European
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Advances in Marine Optics Technology: JRC Hyperspectral Free-fall Profiler

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Contents

Abstract

The Copernicus Sentinel-3 missions, which include the operational Sentinel-3A and -3B as well as the upcoming Sentinel-3C and -3D, present an unparalleled opportunity for long-term Ocean Colour (OC) monitoring to support global environmental and climate research as well as the development, implementation and monitoring of EU legislations. OC missions delivering fit-for-purpose data require comprehensive calibration and validation activities ensuring the indirect calibration of space-based sensors and the validation of derived data products. These activities heavily rely on accurate in situ reference measurements, which in turn depend on advanced measurement techniques and cutting-edge instrumentation.

Since the initiation of operational OC missions in 1997, the Joint Research Centre (JRC) has played a pivotal role in sustaining the necessary calibration and validation activities, developing specialized expertise and establishing dedicated measurement programs and infrastructure, which are now assisting current Copernicus OC missions.

The provision of state-of-the-art reference in situ data, critical for delivering quality-assured satellite derived marine data products, relies on technological developments. With the aim of transferring JRC know-how to the wider user community, this Technical Report details recent technological advancements made at the JRC Marine Optical Laboratory (MarLab) for realizing a hyperspectral free-fall profiler to support the validation of satellite-based OC products.

Acknowledgements

This work contributes to:

- *Earth Observation Knowledge, Innovation, Science and Services,* funded by the Directorate-General Joint Research Centre (JRC), and
- *Reference In Situ Data for Calibration and Validation,* under the Administrative Arrangement on Copernicus between the Directorate-General for Defence, Industry, and Space (DEFIS) and the JRC.

The elements summarized in this Report stem from activities conducted at the JRC Marine Optical Laboratory (MarLab) focusing on advancing marine field measurements to support the validation of Sentinel-3 marine data products.

The authors extend their gratitude to Marco Galparoli and the JRC Central Workshop Facility team for their expert contribution to the manufacture of the mechanical components of the field system detailed in this report.

Authors

Pietro Sciuto, Giuseppe Zibordi, Marco Talone, Barbara Bulgarelli.

Executive summary

The Copernicus Regulation (EU N°377/2014) emphasizes that *the Commission should continue relying on the JRC's scientific and technical support for the implementation of Copernicus*. In agreement with the need to enhance Copernicus Services, the JRC contributes through its scientific and technical role by adopting implementing acts to ensure the highest accuracy for aquatic Earth Observation data products, which can be applied for environmental and climate scientific investigations, as well as trustfully utilized to support the development of evidence-informed policies.

Specifically, the JRC plays a crucial role in providing comprehensive, spatially distributed, long-term, cross-site consistent, and standardized *in situ* reference data to support the delivery of accurate and reliable information through Copernicus Services. Achieving this objective has often necessitated technological innovations to maintain high measurement accuracy and standardization in laboratory and field settings.

This *Technical Report* provides a concise overview of the rationale, methods, and requirements underpinning a recent technological advancement at the JRC Marine Optical Laboratory (MarLab). The *Technical Report* is intended to assist the scientific community involved in producing *in situ* reference data by sharing details, such as technical drawings, that are typically excluded from peer-reviewed publications, but are critical for replicating field systems. It is additionally intended to make technological innovations openly available to any operator in the sector.

Among the recent technological advancements achieved at the MarLab, it is of relevance the development of the JRC Hyperspectral Free-fall Profiler (*J-HFP*). This technology, which allows deploying radiometers using free-fall systems, is widely regarded as a reliable method for obtaining reference data in support of satellite OC missions. The *J-HFP* introduces several advantages over existing commercial radiometer systems:

- Reduced deployment speed near the sea surface, which enhances data density in the upper water column where measurements are most affected by wave perturbations.
- Minimal shading perturbation by the deployment structure, which ensures accurate measurements of upwelling radiance (L_u) by avoiding unquantifiable shading effects.
- Low tilt during descent, which reduces the impact of perturbations due to in-water bidirectional reflectance on profile data.

These advancements position the *J-HFP* as an outstanding solution for deploying RAMSES (TriOS; Rastede, Germany) hyperspectral radiometers to ensure field measurements for satellite OC missions.

1 Introduction

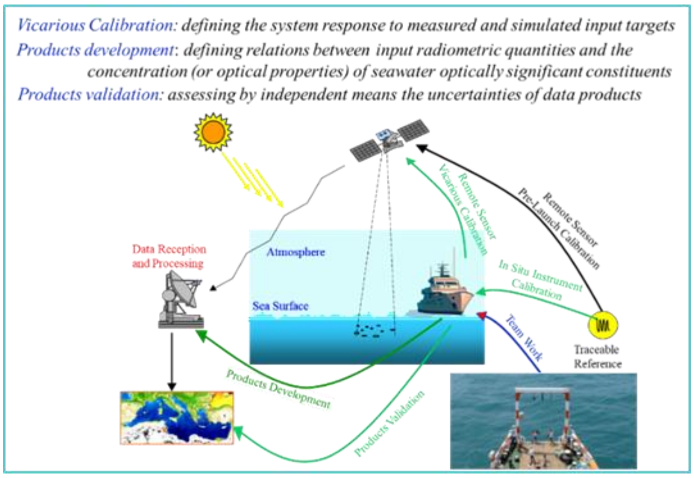
The Copernicus Program, established by the European Commission, aims to provide long-term, reliable, and accurate data on environmental and security issues through specialized services. Among these, the Copernicus Marine Service and the marine component of the Copernicus Climate Change Service both rely on satellite OC observations to deliver critical data in support to the development, implementation and monitoring of EU policies. This includes water quality metrics and climate-relevant variables such as chlorophyll-a concentration, a key proxy for phytoplankton biomass.

Decadal time series of satellite data from multiple missions offer a unique resource for deriving climate variables across various spatial scales. However, utilizing satellite data for quantitative analyses, such as detecting and quantifying subtle trends within natural variability, requires strict adherence to traceability standards based on the International System of Units (SI) and well-documented uncertainties for these data products.

Meeting these requirements for satellite OC data, involves:

- Rigorous pre-launch sensor characterization and calibration of space sensors, which ensure traceability of satellite derived data products.
- On-orbit monitoring of sensor radiometric stability, which entails tracking and adjusting changes in sensor responsivity during operation.
- System vicarious calibration, which is the indirect sensor calibration accounting for combined sensor responsivity and data reduction algorithms.
- Validation of data products, which requires determining statistical indices such as bias and dispersion to evaluate product accuracy.
- Radiative transfer simulations, which entail assessing uncertainties satisfying application needs.
- Comprehensive analysis and inter-comparison, which imply verifying the accuracy and consistency of satellite data products across multiple missions.

Figure 1. Schematic showing the development, calibration and validation components of ocean colour missions.



Vicarious Calibration: defining the system response to measured and simulated input targets

Products development: defining relations between input radiometric quantities and the concentration (or optical properties) of seawater optically significant constituents

Products validation: assessing by independent means the uncertainties of data products

Source: Zibordi and Sciuto, 2022

Executing these tasks requires establishing and implementing robust calibration and validation programs, which are essential to ensure the reliability of satellite-derived OC data for environmental and climate applications.

Accurate *in situ* measurements (*i.e., reference* data) are fundamental to OC calibration and validation programs. These measurements play a crucial role in the system vicarious calibration, the validation of satellite data products, and the development and evaluation of bio-optical models for generating advanced data products (see Fig. 1). Consequently, the collection and handling of *in situ* reference data are integral to post-launch Earth Observation strategies, ensuring the delivery of quality-controlled satellite data products, which can then be trustfully applied in support to EU policies.

Both, the validation of data products and bio-optical modelling, require *in situ* data that represent the range of marine water types worldwide. To meet this need, validation and modelling datasets are often assembled using measurements from various instruments operated by independent teams across different deployment platforms, such as ships, buoys, and offshore structures. However, despite efforts to promote the use of community protocols for instrument calibration, data collection, processing, and quality control, datasets from diverse sources often lack the traceability, accuracy, or consistency needed for a rigorous support of validation and development activities.

These challenges highlight the importance of initiatives aimed at producing standardized and highly accurate *in situ reference measurements.*

Adhering to the principle that *adequately sampled, carefully calibrated, quality controlled, and archived data for key elements of the climate system will be useful indefinitely* (Wunsch et al. 2013), and building *on requirements for in situ measurements supporting satellite OC missions* (Zibordi and Voss 2014), this report summarizes recent technological advancements essential for the production of in situ reference data supporting satellite OC missions. In specific, the recently developed JRC Hyperspectral Free-fall Profiler (*J-HFP*) is illustrated.

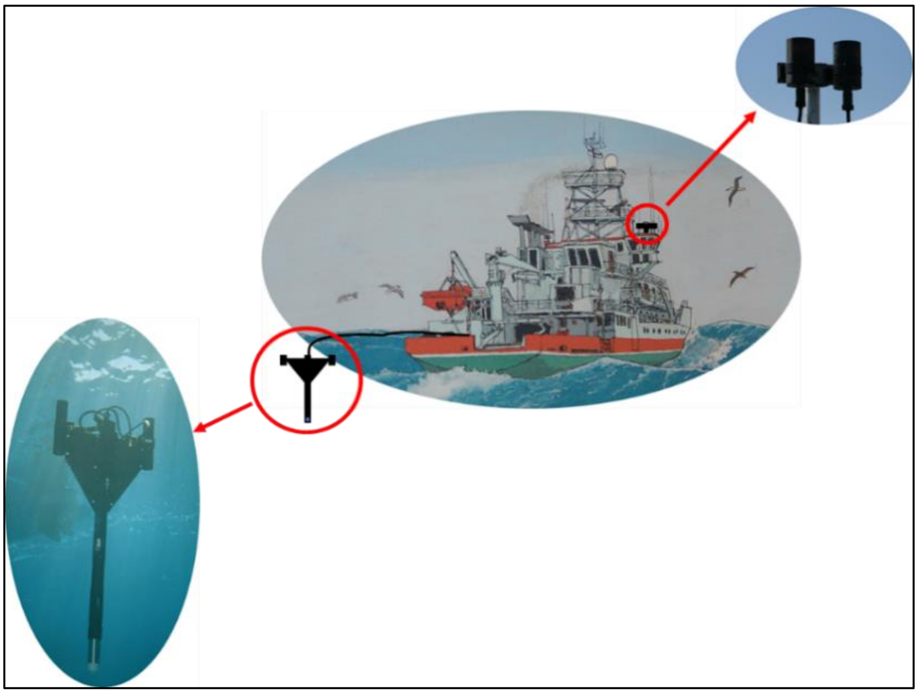
2 Free-fall optical radiometry

2.1 Background

In-water radiometric profiling is an established methodology for measuring key physical quantities that support satellite OC applications. These quantities include the in-water upwelling radiance $L_u(z, \lambda, t)$ measured at various depths z, centre-wavelengths λ and time t with systems such as free-fall profilers (see Fig. 2). These measurements need to be accompanied by the simultaneous collection of above-water downward spectral irradiance $E_s(\lambda, t)$.

The primary data product derived from $L_u(z, \lambda, t)$ is the value $L_u(0^-, \lambda, t_0)$ extrapolated to the sub-surface depth $z = 0^-$ at time t_0. Higher-level data products include the spectral normalized water-leaving radiance $L_{WN}(\lambda)$ (*i.e.*, the sub-surface radiance quantified above the surface with nadir view, no atmosphere , the sun at the zenith and at the mean sun-earth distance) and the equivalent remote sensing reflectance $R_{RS}(\lambda)$. These products are essential for validating primary satellite OC data products, as detailed in Zibordi et al. (2019).

Figure 2. Schematic illustrating field operations of a free-fall optical profiler delivering $L_u(z, \lambda, t)$ radiometric data.



Source: Zibordi and Sciuto, 2022

2.2 Methods and requirements

The production of radiometric data essential for satellite OC validation demands adherence to several requirements to ensure the accuracy and reliability of the measurements. First and foremost, data must be acquired under **clear sky conditions**, characterized by at least unobstructed sunlight and minimal cloud coverage. Additionally, **bottom perturbations**, which can significantly affect the measurements, **must be negligible**. The location of the measurements should also ensure that adjacency effects, such as land-based perturbations, do not influence the satellite data, requiring a **sufficient distance from land**. Still, the availability of measurements in areas affected by nearby land perturbations can support the validation of algorithms specifically targeted to the correction of the adjacency effects.

Beyond these conditions, several actions are necessary to minimize uncertainties in the radiometric data. One key factor is the avoidance of perturbations caused by deployment structures, such as ships, which could introduce measurement artefacts. The minimum **measurement distance** depends on the specific characteristics of the deployment structure, still values of **20-30 m** are typically considered adequate. This requirement translates into a constraint on the towing speed: a too high towing speed prevents controlling the system fall (*i.e.*, the system tilt). A too low speed does not allow to take the system far enough from the ship (which perturbs measurements). Because of this, optical free-fall profilers need to be **towed at an absolute speed of approximately 0.5-0.8 knots** and need to be **deployable and recoverable from the foredeck**. Another crucial consideration is the minimization and correction for self-shading effects. Self-shading (Zibordi et al., 2019) is inherent to the measurement process and affect $L_u(z, \lambda, t)$ data. The extent of these effects varies depending on the size of the radiometers, the optical properties of the water, and the illumination conditions. To minimize self-shading, it is critical to position the radiometers in such a way that the measurements are not perturbed by other components of the profiling system. Specifically, **the L_u radiometer should be positioned on the side exposed to direct sunlight**, with an **unobstructed field-of-view**, ideally at **the highest point of the profiling system**. Additionally, it is essential to ensure a sufficient number of measurements in the near-surface layer where wave-induced light focusing and de-focusing perturbations occur. The effects of such perturbations on the measurements vary according to the sensor field-of-view, the vertical deployment speed, the acquisition rate (and likely the integration time), the surface wave characteristics, the illumination conditions and the optical properties of the water layer (Zibordi et al., 2019). To account for them, it is essential to ensure that the measurement density (*i.e.*, the number of measurements per unit depth) adequately apprehends the variability of the light field at each measurement depth. This requires either a low deployment speed or a high sampling rate, or ideally, a combination of both. Studies have demonstrated that the density of measurements needed to reduce uncertainties below a given threshold varies depending on the sensor characteristics. For the specific case of $L_u(z, \lambda, t)$ measurements in the visible spectral region, a **minimum of 10 measurements per meter** are required to reduce uncertainty caused by wave perturbations to below 2% in moderately optically complex waters (Zibordi et al., 2004; D'Alimonte et al., 2018). This requirement, which can be lessen in very clear oligotrophic waters, is generally used to determine the minimum number of independent profiles or concatenated casts per measurement station.

Concerning the **reference above-water radiometer** producing $E_s(\lambda, t)$ measurements, during measurements stations it needs to be operated on the **sunny side of the ship** and at a location to **prevent** that nearby **obstacles or sources of pollution are seen** in the field-of-view of the radiometer.

Best practices suggest that sub-surface values should be derived from profiles (either single or multiple) along with contemporaneous measurements of $E_s(\lambda, t)$. These are collected during brief measurement sequences lasting only a few minutes, still the incident light field can vary during this period. To minimize these effects, $L_u(z, \lambda, t)$ **measurements collected at times t are normalized to the incident light field at a reference time t_0** according to:

$$L'_u(z,\lambda,t_0) = L_u(z,\lambda,t) \times \frac{E_s(\lambda,t_0)}{E_s(\lambda,t)}$$

Although any measurements time can be ideally selected as the reference, t_0 is typically chosen to correspond with the beginning of the acquisition sequence.

Omitting the dependence on the measurement time t minimized by the aforementioned normalization, and assuming that measurements satisfy the requirement for a linear decay of $ln[L'_u(z,\lambda)]$ with depth within an extrapolation interval defined by $z_0 < z < z_1$, the sub-surface values $L_u(0^-, \lambda)$ at time t_0 can be determined by solving a linear problem that involves the logarithmic transformation of radiometric data as a function of depth z. These values are obtained from the exponential of the intercepts derived from least squares linear regression of $L'_u(z,\lambda)$ versus depth z in the extrapolation layer. Therefore, assuming the exponential decay of $L'_u(z,\lambda)$ with z and a constant slope $K_L(\lambda)$ called diffuse attenuation coefficient:

$$\ln[L'_u(z,\lambda)] = \ln[L'_u(0^-,\lambda)] - K_L(\lambda) \cdot z$$

2.3 The JRC Hyperspectral Free-fall Profiler (*J-HFP*)

The development of the *J-HFP* was deemed essential due to the absence of commercial systems capable of meeting the following requirements:

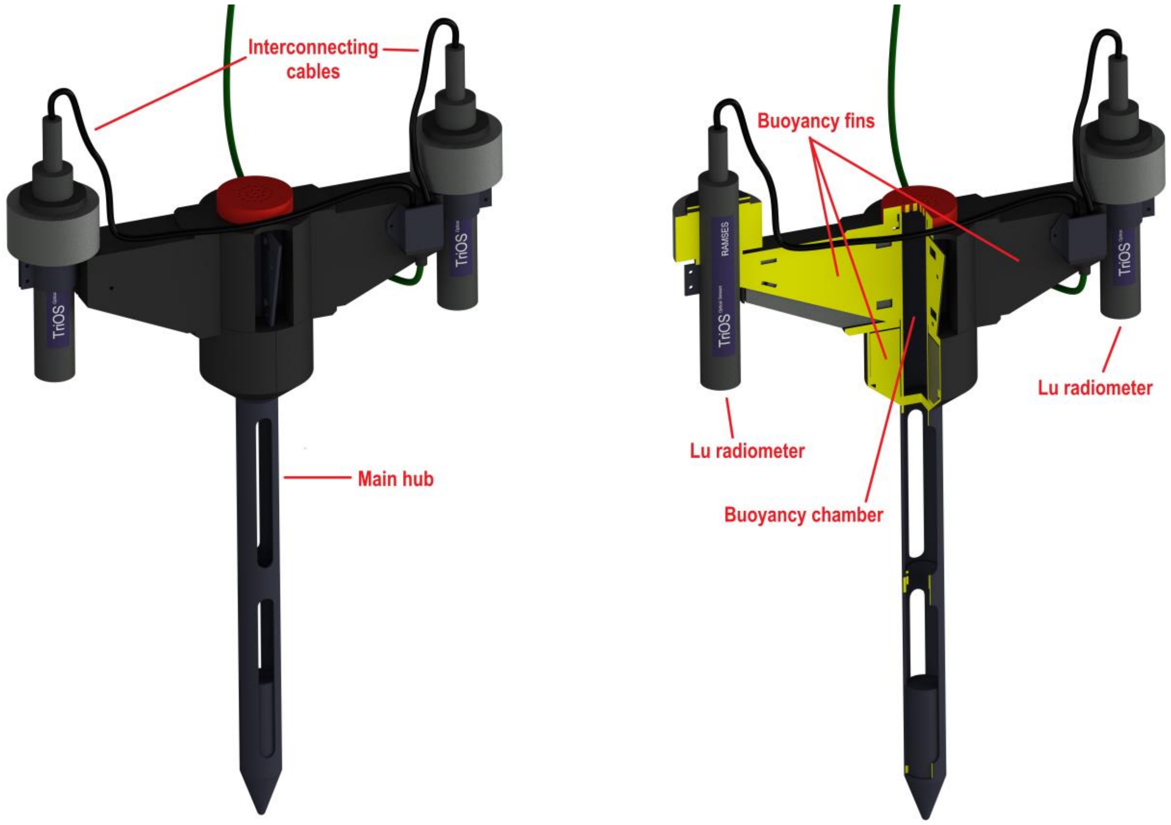
- Collection of hyperspectral $L_u(z, \lambda, t)$ using a rocket-shaped carrier designed to minimize self-shading effects (the only commercial system designed for such an application has been discontinued during 2024).
- Controlled deployment speed through a buoyancy chamber to adjust deployment speed with depth, typically starting at ~0.1 m/s near the surface and increasing to ~0.3 m/s at a few meters depth, to ensure higher depth resolution in the subsurface layer.

Components of the *J-HFP* (see Fig. 3):

- Main Hub: Constructed from anodized dull black aluminium to minimize light reflections.
- Buoyancy Components:
  - Floating foam fins with a density of ~100 kg/m³.
  - Inflatable buoyancy chamber to regulate the deployment speed and maintain system stability.
- Two radiometers for measuring $L_u(z, \lambda, t)$, including at least one equipped with tilt and depth sensors (the use of two equivalent radiometers is intended to support quality control procedures).
- Interconnecting cables among system components.

Detailed mechanical specifications of the *J-HFP* are provided in Annex 1.

Figure 3. JRC Hyperspectral Free-fall Profiler (*J-HFP*) configuration (left panel) and sectioned components (right panel).



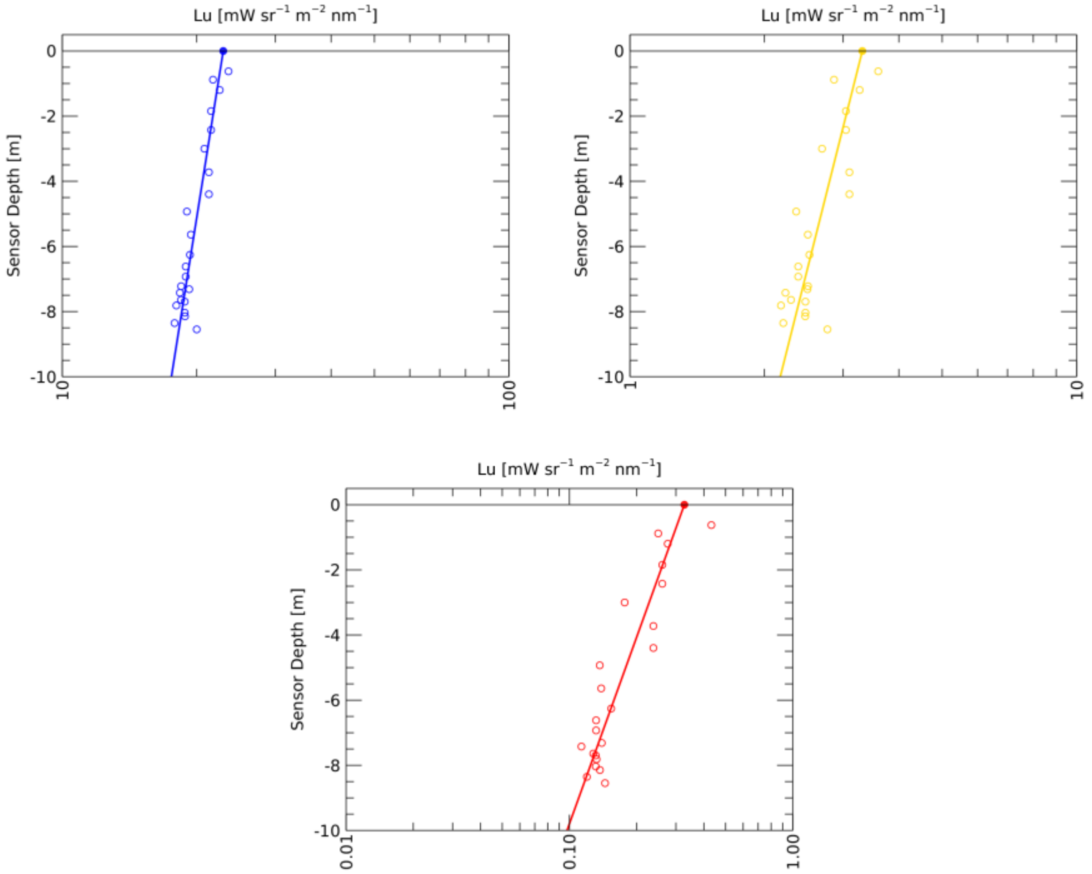
Source: Sciuto et al., 2025

2.4 The system and sample data

The *J-HFP* was successfully deployed with RAMSES hyperspectral radiometers (TriOS; Rastede, Germany) during an oceanographic campaign performed in July 2024 in the Eastern Mediterranean Sea, south of Crete Island. Figure 4 illustrates sample $L_u(z, \lambda, t)$ data collected on 19 July 2024 by the *J-HFP* at various centre-wavelengths λ as a function of depth z and time *t*, using RAMSES radiometers with full-angle field-of-view of 7 degrees and depth resolution of approximately 4 samples per meter when applying the multicast methodology and relying on at least three combined profiles.

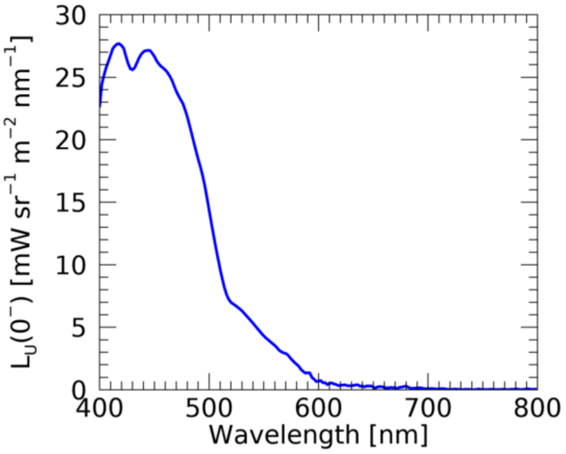
Notably, the linearity of log-transformed $L_u(z, \lambda, t)$ suggests a potentially accurate determination of the $L_U(0^-, \lambda, t_0)$ subsurface values at the time t_0, which are provided in Figure 5.

Figure 4. J-HFP $L_u(z, \lambda, t)$ data at various centre-wavelengths (top left panel: 400 nm; top right panel: 560 nm; lower panel: 620 nm) as a function of depth.



Source: Sciuto et al., 2025

Figure 5. *J-HFP* $L_u(0^-, \lambda, t_0)$ values derived in the 400-800 nm spectral range from the same profiles plotted in Fig. 4.



Source: Sciuto et al., 2025

3 Conclusions

The Copernicus Regulation (EU N°377/2014) emphasizes *the Commission should continue relying on the JRC's scientific and technical support for the implementation of Copernicus*. In alignment with the need to enhance Copernicus Services, the JRC plays a pivotal role in adopting implementing acts to ensure the highest accuracy of water Earth Observation data products utilized within the Marine Service and the Climate Change Service to provide a comprehensive monitoring of the aquatic environment, promoting water resilience strategies and ocean protection.

To support the delivery of accurate and reliable information through Copernicus Services, the JRC is tasked with providing highly accurate *in situ* reference data essential for the continuous calibration and validation of mission-specific data. Within the framework of the Sentinel-3 missions, the JRC has a critical role in ensuring access to comprehensive, spatially distributed, long-term, and cross-site consistent standardized *in situ* reference data across European seas.

Achieving this objective has often required the development of specialized devices to ensure high standardization and precision in both laboratory and field measurements. A recent advancement includes the development of the JRC Hyperspectral Free-fall Profiler (*J-HFP*), designed to ensure lower deployment speeds near the surface, minimize shading perturbations on L_u sensors, and reduce tilt, all factors critical to ensure the collection of highly accurate in situ measurements supporting the validation of satellite OC data products.

This report provides an overview of the rationale, methods, and requirements underpinning these developments. Mechanical drawings of the system are included in Appendix 1 to facilitate, where relevant and of interest, replication by members of the OC community.

References

D’Alimonte D., Zibordi G. and Kajiyama T., Effects of integration time on in-water radiometric profiles. Optics Express, Vol. 26, 2018, pp. 5908–5939, https://doi.org/10.1364/oe.26.005908.

Wunsch, C., Schmitt, R.W. and Baker, D.J., Climate change as an intergenerational problem, Proceedings of the National Academy of Sciences, Vol. 110, 2013, pp. 4435–4436, https://doi.org/10.1073/pnas.130253611.

Zibordi G., D'Alimonte D. and Berthon, J.F., An evaluation of depth resolution requirements for optical profiling in coastal waters. Journal of Atmospheric and Oceanic Technology, Vol. 21, 2004, pp. 1059–1073, https://doi.org/10.1175/1520-0426(2004)021<1059:AEODRR>2.0.CO;2

Zibordi, G. and Sciuto, P., Advances in Marine Optics Technology, Publications Office of the European Union, Luxembourg, 2022, https://doi.org/10.2760/387681.

Zibordi G. and Voss K.J., In situ optical radiometry in the visible and near infrared, Experimental Methods in the Physical Sciences, Vol. 47, 2014, pp. 247–304, https://doi.org/10.1016/B978-0-12-417011-7.00010-6.

Zibordi G., Voss K., Johnson B.C. and Mueller J.L., Protocols for satellite ocean colour data validation: in situ optical radiometry. IOCCG Protocols Series Volume 3.0, IOCCG, Dartmouth, NS, Canada, 2019, http://dx.doi.org/10.25607/OBP-691.

List of abbreviations and definitions

Abbreviations	**Definitions**
JRC	Joint Research Centre
MarLab	JRC Marine Optical Laboratory
DEFIS	Directorate-General for Defence, Industry, and Space
J-HFP	JRC Hyperspectral Free-fall Profiler
L_u	In-water upwelling radiance
Chla	Chlorophyll-a
SI	International System of Units
E_s	Above-water downward spectral irradiance
z	Sub-surface depth
L_{WN}	Normalized water-leaving radiance
R_{RS}	Remote sensing reflectance
K_L	Diffuse attenuation coefficient

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Table 8a/8b: Floating container

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Table 10: Small floating ring (internal)

Table 11: Disks

Table 12: Tip

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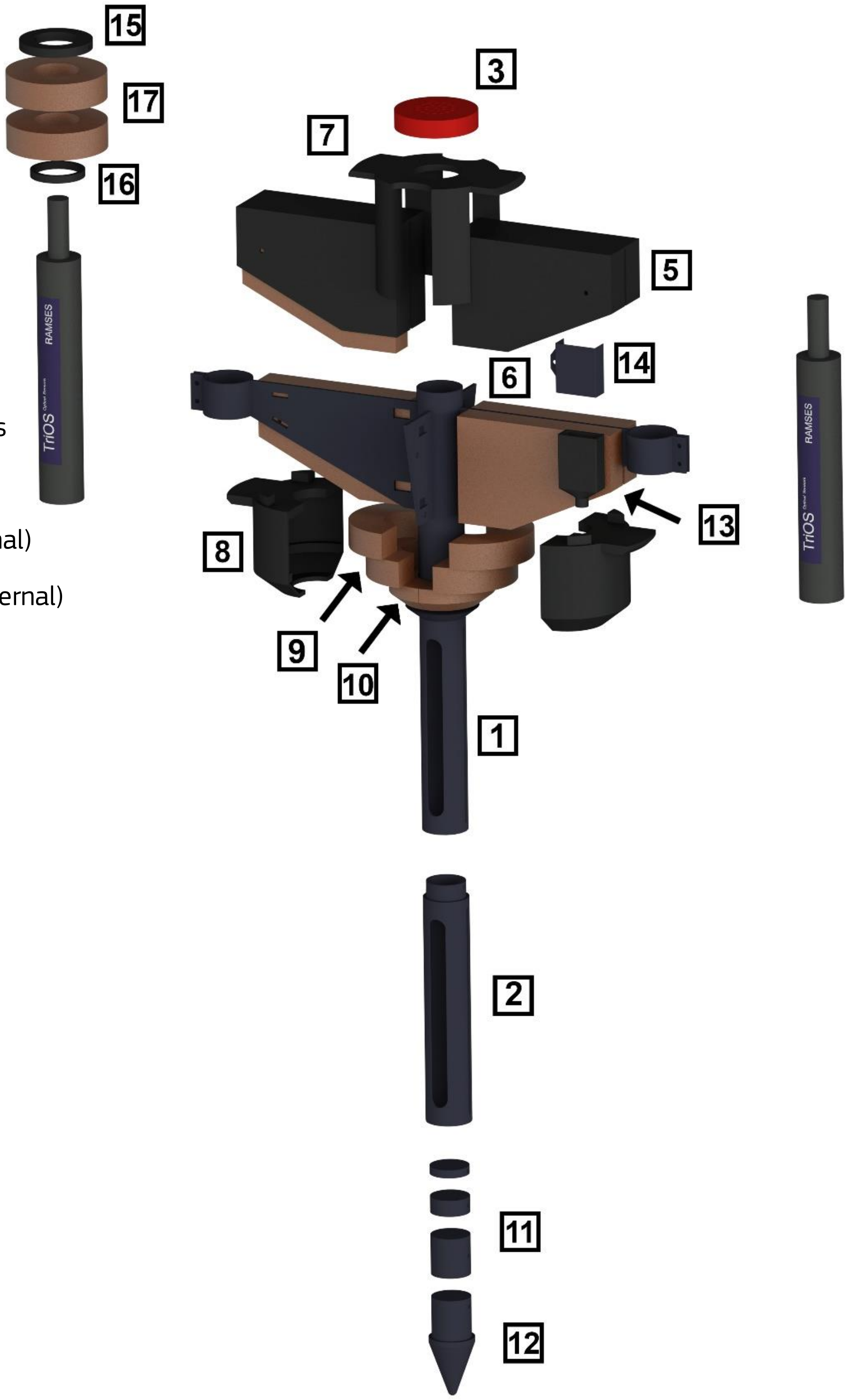
Table 14: Cable shell fixing

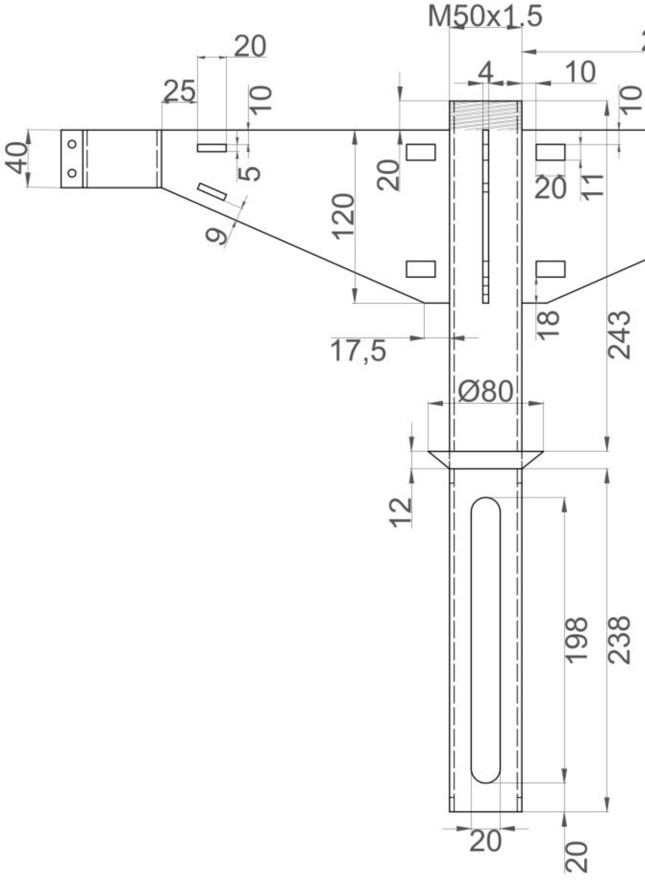
Table 15: Locking ring

Table 16: Spacer ring

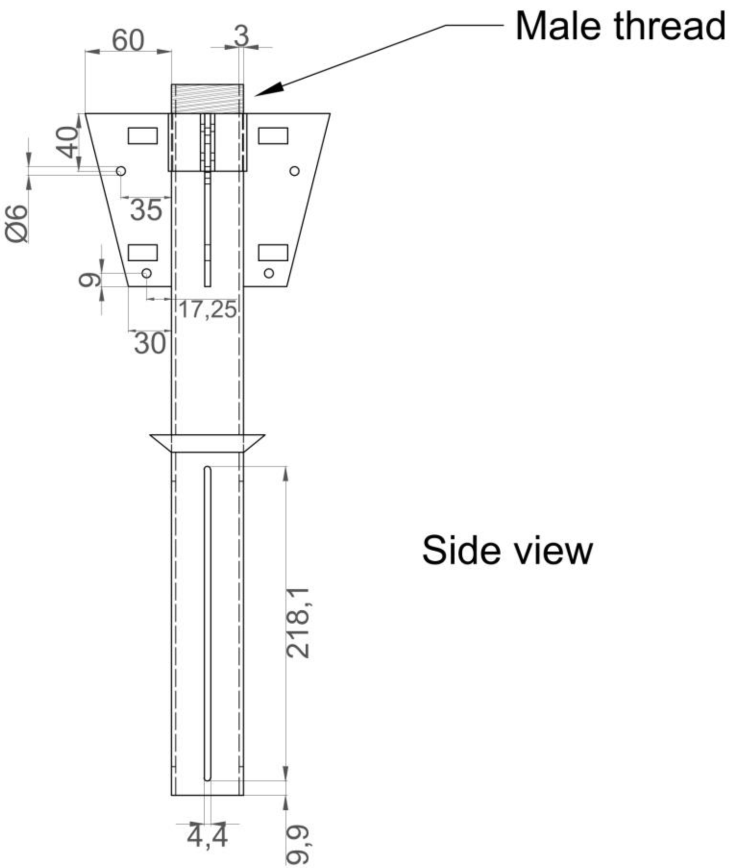
Table 17: Foam ring (external)

Table 18: Weighting rings





Front view



Side view

European Commission

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Top a

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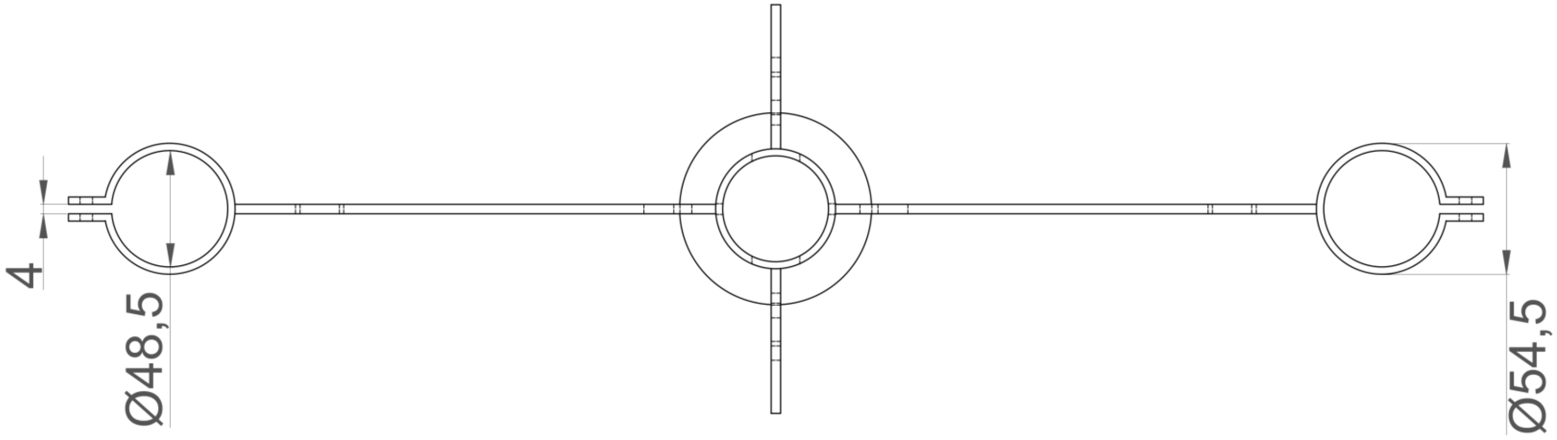

Top view

Joint Research Centre

Top b

Material	Aluminum	*Unit*	mm
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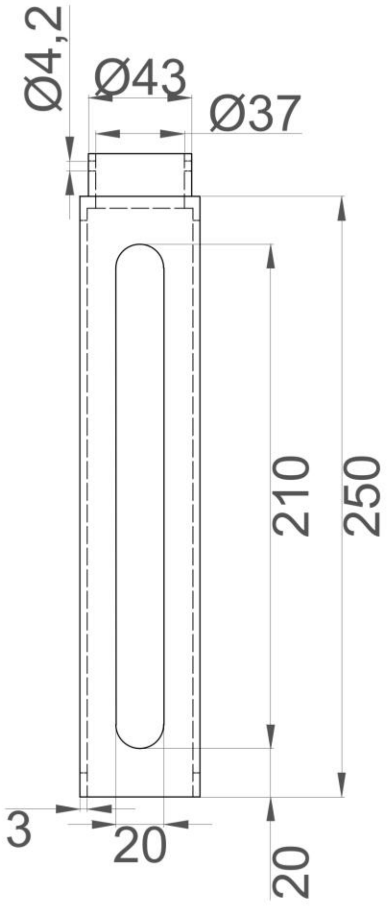
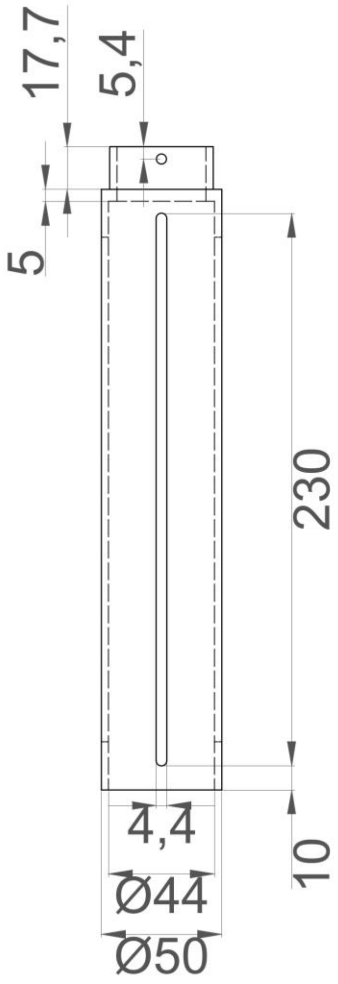
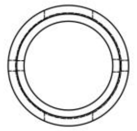
Scale	1:3	*Sheet*	1b of 18



Front view



Side view



Top view

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Extension

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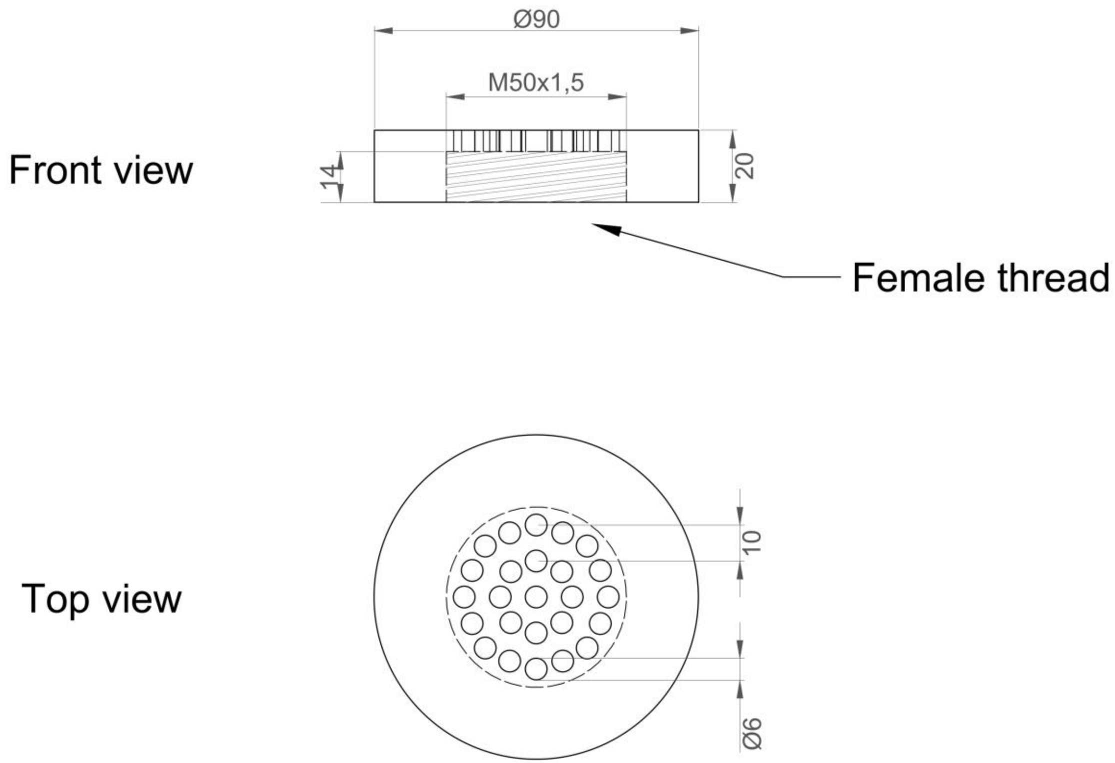

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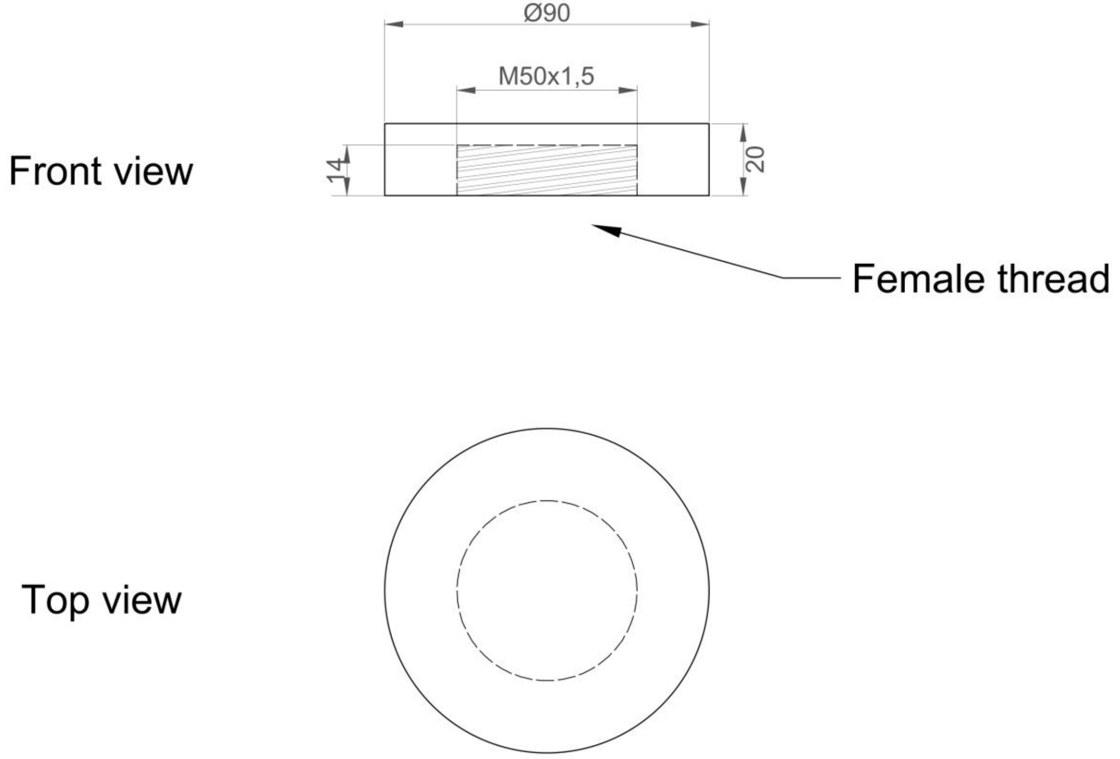
Perforated cap

Material	Aluminum	*Unit*	mm
Quantity	1	*Color*	Red
Scale	1:2	*Sheet*	3 of 18



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Cap

Material	Aluminum	*Unit*	mm
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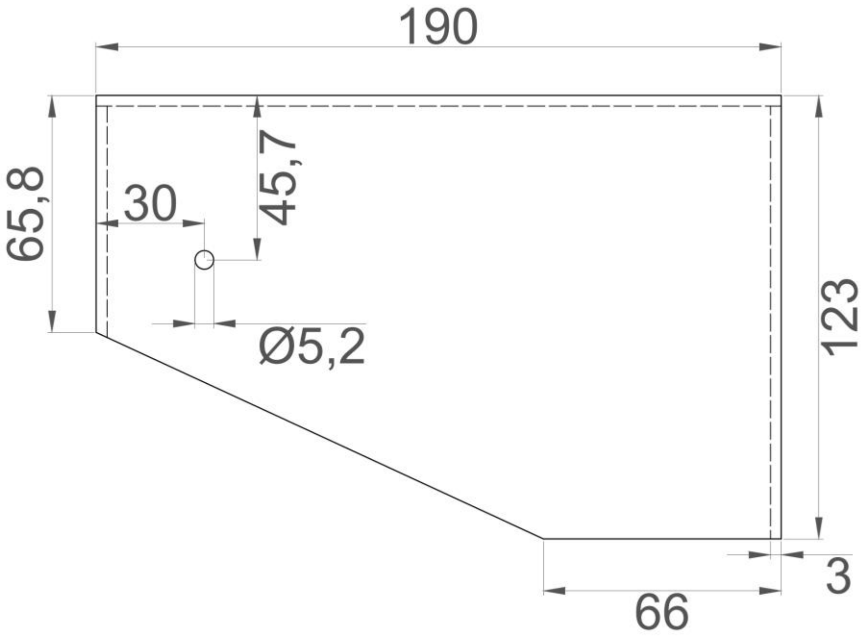
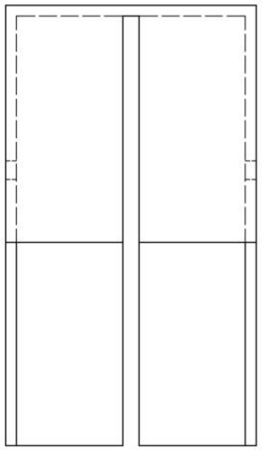


Front view



Side view

Top view

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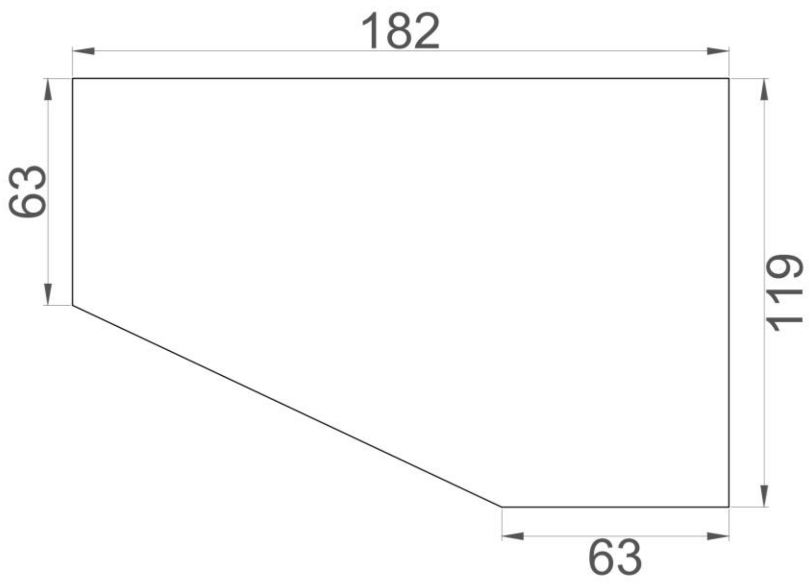
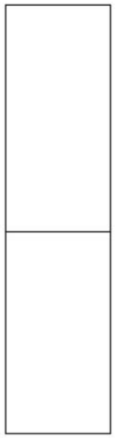
Floating fin cover

Material	ABS (printed)	*Unit*	mm
Quantity	2	*Color*	Black
Scale	1:2	*Sheet*	5 of 18



Front view



Side view

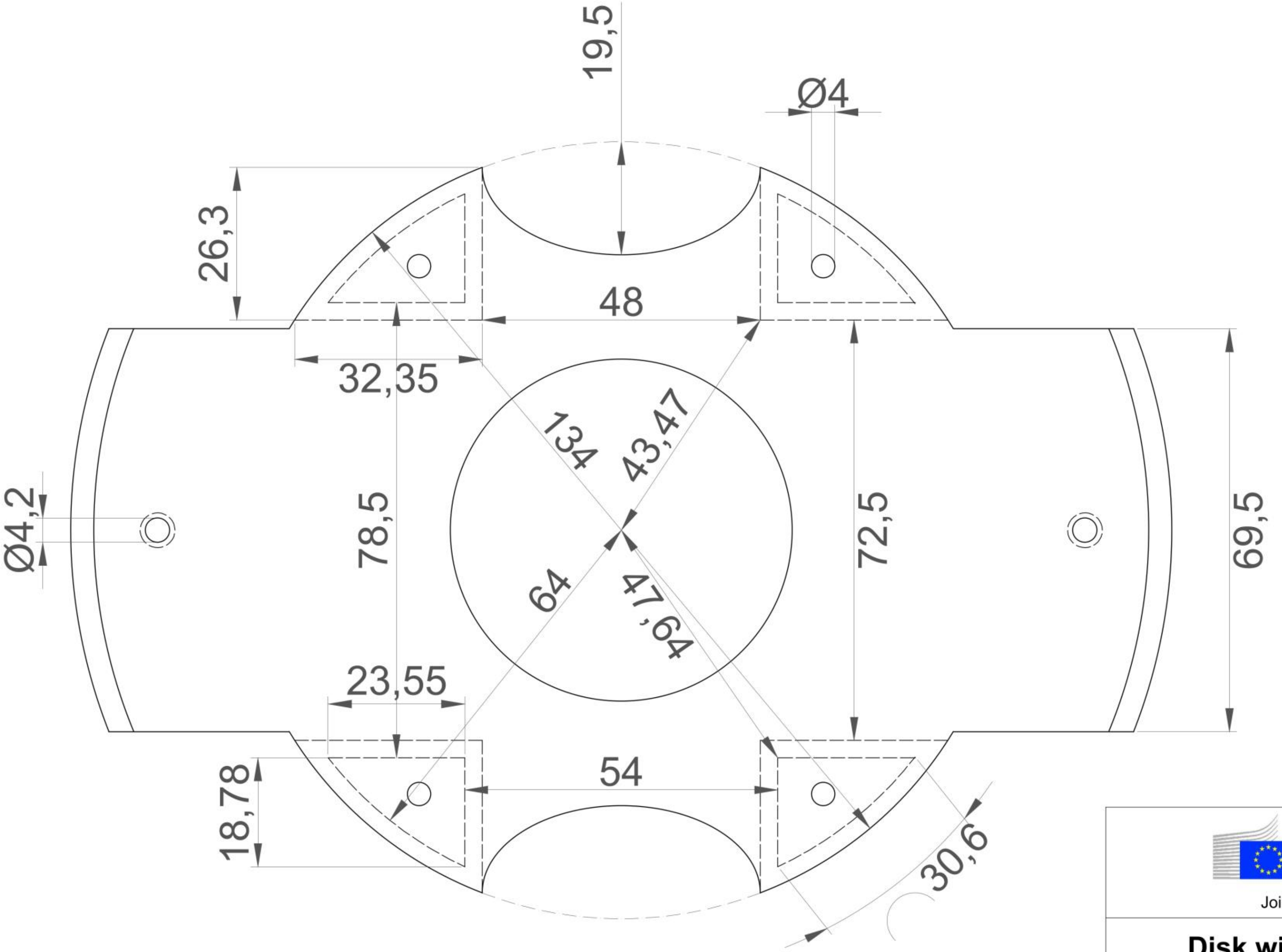
Top view

European Commission

Joint Research Centre

Floating fin

Material	Foam	*Unit*	mm
Quantity	4	*Color*	Black
Scale	1:2	*Sheet*	6 of 18

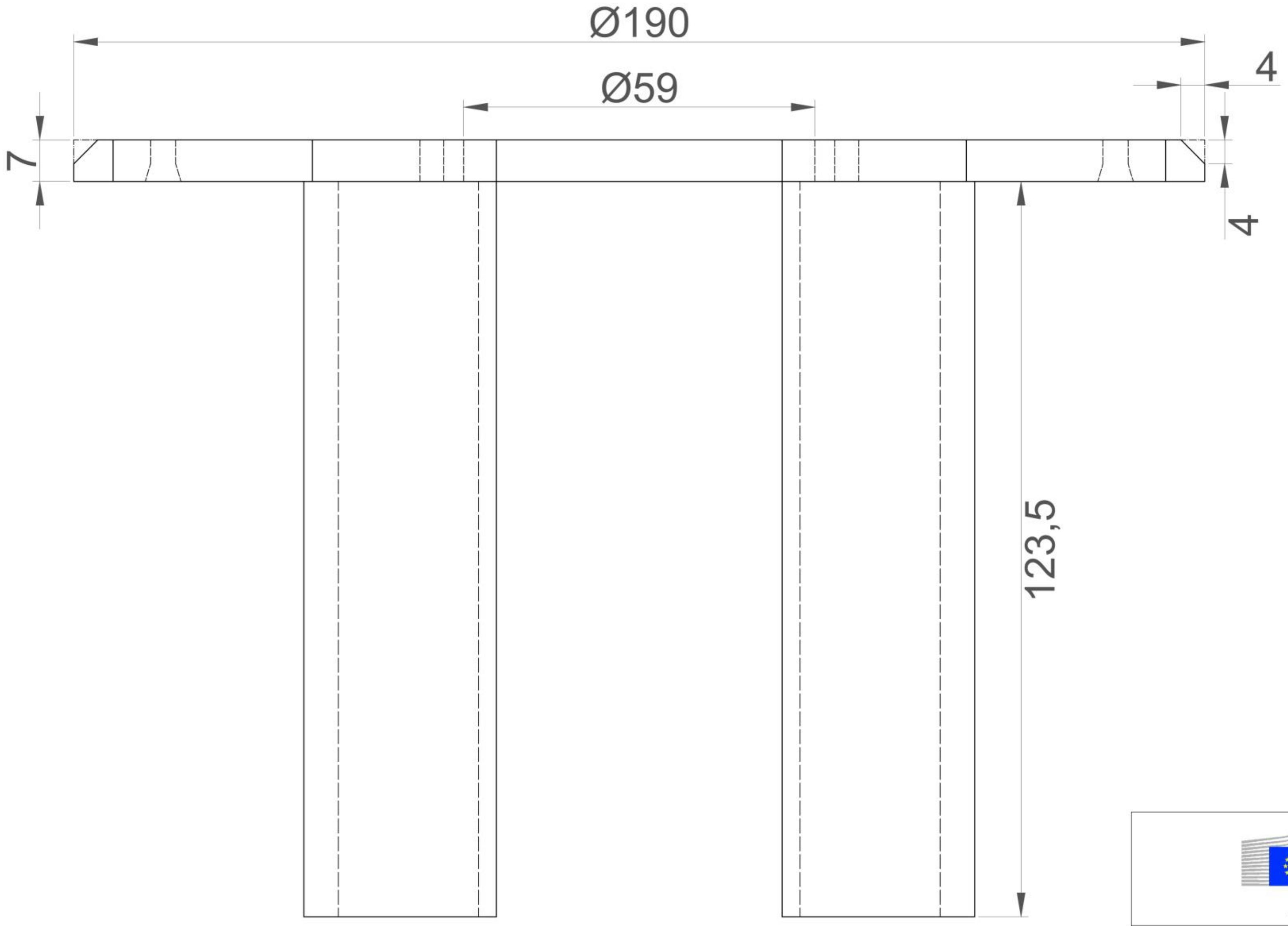


Top view

Joint Research Centre

Disk with containers a

Material	ABS (printed)	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:1	*Sheet*	7a of 18



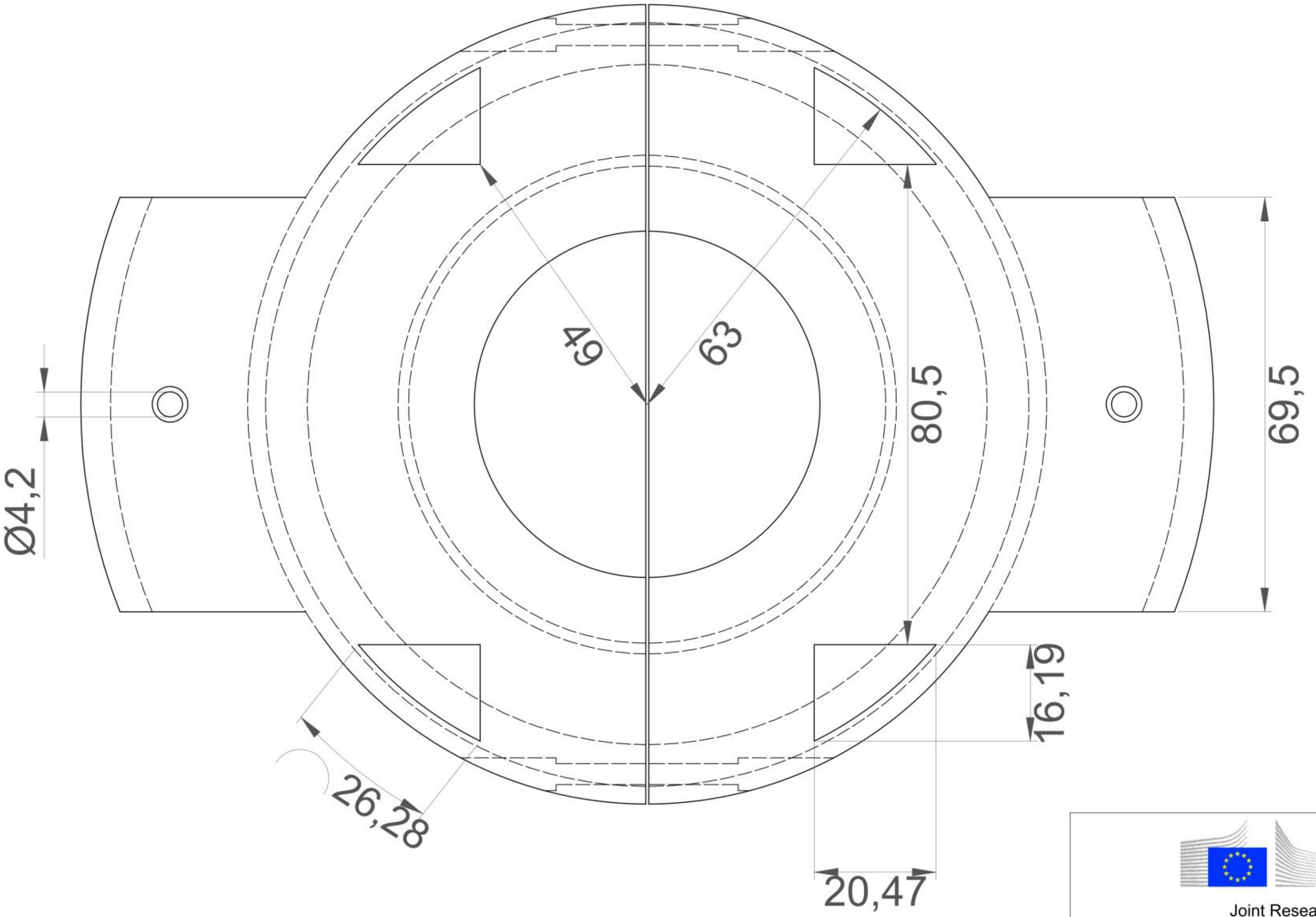
Front view

European Commission

Joint Research Centre

Disk with containers b

Material	ABS (printed)	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:1	*Sheet*	7b of 18

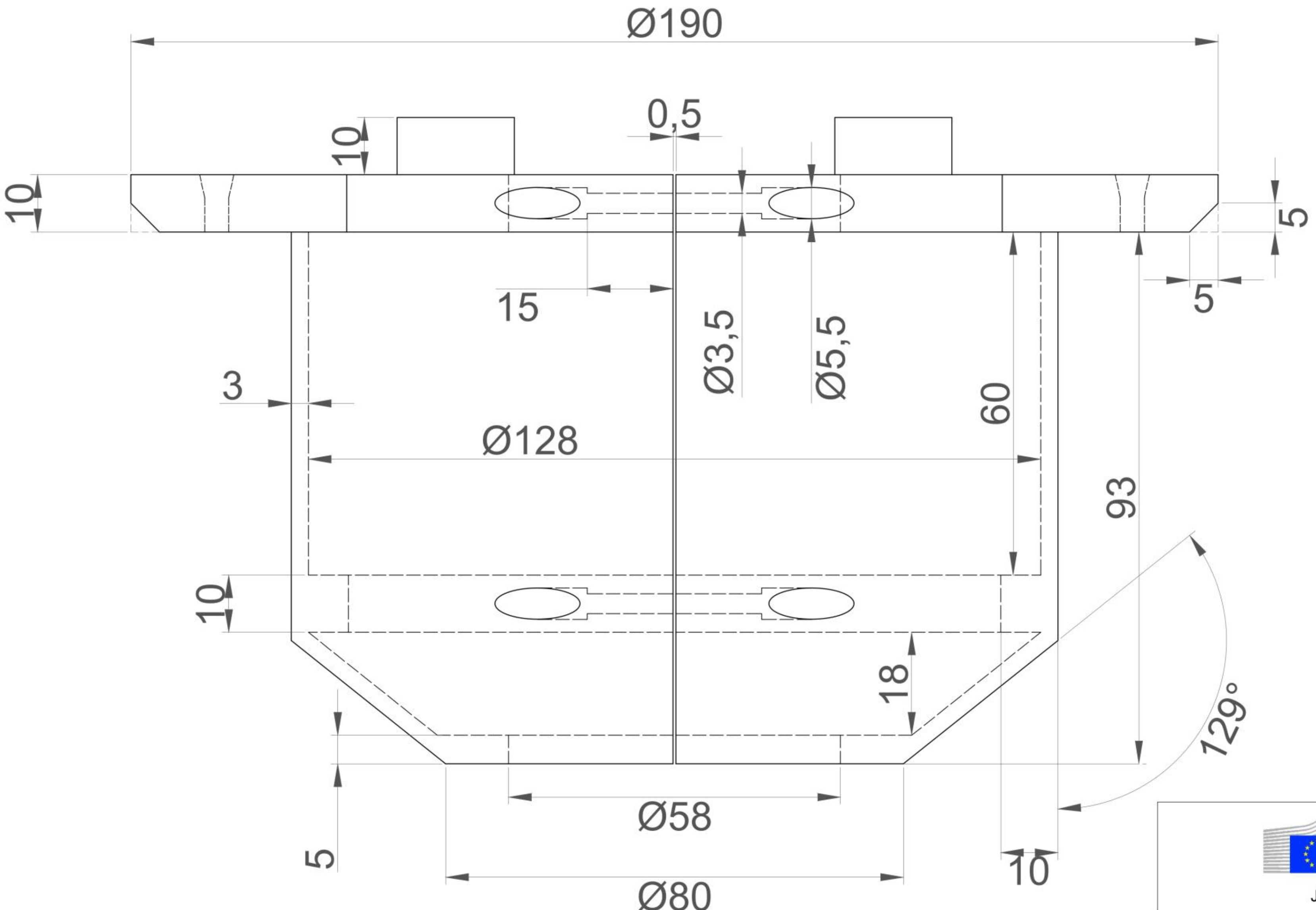


Top view

Joint Research Centre

Floating container a

Material	ABS (printed)	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:1	*Sheet*	8a of 18

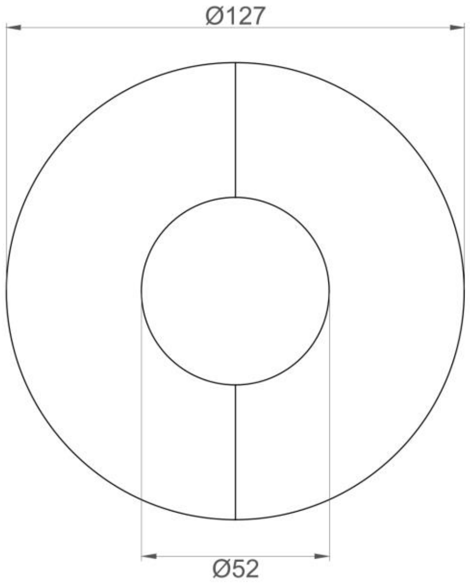


Front view

European Commission
Joint Research Centre

Floating container b

Material	ABS (printed)	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:1	*Sheet*	8b of 18



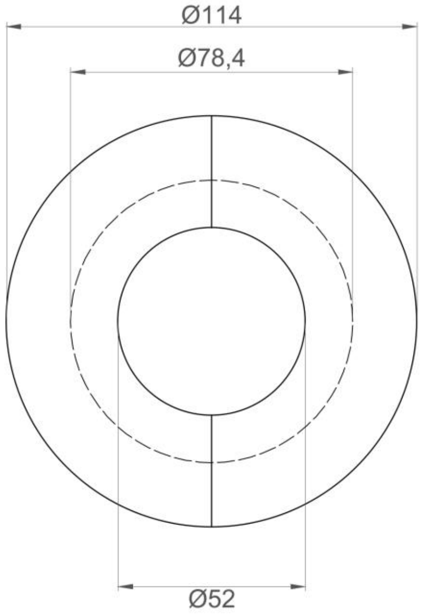
Top view

Front view

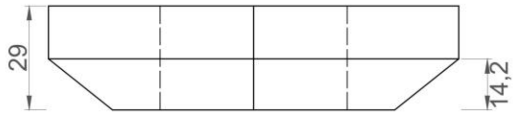
European Commission
Joint Research Centre

Big floating rings

Material	Foam	*Unit*	mm
Quantity	2	*Color*	Black
Scale	1:2	*Sheet*	9 of 18



Top view



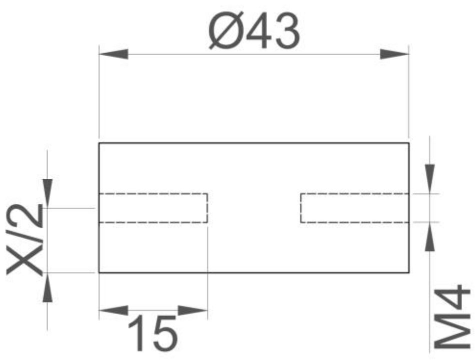
Front view

European
Commission

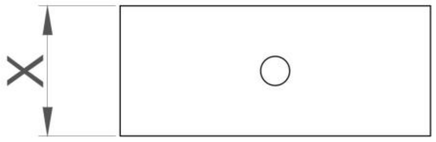
Joint Research Centre

Small floating ring

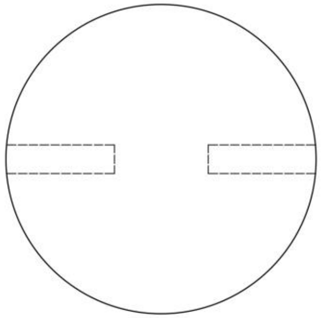
Material	Foam	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:2	*Sheet*	10 of 18



Front view



Side view



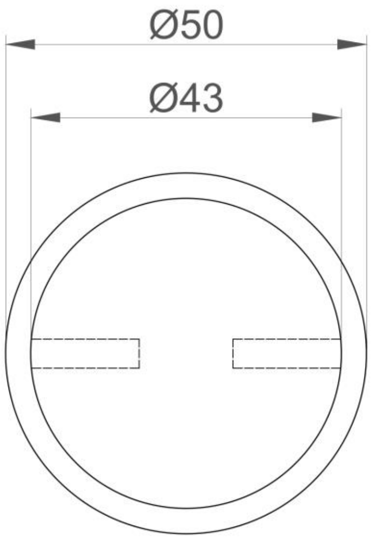
Top view

X = 9 mm (x2)
X = 18 mm (x2)
X = 44 mm (x2)

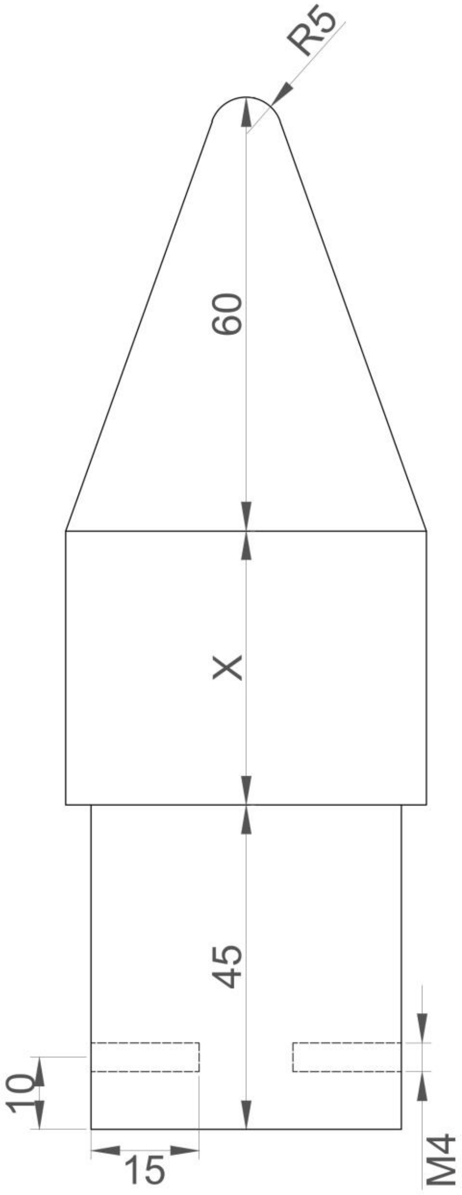
European Commission
Joint Research Centre

Disks

Material	Stainless steel	*Unit*	mm
Quantity	2 + 2 + 2	*Color*	Black
Scale	1:1	*Sheet*	11 of 18



Top view



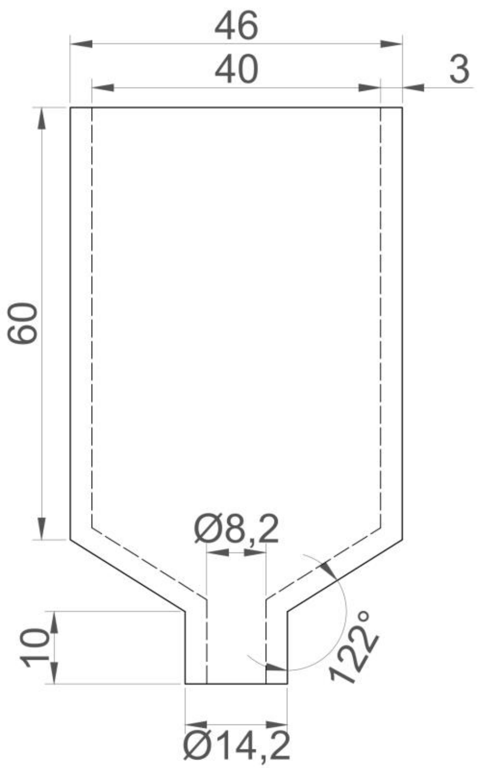
Front view

X = 6 mm (x1)
X = 38 mm (x1)
X = 70 mm (x1)

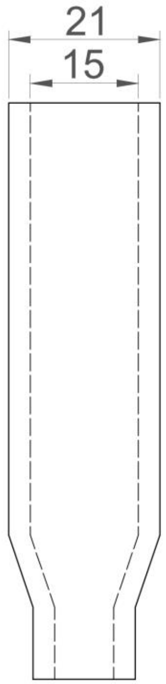
European Commission
Joint Research Centre

Tip

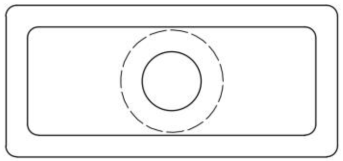
Material	Stainless steel	*Unit*	mm
Quantity	1 + 1 + 1	*Color*	Black
Scale	1:1	*Sheet*	12 of 18



Front view



Side view



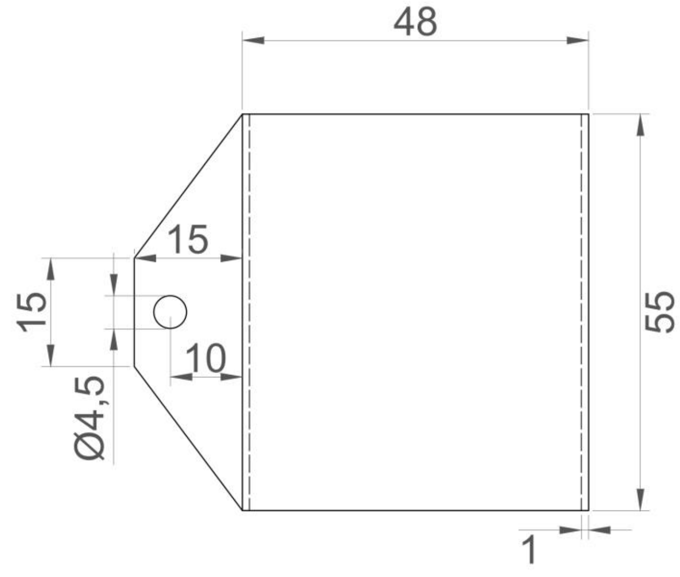
Top view

European Commission

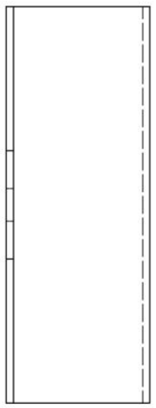
Joint Research Centre

Cable junction shell

Material	ABS (printed)	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:1	*Sheet*	13 of 18



Front view



Side view

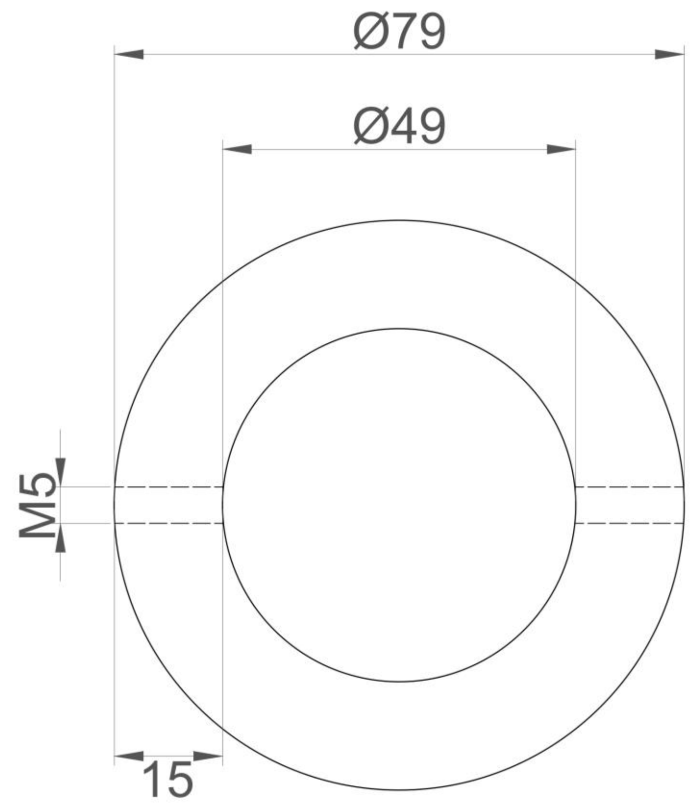
Top view

European Commission

Joint Research Centre

Cable shell fixing

Material	Stainless steel	*Unit*	mm
Quantity	1	*Color*	Black
Scale	1:1	*Sheet*	14 of 18



Top view

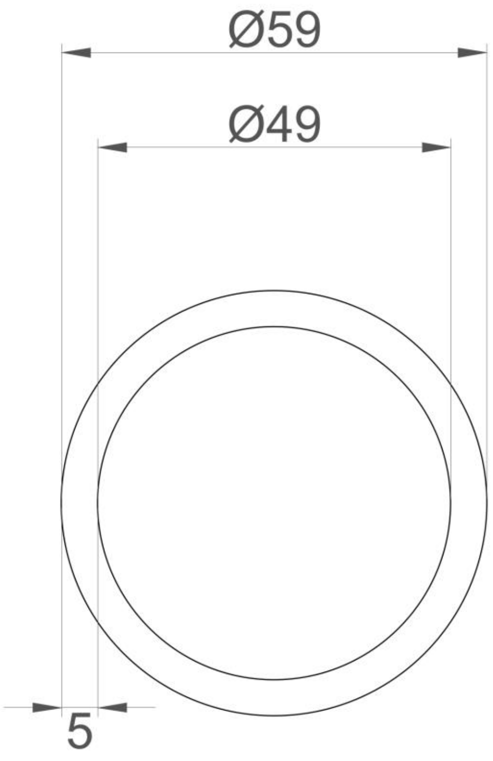
Front view

European Commission

Joint Research Centre

Locking ring

Material	PVC	*Unit*	mm
Quantity	2	*Color*	Black
Scale	1:1	*Sheet*	15 of 18



Top view

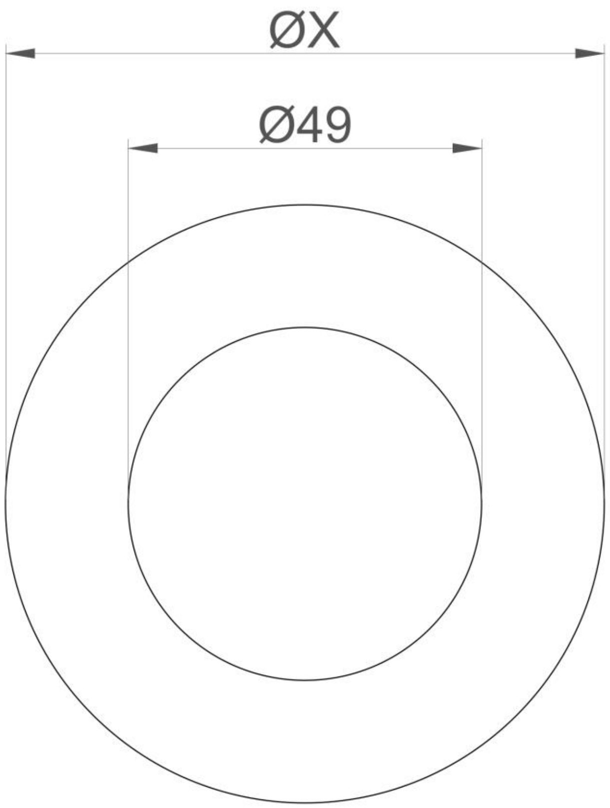
Front view

European Commission

Joint Research Centre

Spacer ring

Material	PVC	*Unit*	mm
Quantity	2	*Color*	Black
Scale	1:1	*Sheet*	16 of 18



Top view

Front view

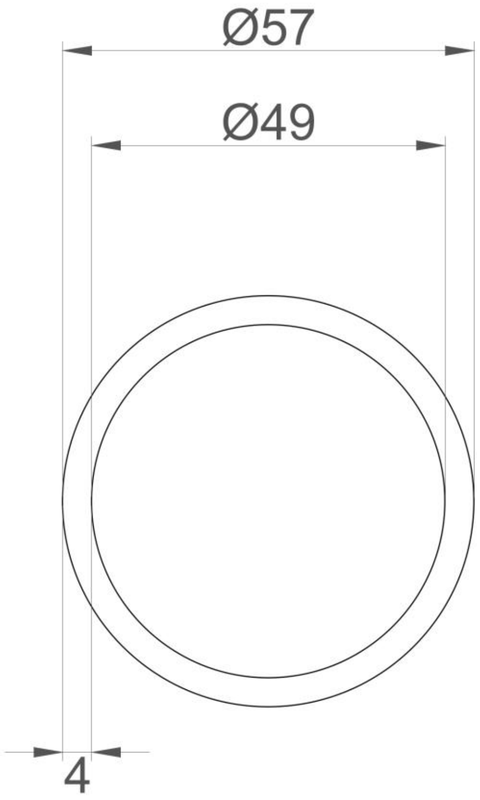
X = 83 mm (x6)
X = 109 mm (x6)

Joint Research Centre

Foam ring

Material	Foam	*Unit*	mm
Quantity	6 + 6	*Color*	Black
Scale	1:1	*Sheet*	17 of 18

Front view



Top view

X = 10 mm (x2)
X = 10 mm cut in half in height (x1)
X = 10 mm cut into quarters in height (x1)
X = 20 mm x2
X = 20 mm cut in half in height (x1)
X = 20 cut into quarters in height (x1)

European Commission
Joint Research Centre

Weighting rings

Material	Stainless steel	*Unit*	mm
Quantity	4 + 4	*Color*	Black
Scale	1:3	*Sheet*	18 of 18

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