

# STATUS OF THE MEMS INDUSTRY 2021

## Market & Technology Report - July 2021

*The MEMS market will grow due to new opportunities in audio for microphones, microspeakers and inertial MEMS, AR/VR for optical MEMS, and other emerging applications.*

### WHAT'S NEW

- Updated market data and forecasts in \$ and units for the period 2018–2026
- Up-to-date analysis of more than 15 different devices, including inertial, microphones, pressure in six different markets, including consumer, automotive, industrial, medical, telecom, defense and aerospace
- 2019 and 2020 estimates for sensor manufacturers' revenues and market shares
- Latest market trends by device type and ecosystem development
- Technology trends at the manufacturing level, device level and system level

### KEY FEATURES

- MEMS market forecast 2018-2026 (volume, \$M value)
- Market shares of MEMS players by device
- Market trends by MEMS device
- Newest MEMS products, funding, M&A and ecosystem development
- Technology trends:
  - Manufacturing
  - By device
  - From sensor to system

### A \$2.1B MARKET OPPORTUNITY BY 2026 FOR FAST-GROWING APPLICATIONS, IN A \$18B MEMS WORLD

Last year when COVID-19 erupted, the effects on various industries were felt immediately, which in turn had an after-effect on the MEMS business. But the crisis did not impact all end-markets the same way. The MEMS market relies heavily on consumer applications, which are 62% of the total market, and the automotive industry, which is 16% of the total market. We therefore expected that last year the MEMS market would suffer due to COVID-19's negative effects on end-system shipments of smartphones and cars. But this was not the case. MEMS sensor sales recovered during H2 2020. Manufacturers resumed refilling their inventories after signs of stabilization and recovery in key end markets. In fact, the strong demand for consumer MEMS has completely offset the automotive industry slowdown. Therefore, the MEMS market was worth almost \$12.1B in 2020, up almost 2% from the year earlier.

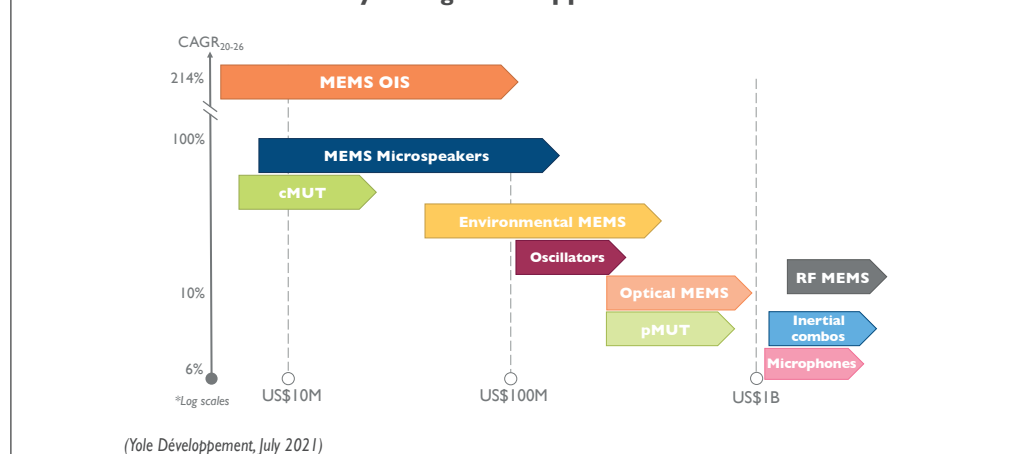
After a weak 2019 and 2020, we expect the market to grow by 11% in 2021, reaching \$13.4B. After that, high-single digit growth will increase annual MEMS revenue to \$18.2B by 2026. This promised growth could be delivered by new emerging technologies and opportunities, with a few notable ones such as:

- Microphones and inertial MEMS in wearables and particularly True Wireless Stereo (TWS) earbuds. This is driven by the need for better sound capture using microphones and voice activity detection (VAD), noise reduction with accelerometers for voice detection and bone conduction. 3D Audio is being pushed forward by Apple and will probably jump to Android

devices, causing a surge in demand for Inertial Measurement Units (IMUs).

- Gas sensors and environmental combos, integrated in wearables or automotive in-cabin air monitoring. These help monitor indoor and outdoor air quality around users, as they become more concerned about the air they breathe, and especially due to COVID-19.
- Optical MEMS for Light Detection and Ranging (LiDAR) and Augmented and Virtual Reality (AR/VR). Revenue in this sector might still be weak in five years' time. However, opportunities lie beyond this horizon, as the Advanced Driver Assistance System/Autonomous Vehicle (ADAS/AV) and AR/VR markets further develop.
- Piezoelectric Micromachined Ultrasonic Transducer (PMUT) devices, which are used in ultrasonic fingerprinting. PMUTs could also be used as a replacement for physical buttons and haptics in smartphones and cars. Capacitive MUT (CMUT) devices are also very promising for the consumerization of low-cost ultrasound imaging, close to the Point-of-Care (PoC).
- MEMS microspeakers, which should show their advantages in TWS in-ear designs first, replacing older electrodynamic or balanced armature speakers.
- MEMS-based sensor-shift optical image stabilization (OIS). This could replace the flexible Printed Circuit Board (PCB)-based sensor shift used for the first time in the iPhone 12 Pro's camera module. It may also enter other camera modules in other handsets or consumer devices.

2020-2026 MEMS industry best growth opportunities: revenues vs. CAGR\*



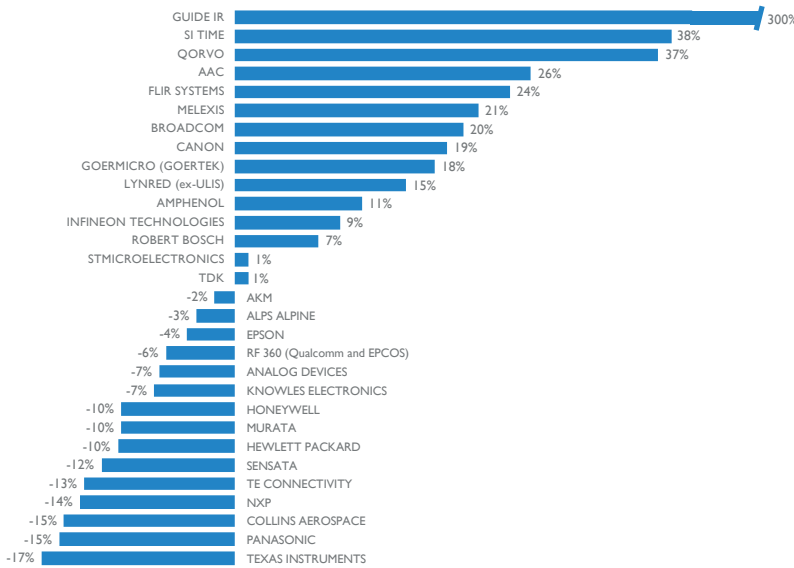
### PLAYERS' REVENUE GROWTH AND RANKING DYNAMICS

The pandemic, global lockdowns and the US-China trade war heavily impacted the supply chain of the semiconductor industry. A proper development strategy has therefore become the key to success. Some players profited from the crisis and some didn't, leading to significant changes in our global MEMS ranking. Bosch, Broadcom, Qorvo, STMicroelectronics, Texas Instruments, Goermicro (Goertek), HP, Knowles, TDK and Infineon now comprise the top-10 with at least \$6.5B combined revenues, more than half

of the total market. However, the companies that increased their revenue were not necessarily the ones holding the biggest market shares.

- Companies related to COVID-19 prevention technologies, such as thermal imaging and sensing or pressure sensors, grew strongly last year. For example, Guide IR, FLIR Systems, Lynred, which sell microbolometers, and Melexis, which sells thermopiles, profited due to the increased demand for elevated body temperature measurement application, while Amphenol saw its pressure MEMS grow due to demand for respiratory end-systems like ventilators and Continuous Positive Air Pressure (CPAP) machines.
- Broadcom and Qorvo grew significantly last year, providing highly reliable RF MEMS filters for 5G deployment, which was stronger than expected. SiTime is continuing to push strongly for replacement of traditional quartz timing solutions with its MEMS-based timing products.
- AAC and Goermicro (Goertek) profited from a fruitful MEMS microphone demand environment. For the first time in 15 years, the MEMS microphone leader Knowles has been replaced by Goermicro.
- Companies with business both in consumer and automotive like Bosch, STMicroelectronics and TDK, were able to offset some negative effects from automotive due to the impressive consumer MEMS business, new design wins and the pick-up in demand during H2 2020. Infineon has entered the top 10.

2020 top MEMS manufacturers – Year-over-year changes



(Yole Développement, July 2021)

### GOING FROM SENSORS TO SYSTEMS: MEMS PLAYERS CLIMBING THE VALUE CHAIN

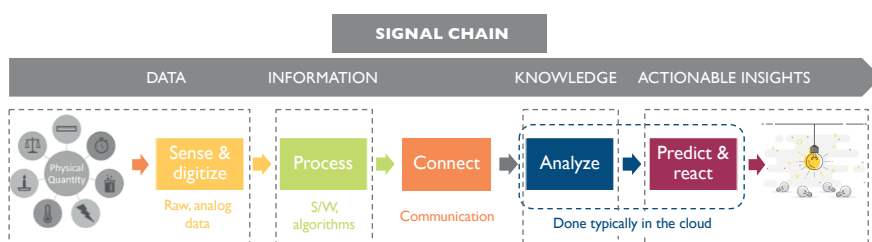
MEMS market challenges are evolving. In the past, focus was on product shrinking, price decrease and volume increase. Today, the requirements are changing with use cases being more important while different sensors must fuse with software. Power consumption must fall at the system level even though significant data processing is needed, especially for always-on applications like audio/voice human-to-machine interfaces (HMI).

Normally, all the data coming from the sensors are processed. The trend is to process them nearer to the sensors. This allows low latency, more safety

and more privacy, since no cloud computing is implicated. However component value is tied to the data. The higher the position on the signal chain, the higher the value will be. We see a growing movement toward a mix of competencies across the supply chain, from front-end manufacturing to packaging, the modules and the integration of systems. The move to a system level approach and the integration of different components like MEMS, application specific integrated circuits (ASICs), antennas and power sources that use different materials and processes in the same housing, is creating needs for more sophisticated System-in-Package (SiP) technologies, with the goal to increase system level performance and decrease overall power consumption.

We have been seeing various movements from MEMS manufacturers going to a system level approach, either by internal development or by mergers and acquisitions. For example, Knowles started selling a stand-alone Digital Signal Processor (DSP) for the Google Pixel phone in 2019. STMicroelectronics has an IMU with Artificial Intelligence/Machine Learning (AI/ML)

MEMS industry - Moving up the signal and value chain



(Yole Développement, July 2021)

libraries in the embedded Microcontroller Unit (MCU). Bosch released an accelerometer with edge AI on an MCU and a gas sensor with AI for olfactometry and odor detection. TDK also released a new family of smart sensors. STMicroelectronics has acquired Cartesiam for its edge AI capabilities, to further enhance its existing inertial products that include AI/ML. Finally, mCube has acquired Kinduct for its cloud analytics capabilities, offering actionable insights to customers.

We are now starting to witness the first signs that our devices could emulate and sense their environment with human-like capabilities, using the five best-known senses in a “phy-gital” meta-world. The final step for MEMS would be to evolve from simple deterministic data-collection sensors to more empathic data-interpretation machines. Such devices could discern and predict user moods, feelings and emotions, responding and reacting to needs and intentions, much like some humans are empathic.

**REPORT OBJECTIVES**

This report is an update of Yole Développement's best-selling “Status of the MEMS Industry” report, which was first released in 2004. This latest edition updates 2020's volumes, ASPs and market sizes. It provides an overview of the best future growth opportunities for MEMS. It explores the ecosystem development product-wise and funding-wise and details the main stakeholders involved. The report was finalized at the end of June 2021 therefore, the data that is the best available. This report summarizes the status of the 2021 MEMS industry in a thorough manner, taking into account the trends for each application separately.

**COMPANIES CITED IN THE REPORT (non exhaustive list)**

AAC, AKM, Alps Electric, Amphenol, Ams, Analog Devices, Apple, Arioso, Asia Pacific Microsystems, Aspinity, Atomica (ex IMT), Audiopixels, Boehringer Ingelheim Microparts, Bosch, Broadcom, Butterfly Network, Canon, Cartesiam, Colibrys, Collins Aerospace (EX UTC), Cirrus Logic, CSEM, Denso, DRS, Epcos, Epson, First Sensor Technology, FLIR Systems, Formfactor, Fraunhofer IPMS, Fujifilm Dimatix, Gettop, Goermicro (Goertek), Google, Hanking Electronics, Hewlett Packard, Honeywell, Imec, Infineon Technologies, Knowles Electronics, Lynred, Maxim, Melexis, Memscap, Memsensing, Memsic, Micralyne, Murata, Nxp, Omron, On Semi, Panasonic, Qorvo, Qualcomm, Raytheon, RF360, Rohm, Samsung, Sensata, Sensirion, Si Time, Silex Microsystems, Silicon Sensing Systems, Sintef, SMI, Sony, STmicroelectronics, Syntiant, Taiyo Yuden, TDK, TE Connectivity, Teledyne Dalsa, Texas Instruments, TowerSemi, VIS (Vanguard International Semiconductor), VTT, TSMC, UMC, Usound, X-Fab, Xmems, and more.

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**RELATED REPORTS, MONITORS & TRACKS**



- Gas and Particle Sensors – Technology and Market Trends 2021
- MEMS Pressure Sensors – Technology and Market Trends 2021
- Wearables in Consumer and Medical Applications 2020
- Consumer MEMS Microphones Comparison 2020
- Analog Devices High-End Accelerometers and Gyroscopes Comparison 2021

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**AUTHORS**

**Dimitrios Damianos, Ph.D.**, is a Senior Technology & Market Analyst, part of the Photonics & Sensing Division at Yole Développement (Yole). Based on solid technical expertise in imaging, sensing, display, lighting, and photonics, Dimitrios oversees the day-to-day production of valuable technology & market reports and custom consulting projects. Dimitrios also serves as a member of the Custom Project Business Development division (CPBD), supporting the development of strategic projects and following Yole's leading customers within the semiconductor industry. Dimitrios holds a BSc in Physics and an MSc in Photonics, both from the University of Patras (GR), and a Ph.D. in Optics & Microelectronics from the University of Grenoble-Alpes (FR).

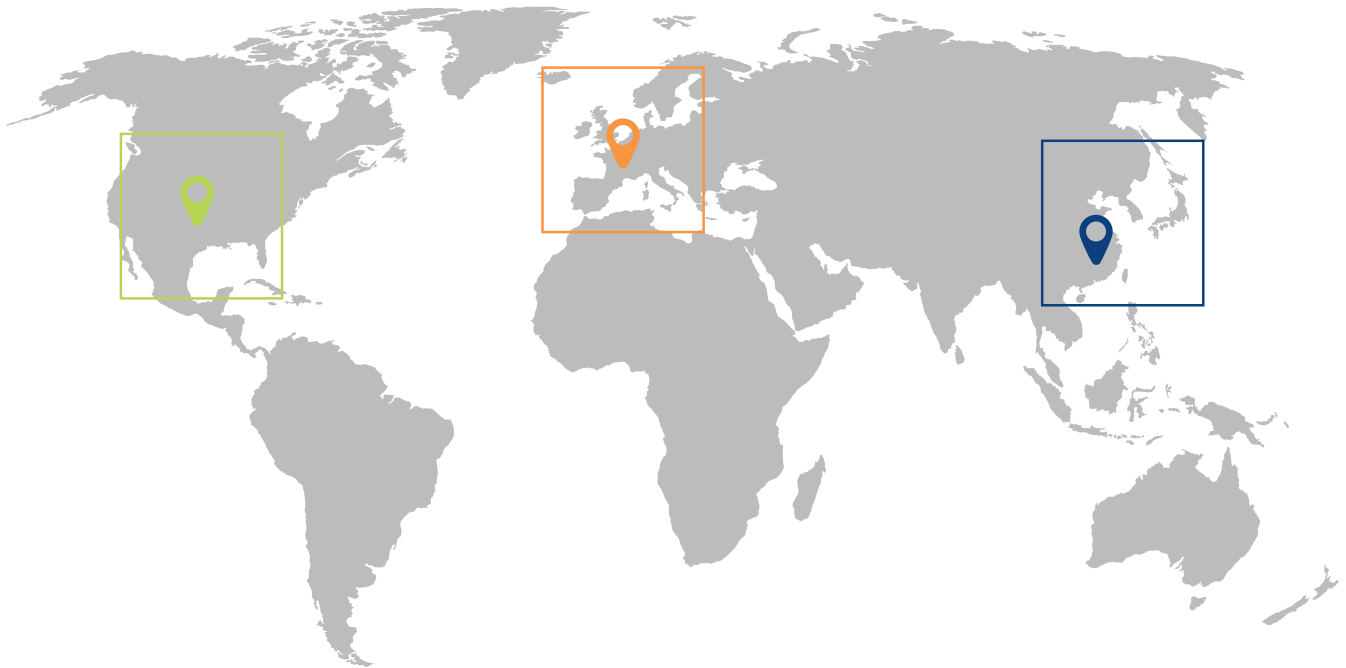


**Jérôme Mouly** is Team Lead Analyst in the Sensing & Actuating team within the Photonics & Sensing Division at Yole Développement (Yole). Jérôme manages the expansion of the technical expertise and market know-how of the team. He actively supports and assists in the development of a dedicated collection of market & technology reports as well as custom consulting projects. He has conducted more than 100 marketing and technological analyses for industrial groups, start-ups, and institutes in the field of MEMS and sensing technologies. Jérôme is regularly involved in international conferences, with presentations and keynotes. Jérôme Mouly earned a Master of Physics degree from the University of Lyon (FR).



**Pierre Delbos** is a Technology & Market Analyst in the Photonics & Sensing Division at Yole Développement. Pierre is involved in the development of technology and market reports covering MEMS & sensing technologies, including inertial sensors, microphones, gas sensors and electronic noses. He also collaborates with his team on custom studies for key players in the MEMS Industry. Pierre is preparing his Microelectronics and Photonics Engineering degree at the Grenoble Institute of Technology PHELM (Grenoble, France).

## CONTACT



### Western US & Canada

Steve Laferriere - [steve.laferriere@yole.fr](mailto:steve.laferriere@yole.fr)  
+ 1 310 600-8267

### Eastern US & Canada

Chris Youman – [chris.youman@yole.fr](mailto:chris.youman@yole.fr)  
+1 919 607 9839

### Europe and RoW

Lizzie Levenez - [lizzie.levenez@yole.fr](mailto:lizzie.levenez@yole.fr)  
+49 151 23 54 41 82

### DACH (North Germany, Austria, Switzerland)

Neha CHAUDHURY - [neha.chaudhury@yole.fr](mailto:neha.chaudhury@yole.fr)  
+49 172 97 47 248

### South Germany & France

Martine Komono - [martine.komono@yole.fr](mailto:martine.komono@yole.fr)  
+49 173 69 43 31

### Benelux, UK & Scandinavia

Marine Wybraniez - [marine.wybraniez@yole.fr](mailto:marine.wybraniez@yole.fr)  
+49 171 81 42 641

### India and RoA

Takashi Onozawa – [takashi.onozawa@yole.fr](mailto:takashi.onozawa@yole.fr)  
+81-80-4371-4887

### Korea

Peter Ok - [peter.ok@yole.fr](mailto:peter.ok@yole.fr)  
+82 1040890233

### Greater China

Mavis Wang – [mavis.wang@yole.fr](mailto:mavis.wang@yole.fr)  
+886 979336809 +86 136 61566824

### Japan

Miho Ohtake – [miho.ohtake@yole.fr](mailto:miho.ohtake@yole.fr)  
+81 34405-9204

Toru Hosaka – [toru.hosaka@yole.fr](mailto:toru.hosaka@yole.fr)  
+81 90 1775 3866

### Japan and Singapore

Itsuyo Oshiba – [itsuyo.oshiba@yole.fr](mailto:itsuyo.oshiba@yole.fr)  
+81-80-3577-3042

### Sales Coordination & Customers Service

David Jourdan – [david.jourdan@yole.fr](mailto:david.jourdan@yole.fr)  
+33 472 83 01 90

Fayçal El Khamassi – [faycal.khamassi@yole.fr](mailto:faycal.khamassi@yole.fr)  
+33 472 83 01 95

## ABOUT YOLE DEVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

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- Market data & research, marketing analysis
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### CONTACTS

For more information about :

- Consulting & Financial Services: Jean-Christophe Eloy ([eloy@yole.fr](mailto:eloy@yole.fr))
- Reports & Monitors: David Jourdan ([david.jourdan@yole.fr](mailto:david.jourdan@yole.fr)) & Fayçal Khamassi ([faycal.khamassi@yole.fr](mailto:faycal.khamassi@yole.fr))
- Public Relations: Sandrine Leroy ([sandrine.leroy@yole.fr](mailto:sandrine.leroy@yole.fr))
- Marketing & Communication: Jean-Christophe Eloy ([eloy@yole.fr](mailto:eloy@yole.fr))

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1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email. In the absence of any confirmation in writing, no order shall be deemed to have been accepted.

## 2. MAILING OF THE PRODUCTS

- 2.1 Products are sent by email to the Buyer after Seller’s confirmation:
  - Within a few days from the Seller’s confirmation of the order for Products already released and paid; or
  - Within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.
- 2.2 The Seller shall by no means be responsible for any delay pursuant to Article 2.1 above, in particular in cases where a new event or access to new contradictory information would require the Seller analyst to dedicate extra time to compute or compare the data in order to enable the Seller to deliver a high quality Product.
- 2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in Article 3 above.

2.4. The mailing is operated through electronic means either by email via the sales department or automatically online via an email/password. The Buyer is responsible for ensuring that the Buyers platform has the required capacities and authorisations to receive the Product(s) emailed by the Seller. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that the Seller is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.5 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity with the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects.

2.6 No return of Products shall be accepted without prior written notification from the Buyer to the Seller, even in case of delayed delivery. Any Product returned to the Seller without the Buyer providing prior notification to the Seller as required under Article 2.5 above shall remain at the Buyer’s risk. In no event shall the Seller incur any liability for Products erroneously ordered by the Buyer, or for any request from the Buyer to replace a Product previously ordered by a different Product.

## 3. PRICE, INVOICING AND PAYMENT

3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are deemed to be inclusive of all taxes applicable in the country where the Seller is based (except for France where VAT will be added). The prices are re-evaluated from time to time by the Seller. The effective price is deemed to be the one applicable at the time of the order.

3.2 Payments due by the Buyer shall be sent by cheque payable to Yole Développement, or made by credit card or by electronic transfer to the following account:  
HSBC, 1 place de la Bourse 69002 Lyon France  
Bank code: 30056  
Branch code: 00170  
Account n°: 0170 200 1565 87  
BIC or SWIFT code: CCFRFRPP  
IBAN: FR76 3005 6001 7001 7020 0156 587

To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the “BCE” + 7 points, in accordance with article L.441-6 of the French Commercial Code.

3.4 The Seller publications (reports, monitors, tracks...) are due for delivery only after receipt by the Seller of any payment due by the Buyer prior to delivery.

3.5 In the event of termination of the contract by the Seller attributable to Buyer misconduct during the contract, the Seller will have the right to invoice all work performed at the time of termination, and to take legal action for damages.

## 4. LIABILITIES

4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for the choice of the Products purchased as well as for the use and interpretations the Buyer makes of the documents it purchases, of the results the Buyer obtains, and of the advice and acts the Buyer bases thereon .

4.2 In no event shall the Seller be liable for:

- a) Damages of any kind, including without limitation, incidental or consequential damages (including, but not limited to, damages for loss of profits, business interruption and loss of programs or information) arising out of the use of a Product or the use of or the inability by the Buyer to use the Seller’s website, or any information provided on the website, or contained in a Product;
- b) Any claim attributable to errors, omissions or other inaccuracies in a Product or interpretations thereof.

4.3 All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy, completeness adequacy or reliability of such information, which cannot be guaranteed to be free from errors.

4.4 Any Product that the Seller sells may, upon prior notice to the Buyer from time to time be modified by Seller or substituted with a similar Product meeting the needs of the Buyer. Such modification shall not lead to any liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

4.5 In the case where, after inspection, it is acknowledged that a Product contain defects, the Seller undertakes to replace the defective product to the extent reasonably feasible and without indemnification or compensation of any kind for labour costs, delays, loss caused or any other reason being due by the Buyer . This undertaking from the Seller shall be effective for a maximum of two months starting from the delivery date but shall not be applicable in the event of force majeure as described in Article 5 below.

4.6 The deadlines that the Seller is asked to provide for the mailing of a Product are given for information purposes only and are not guaranteed. If such deadlines are not met, this shall not, without the agreement of the Seller lead to any claim for damages or right of cancellation of one or more orders by the Buyer, except for non-acceptable delays exceeding [3] months from the stated deadline. In such case only i.e. only in the event of a delay exceeding (3) months from the stated deadline the Buyer shall be entitled to ask for a reimbursement of any down payment previously made to the Seller, to the exclusion of any other damages.

4.7 The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to any Products. Although the Seller shall take reasonable steps to screen Products for infection of viruses, worms, Trojan horses or other codes containing contaminating or destructive properties before making Products available, the Seller cannot guarantee that any Product will be free from infection.

## 5. FORCE MAJEURE

The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labour difficulties, epidemics, major health event (e.g. Corona virus), equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not attributable to the fault of the Seller.

## 6. PROTECTION OF THE SELLER’S IPR

6.1 All the IPR attached to the Products are and remain the property of the Seller and are protected under French and international copyright law and conventions.

6.2 The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or publish a Product, or any part of it to any other party other than employees of the Buyer Company (and only in the country of the Primary User for Multi-User Licenses). The Buyer shall have the right to use Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use any Product for purposes such as:

- Information storage and retrieval systems;
- Recordings and re-transmittals over any network (including any local area network);
- Use in any timesharing, service bureau, bulletin board or similar arrangement or public display;
- Posting any Product to any other online service (including bulletin boards or the Internet);
- Licensing, leasing, selling, offering for sale or assigning a Product or any derivative thereof.

6.3 If the Buyer would like to use data coming from a Product for presentations, press announcements and any other projects, the Buyer needs to contact Yole Développement’s Public Relations Director (info@yole.fr) to get an official authorization and confirm that the data are up to date. In return the Seller will make sure to provide up-to-date data under a suitable public format.

6.4 The Buyer shall be solely responsible towards the Seller for any infringement of the obligation described in Article 6.3 above, whether such infringement originates from the Buyer’s employees or any person to whom the Buyer has sent the Products. Furthermore, the Buyer shall initiate and personally take care of any related proceedings in coordination with the Seller, and the Buyer shall bear the related financial consequences in their entirety.

6.5 The Buyer shall define within its Company an identified user who shall serve as a contact person for the License purchased by the Buyer. This person will be the recipient of each new report. This person shall also be responsible on behalf of the Buyer, for compliance with all copyrights and other obligations relating to the protection of the Seller’s IP rights and general compliance with the terms of the License purchased by the Company. In the context of Bundle and Annual Subscriptions, the contact person shall decide within the Buyer which person(s) shall be entitled to receive the protected link that will allow the Buyer to access the Products.

6.6 It is acknowledged and accepted by the Buyer that whether purchased in the form of Bundles or Annual Subscription, all unselected reports will be deemed cancelled and lost after a period of 12 month following acceptance of the corresponding order by the Seller in accordance with provisions of Article 1.3 above .

6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

## 7. TERMINATION

If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

## 8. MISCELLANEOUS

8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

## 9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.