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| Logo%20Kayser%20182x211pixels | **IDOS Executive Summary Report**  | *Doc. N. :* | **KI-IDOS-RP-018** | **1/****0** |
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# INTRODUCTION

This document was prepared by Kayser Italia under the ESA Contract No. 4000132951/20/NL/KML.

This document is the “IDOS Executive Summary Report”.

# CONTRACT MAIN FEATURES AND FINDINGS

The IDOS program was addressed to the design and development of a breadboard aimed to demonstrate the functionality of a label-free optofluidic refractometric biosensor array with integrated sources and detector to detect a pre-defined set of biomarkers.

In order to achieve the scope, the IDOS team elaborated the following approach:

* Review of the state of the art of the integrated opto-fluidic detection technologies and methods
* Trade off and selection of the most promising technology.
* Design concept of the breadboard. In this phase, the team decided, in agreement with the Agency, to develop 2 separate breadboards; one(Breadboard 1) to be used for bioassay development/biomarkers detection the other (Breadboard 2) to be used as a proof of technology.
* Elaboration of the Development Roadmap and conclusions

### Breadboard 1: assay development

Breadboard 1 (BB1) serves a role in the assay development for the detection of the biomolecules. It consists of:

* External laser and detector, integrated in an optical signal read-out module (OSROM) system
* Fluidic system with pumps and valves to administer the liquids, integrated in an external box
* aMZI passive photonic chips without functionalization
* Holder for aMZI chips to connect external light and fluidics
* Software and electronics to control all elements

By using easily replaceable, one-time-use passive aMZI photonic chips, the experiments for the development of the assay for the detection of the biomolecules have been performed in an optimal way. These passive chips have been biofunctionalized. The sensitivity goal as a refractive index sensor was 5x10-6  or better down to 10-8 RIU.

This breadboard was tested for four assays which are suitable for the detection of four biomolecules as per the SoW.

### Breadboard 2: hybrid integration

Breadboard 2 (BB2) was built to demonstrate the hybrid integration of laser, detectors and microfluidics in an aMZI photonic chip. It consists of:

* aMZI photonic chip
* Laser (VCSEL) and detectors (photodiodes) integrated on the chip
* Microfluidic rotary valve integrated on the chip
* External pumps for the microfluidics
* External software and electronics to control all elements

A demonstrator chip was built where a step in refractive index can be measured using known salt concentrations, where the sensitivity goal will be 5x10-6  or better down to 10-8 RIU, using the integrated laser/detectors and microfluidics. The chip was not biofunctionalized and the assay demonstration was not performed. The development of this second breadboard aimed to the demonstration of the opto-fluidics integration capabilities.

### Test Results

The two breadboards were tested in terms of functionality and performance (sensitivity).

The BB1 (bulky and with the laser source and detection outside the chip) was tested to evaluate the functionality of the setup and performance of the bioassays versus the selected biomarkers that are the following:

•C-Reactive Protein (CRP)

•Human Serum Albumin

•Bacterial DNA (Aeromonas)

•Benzo(a)Pyrene - B(a)P

Test Results:

•Successful detection of CRP, LOD <0.01 µg/ml

•Successful detection of HSA, LOD <0.01 µg/ml

•Successful detection of DNA, LOD ~0.1 nM

•Successful detection of B(a)P, LOD <5 ng/ml

The test campaign demonstrated that the breadboard sensitivity is at the 5 x 10-6 RIU level.

The BB2 (based on integrated on the chip light source and detector) did not use biomarkers/bioassays but only salt solutions and tested with has a sensitivity of 4 x 10-7 RIU.

The test results are reported in KI-IDOS-TN-013.

### Development roadmap toward TRL 5

IDOS Technology Reediness Level (TRL) is at level 4 (🡪 Breadboard demonstration into laboratory environment).

To reach the TRL5, tests in relevant environment are necessary, while the IDOS BBs was tested in laboratory environment so far. Identification of ‘relevant environment’ is highly dependent on the mission scenario, which will be a subject of a hypothetical next investigation phase. In that case assessment of critical functions with respect to the ‘relevant environment’ should be assessed in order to define the list of tests to be performed in ‘relevant environment’.

* The starting point for the next phase is the integrated breadboard 2.

All the components in BB2 are tightened, strongly clamped or screwed together. The optical components are flip chipped on the chip, and then overflown with glue. The wirebonds have not yet been, but can be easily protected with a substance called ‘globtop’, which is specifically made to protect wirebonds. After this single change, all these critical components in BB2 should be stable against heavy vibrations. The electronics are also not stable against vibrations, so should be upgraded for the next TRL level.

After these improvements, the full system should be tested with respect to the launch loads and launch thermal cycles. Therefore, launcher environment could be considered as a relevant environment as well.

In general, the relevant environment would be the ISS ambient, which is quite similar to the laboratory one, except for microgravity and necessity for electromagnetic compatibility. Thermal environment depending on the selected mission profile is a crucial point as well.

As a result, the technology development toward TRL 5 should include the following tests:

* Launch/load tests
* LDC tests
* Thermal cycling test
* Launch/load test will be driven by the definition of the launch scenario (type of vector/carrier).
* LDC tests: in order to execute the hyper-gravity test at LDC, special care shall be put during the design phase in the selection of electro-optical-mechanical components that can sustain the high loads/high g-levels coming from the LDC. Indeed, in most cases, the limiting factor for the execution of the tests at LDC is the capability of the selected components to operate up to 20 g (maximum g level at LDC) meaning that the component is not robust enough to survive to these high g-levels. In case the LDC tests are requested as test step for future developments, the idea is to test robustness and mechanical structure at maximum 3g.
* Thermal cycling will be driven by the definition of the launch scenario (type of vector/carrier) and by the definition of the experiment profile on board the ISS.

The execution of the vibration and thermal tests is hence to be considered as an elaboration of the IDOS Mission profile which is expected to be provided at the beginning of the next phase.

The launch/load and thermal tests will aim to the demonstration of the adequacy and robustness on the IDOS design toward environmental requirements.

**Integration of macrofluidic components and electronics**

Large developments that were left out of IDOS project are the integration of the microfluidic pumps and the interfacing and driving electronics. This should be addressed in the follow-up to reach a higher TRL level.

Moreover the IDOS breadboard only consists of the analyzing system whereas for an application a sample pre-treatment system has to be implemented depending on the mission scenario.

### Application and missions

**Science missions**

Next to the further development of the IDOS system, some activities are proposed with the objective to prepare a real (science) mission:

* *Sample extraction and pre-treatment*

The system requires a (mission/application dependent) sample extraction and pre-treatment system. It would be logical to develop a breadboard system and to demonstrate the functioning of the two systems in combination which will give (new) challenges as this combination will impose interactive requirements (as has been experienced in the LMC project). A starting base can be the (prototype) *analysis* subsystem developed in the LMC project as the conceptual requirements are about the same. For instance, in the LMC protype, sample introduction and liquid pumping function is combined in a dedicatedly developed bellow-based mechanism (see **Errore. L'origine riferimento non è stata trovata.**).

For such an activity additional partners should be involved while the role of Kayser itself would be enlarged in such a development.

* *Science case and involvement of planetary science researchers*

In order to have support of ESA and national space agencies we should involve scientists with an interest in such an instrument. Presently, we have an interest from Inge Loes ten Kate but even more from groups of the TU Delft (Vermeersen, Cazaux, Loicq) to be involved. Their present interest is about (icy) moons of Jupiter and Saturnus. One idea they are working on is taking samples in orbit from plumes of volcanic eruptions[[1]](#footnote-1); another one is to take samples from ice at the surface (on-site)[[2]](#footnote-2). We could think of having them in the team and/or other planetary science groups in Italy/Europe. To encourage TUD we will soon have some experiments on our lab system with the objective to analyze samples that will be taken from ice by an automated sample-taker they are developing.

* *Sample Receiving Facility – Mars Sample Return[[3]](#footnote-3),[[4]](#footnote-4)*

NASA, in partnership with the European Space Agency (ESA), is seeking to return Martian geological and atmospheric samples to Earth for scientific study in the early 2030s. Due to the possibility that the samples could contain extraterrestrial life, Mars Sample Return (MSR) is classified as a Category V: Restricted Earth Return mission by the NASA Planetary Protection Office. As a result of this classification, a MSR Sample Receiving Facility (SRF) must not only provide a pristine environment to ensure samples are protected from terrestrial contamination for scientific investigations, it must also provide high-containment (biosafety level 4 [BSL-4]-equivalence) to isolate the samples from Earth's biosphere until the samples are deemed safe for release and/or sterilized. In such a facility a miniaturised analysis system could have an added value because of the small size and automation opportunities.

* *Medical diagnostic applications*

An alternative application is a medical diagnostic tool in manned missions such as in ISS, to the Moon and Mars in the future.

Such an instrument will be less challenging and complicated as sampling and handling will be (partly) possible with manual procedures. In this case a system based on a cartridge combining the sample intake, pre-treatment and biochip functions and a separate reading instrument is the most appropriate option.

Moreover, this application will completely be in line with the running non-space developments towards a point-of-care diagnostic device for medical and life sciences applications, e.g. detecting biomarkers in blood, urine, or saliva samples. Developing a device for this application field is currently the main focus of Surfix. Human health related space application could benefit from the results from these developments..

# CONCLUSIONS

The IDOS project demonstrated - at breadboard level - the adequacy of the aMZI technology in the detection of the identified biomarkers.

The performance requirements identified in the ITT have been achieved.

The critical point encountered during this breadboarding phase shall feed the next development phase that is aiming to a further opto-fluidics integration.

**\*\*\*\*\*\*\*\*\*\*\*End Of Document\*\*\*\*\*\*\*\*\*\*\*\***

1. [ALMA Spots Volcanic Plumes on Jupiter’s Moon Io](https://www.sci.news/astronomy/alma-volcanic-plumes-jupiters-moon-io-08975.html#:~:text=Astronomers%20using%20the%20Atacama%20Large,KCl)%20from%20Io%27s%20active%20volcanoes.) [↑](#footnote-ref-1)
2. [Exploring icy moons – ESA Vision](https://vision.esa.int/exploring-icy-moons/) [↑](#footnote-ref-2)
3. [Mars Sample Return (MSR) Sample Receiving Facility (SRF) Assessment Study (MSAS) - NASA/ADS (harvard.edu)](https://ui.adsabs.harvard.edu/abs/2022cosp...44..455H/abstract) [↑](#footnote-ref-3)
4. [Life on Mars: The analysis of extra-terrestrial samples in Europe (innovationnewsnetwork.com)](https://www.innovationnewsnetwork.com/life-mars-analysing-extra-terrestrial-samples-europe/20935/) [↑](#footnote-ref-4)