FOR CONFIDENTIALITY REASONS, THE SCALE UP OF SOME MANUFACTURING PROCESSES HAVE NOT BEEN ADRESSED YET	

TRL Calculator Results				
TRL	Questions Answered "Yes"	% Complete	Progress Towards Level	
1)	7 of 7	100%	<div><div></div></div>	
2)	10 of 10	100%	<div><div></div></div>	
3)	10 of 13	77%	<div><div></div></div>	
4)	9 of 13	69%	<div><div></div></div>	
5)	9 of 13	69%	<div><div></div></div>	
6)	6 of 15	40%	<div><div></div></div>	

Detailed Results										
By Question Section					By Technology Readiness Level					
1. General	1-1)	Yes	4. Integration	4-1)	Yes	TRL 1	1-1)	Yes	1-4)	Yes
	1-2)	Yes		4-2)	Yes		2-1)	Yes	2-4)	Yes
	1-3)	Yes		4-3)	Yes		3-1)	Yes	3-14)	Yes
	1-4)	Yes		4-4)	Yes		3-2)	Yes	3-15)	Yes
	1-5)	Yes		4-5)	Yes		3-3)	Yes	3-16)	Yes
	1-6)	No		4-6)	Yes		5-1)	Yes	3-17)	No
2. Market Need	2-1)	Yes		4-7)	Yes	5-2)	Yes	TRL 4	4-3)	Yes
	2-2)	Yes		4-8)	No	1-2)	Yes		4-4)	Yes
	2-3)	Yes	5. Testing and Validation	5-1)	Yes	2-2)	Yes		5-7)	Yes
	2-4)	Yes		5-2)	Yes	3-4)	Yes		5-8)	Yes
	2-5)	No		5-3)	Yes	3-5)	Yes		6-2)	No
	2-6)	Yes		5-4)	Yes	3-6)	Yes		7-3)	No
2-7)	Yes	5-5)		Yes	3-7)	Yes	7-4)	No		
		5-6)		Yes	3-8)	Yes	TRL 5	1-5)	Yes	
3. Design & Development	3-1)	Yes		5-7)	Yes	4-1)		Yes	2-5)	No
	3-2)	Yes		5-8)	Yes	5-3)		Yes	3-18)	Yes
	3-3)	Yes		5-9)	Yes	5-4)		Yes	3-19)	Yes
	3-4)	Yes		5-10)	Yes	1-3)		Yes	3-20)	No
	3-5)	Yes	6. Safety	6-1)	Yes	2-3)		Yes	4-5)	Yes
	3-6)	Yes		6-2)	No	3-9)	Yes	4-6)	Yes	
	3-7)	Yes		6-3)	Yes	3-10)	No	6-3)	Yes	
	3-8)	Yes		6-4)	Yes	3-11)	No	7-5)	No	
	3-9)	Yes		6-5)	No	3-12)	Yes	7-6)	Yes	
	3-10)	No	7. Manufacturing & Scale	7-1)	No	3-13)	Yes	7-7)	No	
	3-11)	No		7-2)	Yes	4-2)	Yes	TRL 6	1-6)	No
	3-12)	Yes		7-3)	No	5-5)	Yes		2-6)	Yes
	3-13)	Yes		7-4)	No	5-6)	Yes		2-7)	Yes
	3-14)	Yes		7-5)	No	6-1)	Yes		3-21)	No
	3-15)	Yes		7-6)	Yes	7-1)	No		3-22)	No
	3-16)	Yes		7-7)	No	7-2)	Yes		3-23)	No
	3-17)	No		7-8)	No				3-24)	Yes
	3-18)	Yes		7-9)	No				3-25)	Yes
	3-19)	Yes		7-10)	No				4-7)	Yes
	3-20)	No					4-8)		No	
	3-21)	No					6-4)	Yes		
	3-22)	No					6-5)	No		
	3-23)	No					7-8)	No		
	3-24)	Yes					7-9)	No		
	3-25)	Yes					7-10)	No		



Technology Readiness Calculator TRL7 issues

SYSTEM TECHNOLOGY PROTOTYPE DEMO IN AN OPERATIONAL ENVIRONMENT	
VII-1) Pressure tests with safety coefficient	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-2) Temperature, vibration and other environment tests	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-3) Interface with platform is validated	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-4) Functional tests in simulated environment	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-5) Functional tests at sea (short or shallow)	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-6) Prototypical engineering scale equipment/process demonstrated in various environment conditions and various functional configurations, incl. testing safety functions?	<input type="radio"/> YES <input checked="" type="radio"/> NO

13. APPENDIX 3: Initial TRL of Seadataview

TRL Calculator Results			
TRL	Questions Answered "Yes"	% Complete	Progress Towards Level
1)	7 of 7	100%	<div><div></div></div>
2)	9 of 10	90%	<div><div></div></div>
3)	10 of 13	77%	<div><div></div></div>
4)	9 of 13	69%	<div><div></div></div>
5)	8 of 13	62%	<div><div></div></div>
6)	6 of 15	40%	<div><div></div></div>

Detailed Results									
By Question Section					By Technology Readiness Level				
1. General	1-1)	Yes	4. Integration	4-1)	Yes	TRL 1	1-1)	Yes	TRL 4
	1-2)	Yes		4-2)	Yes		2-1)	Yes	
	1-3)	Yes		4-3)	Yes		3-1)	Yes	
	1-4)	Yes		4-4)	Yes		3-2)	Yes	
	1-5)	Yes		4-5)	Yes		3-3)	Yes	
	1-6)	Yes		4-6)	Yes		5-1)	Yes	
2. Market Need	2-1)	Yes	5. Testing and Validation	4-7)	No	TRL 2	5-2)	Yes	
	2-2)	Yes		4-8)	No		1-2)	Yes	TRL 5
	2-3)	No		5-1)	Yes		2-2)	Yes	
	2-4)	No		5-2)	Yes		3-4)	Yes	
	2-5)	Yes		5-3)	Yes		3-5)	Yes	
	2-6)	Yes		5-4)	No		3-6)	Yes	
3. Design & Development	2-7)	Yes	6. Safety	5-5)	No	TRL 3	3-7)	Yes	TRL 6
	3-1)	Yes		5-6)	Yes		3-8)	Yes	
	3-2)	Yes		5-7)	Yes		4-1)	Yes	
	3-3)	Yes		5-8)	No		5-3)	Yes	
	3-4)	Yes		5-9)	No		5-4)	No	
	3-5)	Yes		5-10)	No		1-3)	Yes	
	3-6)	Yes	7. Manufacturing & Scale	6-1)	Yes		2-3)	No	
	3-7)	Yes		6-2)	No		3-9)	Yes	
	3-8)	Yes		6-3)	Yes		3-10)	Yes	
	3-9)	Yes		6-4)	No		3-11)	No	
	3-10)	Yes		6-5)	No		3-12)	Yes	
	3-11)	No		7-1)	Yes		3-13)	Yes	
	3-12)	Yes		7-2)	Yes		4-2)	Yes	
	3-13)	Yes		7-3)	Yes		5-5)	No	
	3-14)	Yes		7-4)	Yes		5-6)	Yes	
	3-15)	Yes		7-5)	Yes		6-1)	Yes	
	3-16)	Yes		7-6)	No		7-1)	Yes	
	3-17)	No		7-7)	Yes		7-2)	Yes	
	3-18)	No		7-8)	Yes				
	3-19)	No		7-9)	Yes				
	3-20)	Yes		7-10)	No				
	3-21)	No							
	3-22)	No							
	3-23)	No							
	3-24)	Yes							
	3-25)	No							

14. APPENDIX 4: Example of Initial TRL of Arvor CM

OVERALL SUMMARY OF TECHNOLOGY READINESS		
1-1)	Have the basic technology processes and principles been observed and reported?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-2)	Has an equipment and process concept been formulated?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-3)	Has equipment and process analysis and proof of concept been demonstrated in a simulated environment?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-4)	Has laboratory-scale testing of similar equipment systems been completed in a simulated environment?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-5)	Has bench-scale equipment/process testing been demonstrated in a relevant environment?	<input checked="" type="radio"/> YES <input type="radio"/> NO
1-6)	Has prototypical engineering scale equipment/process testing been demonstrated in relevant environment, incl. testing safety functions?	<input checked="" type="radio"/> YES <input type="radio"/> NO

MARKET AND CUSTOMER NEEDS		
2-1)	Know who cares about the technology (customer, funding source, etc.) (6)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-2)	Customer identified and expressed interest in the application (1,10)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-3)	Customer representative identified to work with development team and participates in requirements generation (11,12)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-4)	Overall system requirements for end user's application known and documented; performance metrics measuring reqt's established (6,7,8)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-5)	Requirements definition with performance thresholds and objectives established for final design (19)	<input type="radio"/> YES <input checked="" type="radio"/> NO
2-6)	Operating environment for final commercial system is known (4)	<input checked="" type="radio"/> YES <input type="radio"/> NO
2-7)	Analysis of project timing ensures technology will be available when required (13)	<input checked="" type="radio"/> YES <input type="radio"/> NO

DESIGN/DEVELOPMENT	
3-1) Physical laws and assumptions used in new technologies defined (2)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-2) Research hypothesis formulated (7)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-3) Know who would perform research and where it would be done (9)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-4) Theoretical or empirical design solution identified with basic elements of technology and initial analysis of major functions included (5,6,11,13)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-5) Potential system/components identified, performance predictions made for each; modeling/simulation only to verify physical properties (2,9,12)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-6) Qualitative idea of risk areas such as cost, schedule, performance (22)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-7) Know what output devices are available, capabilities and limitations of researchers and research facilities, and required experiments (17,19,21)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-8) Preliminary strategy to obtain TRL Level 6 developed (18)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-9) Preliminary system performance characteristics and measures identified and estimated (6)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-10) Science known to extent that mathematical and/or computer models and simulations are possible (5)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-11) Risk areas identified in general terms and risk mitigation strategies identified (24,25)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-12) Design techniques identified/developed; sources of key components for lab testing identified (15,21)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-13) Analysis of present state of the art shows technology fills a need (23)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-14) Scalable prototypes produced (bigger than lab scale) (15)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-15) Conceptual design developed and documented (16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-16) Initial cost drivers identified (19)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-17) Formal risk management program initiated (21)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-18) Preliminary design engineering begins and prototypes of components created (4,7)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-19) Detailed design drawings completed to support engineering-scale system; ability to acquire all components for final prototype (18,22)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-20) Preliminary cost estimates of commercial product prepared	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-21) Performance baseline including total project cost, schedule, and scope completed (6)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-22) Engineering-scale system is high-fidelity functional prototype of operational system (22)	<input type="radio"/> YES <input checked="" type="radio"/> NO
3-23) More precise cost estimates prepared for system	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-24) Operating limits for components determined (7)	<input checked="" type="radio"/> YES <input type="radio"/> NO
3-25) System design specs are complete and ready for detailed design (20)	<input checked="" type="radio"/> YES <input type="radio"/> NO

INTEGRATION		
4-1)	Individual parts of the technology work (no real attempt at integration) (16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-2)	Paper studies indicate that system components should work together (16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-3)	Modeling and simulation used to simulate some components and interfaces; analysis completed to establish component compatability (5,12)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-4)	Available components assembled into lab scale system; integration studies have begun (10,20)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-5)	System interface issues and requirements known and relationships between major system and sub-systems understood on a lab scale with component	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-6)	Integration of modules/functions demonstrated in lab/bench-scale environment (21)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-7)	At engineering scale, relationships between system and subsystems understood and component integration demonstrated (1,11)	<input checked="" type="radio"/> YES <input type="radio"/> NO
4-8)	Preliminary design drawings for final system complete (3)	<input checked="" type="radio"/> YES <input type="radio"/> NO

TESTING AND VALIDATION		
5-1)	Paper studies confirm basic principles; basic characterization data exists (3,4)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-2)	Initial scientific observations reported in journals/conference proceedings/technical reports (5,8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-3)	Paper studies show application is feasible and components of technology have been partially characterized (3,8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-4)	Rigorous analytical studies confirm basic principles; analytical results reported in scientific journals/conference technical reports (14,15)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-5)	Predictions of elements of technology capability validated by analytical studies, lab experiments, and modeling and simulation (3,7,10)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-6)	Lab experiments verify and fully demonstrate feasibility, but not yet at system components level (8, 9,22)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-7)	Individual components and subsystems composed of multiple components tested in lab (3,4)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-8)	Lab experiments in a controlled environment show components work together and demonstrate basic functionality in simulated environment (11,14,18)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-9)	Requirements for technology verification established and include testing and validation of safety functions (5)	<input checked="" type="radio"/> YES <input type="radio"/> NO
5-10)	Lab-scale tests using prototype completed and results validate the design; ready for test in relevant environment; lab environment for testing modified to approximate operational environment (9,11,16,27,32)	<input checked="" type="radio"/> YES <input type="radio"/> NO

ENVIRONMENTAL AND SAFETY		
6-1)	Key process and safety requirements and associated hazards have begun to be identified (2,14)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-2)	Key process variables fully identified, preliminary hazard evaluations completed/documented; safety control strategies being explored (1,31)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-3)	Range of all relevant physical and chemical properties determined to the extent possible (24)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-4)	Limits for process variables, parameters & safety controls defined; integration demos done incl. testing/validating safety functions (24,31)	<input checked="" type="radio"/> YES <input type="radio"/> NO
6-5)	Finalization of required hazardous material forms; identification of system/component level safety controls (26)	<input type="radio"/> YES <input checked="" type="radio"/> NO

Technology Readiness Calculator (Page 7 of 7)

MANUFACTURING AND SCALE UP		
7-1)	Scaling studies have been started (19)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-2)	Current manufacturability concepts assessed (20)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-3)	Equipment scale-up relationships understood/accounted for in technology development; scaling designs completed (17,23)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-4)	Key manufacturing processes identified and assessed in lab; mitigation strategies identified to address manuf/productibility shortfalls (22,24,27)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-5)	Lab to engineering scale scale-up issues understood and resolved (30)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-6)	Manufacturing processes to make components that are new are validated via demonstration in the lab (8)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-7)	Manufacturing techniques have been defined to the point where largest problems are defined (10)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-8)	Engineering to full-scale scale-up issues understood and resolved (29)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-9)	Critical manufacturing processes have been prototyped and scaling issues that remain are identified and understood (12,16)	<input checked="" type="radio"/> YES <input type="radio"/> NO
7-10)	Process and tooling are mature to support fabrication of system and components; at least one product demo has been completed (27,33)	<input checked="" type="radio"/> YES <input type="radio"/> NO

TRL Calculator Results			
TRL	Questions Answered "Yes"	% Complete	Progress Towards Level
1)	7 of 7	100%	<div><div></div></div>
2)	9 of 10	90%	<div><div></div></div>
3)	12 of 13	92%	<div><div></div></div>
4)	11 of 13	85%	<div><div></div></div>
5)	12 of 13	92%	<div><div></div></div>
6)	12 of 15	80%	<div><div></div></div>

Detailed Results											
By Question Section					By Technology Readiness Level						
1. General	1-1)	Yes	4. Integration	4-1)	Yes	TRL 1	1-1)	Yes	1-4)	Yes	
	1-2)	Yes		4-2)	Yes		2-1)	Yes	2-4)	No	
	1-3)	Yes		4-3)	Yes		3-1)	Yes	3-14)	Yes	
	1-4)	Yes		4-4)	Yes		3-2)	Yes	3-15)	Yes	
	1-5)	Yes		4-5)	Yes		3-3)	Yes	3-16)	Yes	
	1-6)	Yes		4-6)	Yes		5-1)	Yes	3-17)	No	
2. Market Need	2-1)	Yes		4-7)	Yes	TRL 2	5-2)	Yes	4-3)	Yes	
	2-2)	Yes		4-8)	Yes		1-2)	Yes	4-4)	Yes	
	2-3)	Yes	5. Testing and Validation	5-1)	Yes		2-2)	Yes	5-7)	Yes	
	2-4)	No		5-2)	Yes		3-4)	Yes	5-8)	Yes	
	2-5)	No		5-3)	Yes		3-5)	Yes	6-2)	Yes	
	2-6)	Yes		5-4)	Yes		3-6)	Yes	7-3)	Yes	
	2-7)	Yes		5-5)	Yes		3-7)	Yes	7-4)	Yes	
3. Design & Development	3-1)	Yes		5-6)	Yes		TRL 3	3-8)	No	1-5)	Yes
	3-2)	Yes		5-7)	Yes			4-1)	Yes	2-5)	No
	3-3)	Yes		5-8)	Yes			5-3)	Yes	3-18)	Yes
	3-4)	Yes		5-9)	Yes	5-4)		Yes	3-19)	Yes	
	3-5)	Yes		5-10)	Yes	1-3)		Yes	3-20)	Yes	
	3-6)	Yes	6. Safety	6-1)	Yes	2-3)	Yes	4-5)	Yes		
	3-7)	Yes		6-2)	Yes	3-9)	Yes	4-6)	Yes		
	3-8)	No		6-3)	Yes	3-10)	Yes	6-3)	Yes		
	3-9)	Yes		6-4)	Yes	3-11)	No	7-5)	Yes		
	3-10)	Yes		6-5)	No	3-12)	Yes	7-6)	Yes		
	3-11)	No	7. Manufacturing & Scale	7-1)	Yes	3-13)	Yes	7-7)	Yes		
	3-12)	Yes		7-2)	Yes	4-2)	Yes	1-6)	Yes		
	3-13)	Yes		7-3)	Yes	5-5)	Yes	2-6)	Yes		
	3-14)	Yes		7-4)	Yes	5-6)	Yes	2-7)	Yes		
	3-15)	Yes		7-5)	Yes	6-1)	Yes	3-21)	No		
	3-16)	Yes		7-6)	Yes	7-1)	Yes	3-22)	No		
	3-17)	No		7-7)	Yes	7-2)	Yes	3-23)	Yes		
	3-18)	Yes		7-8)	Yes	TRL 6	3-24)	Yes			
	3-19)	Yes		7-9)	Yes		3-25)	Yes			
	3-20)	Yes		7-10)	Yes		4-7)	Yes			
	3-21)	No			4-8)		Yes				
	3-22)	No			6-4)		Yes				
	3-23)	Yes			6-5)		No				
	3-24)	Yes			7-8)		Yes				
					7-9)		Yes				
	3-25)	Yes			7-10)		Yes				

Technology Readiness Calculator TRL7 issues

SYSTEM TECHNOLOGY PROTOTYPE DEMO IN AN OPERATIONAL ENVIRONMENT	
VII-1) Pressure tests with safety coefficient	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-2) Temperature, vibration and other environment tests	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-3) Interface with platform is validated	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-4) Functional tests in simulated environment	<input checked="" type="radio"/> YES <input type="radio"/> NO
VII-5) Functional tests at sea (short or shallow)	<input type="radio"/> YES <input checked="" type="radio"/> NO
VII-6) Prototypical engineering scale equipment/process demonstrated in various environment conditions and various functional configurations, incl. testing safety functions?	<input type="radio"/> YES <input checked="" type="radio"/> NO

Technology Readiness Calculator TRL8 issues

SYSTEM TECHNOLOGY QUALIFIED THROUGH TEST AND DEMONSTRATION	
VIII-1) Tested in all environmental conditions	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-2) Manufacturing issues solved for several products	<input checked="" type="radio"/> YES <input type="radio"/> NO
VIII-3) Several demonstrations performed	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-4) Operated by one end user at least	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-5) Commercial system available	<input type="radio"/> YES <input checked="" type="radio"/> NO
VIII-6) Manufacturing and user documentation established	<input checked="" type="radio"/> YES <input type="radio"/> NO