

COMPUTING AND AI TECHNOLOGIES FOR MOBILE AND CONSUMER APPLICATIONS 2021

Market & Technology Report - October 2021

Penetrating everyday products will see the market for AI technologies for the consumer market reach \$5.6B in 2026

WHAT'S NEW

- Inclusion of wearables markets, including smartwatches, True Wireless Stereo (TWS) earbuds, audio headsets, Augmented Reality (AR) and Virtual Reality (VR) headsets with market trends, ecosystems, forecasts, and technology trends
- Hardware technology trends analyzed in detail
- Wider scope including most computing processors, not only focusing on AI. Forecasts for the main processors for all applications studied in volumes shipped, Average Selling Price (ASP) and revenue

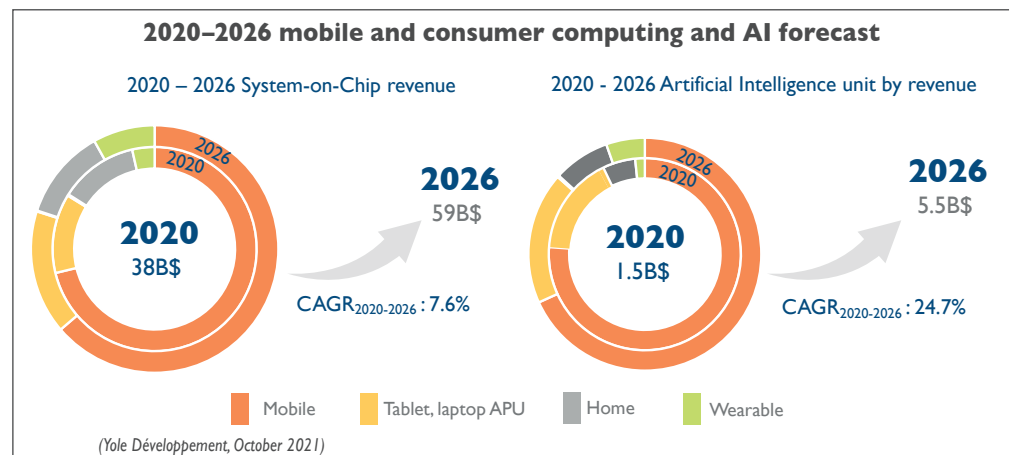
KEY FEATURES

- Types of hardware for smartphones, drones, smart home devices including smart speakers, smart TVs and cameras and wearable devices including smart watches, TWS earbuds, and AR/VR headsets
- Consumer processor forecast in volume shipments, ASP and revenue
- Forecast for AI penetration rate into main processors, with unit ASP and revenue
- AI technologies used in consumer applications
- Edge computing for AI
- Ecosystems, market forecast, and trends
- AI consumer technology trends, including hardware evolution and AI integration
- Investments, mergers and acquisition analysis

AI FEATURES ARE BECOMING STANDARD IN CONSUMER APPLICATIONS

Artificial Intelligence (AI) technologies are already in many products that we use every day. They started in our smartphones, through applications such as face recognition or photography setting optimization. They are now spreading into most consumer applications, from smart home cameras with features such as intrusion detection to smart assistant support integrated into earbuds. Today imaging AI and audio AI are the most widespread applications. For several reasons including privacy protection and low latency requirements, AI inference is increasingly computed at the edge of the network, in the

actual consumer device. This requires special processor capabilities to run these operations in real time. The share of processors dedicated to run AI is therefore growing. In this report, we analyze and forecast both the processor and AI unit markets, including the area of silicon specifically dedicated to accelerating AI operations. Figure 1 shows that the processor market has a 7.6% Compound Annual Growth Rate from 2020-2026 (CAGR20-26) driven by dynamic applications like earbuds. AI unit revenue has a 24.7% CAGR20-26, boosted by strong penetration of AI into most consumer applications.



AI UNITS FOLLOW THE INTEGRATION TREND IN THE CONSUMER MARKET

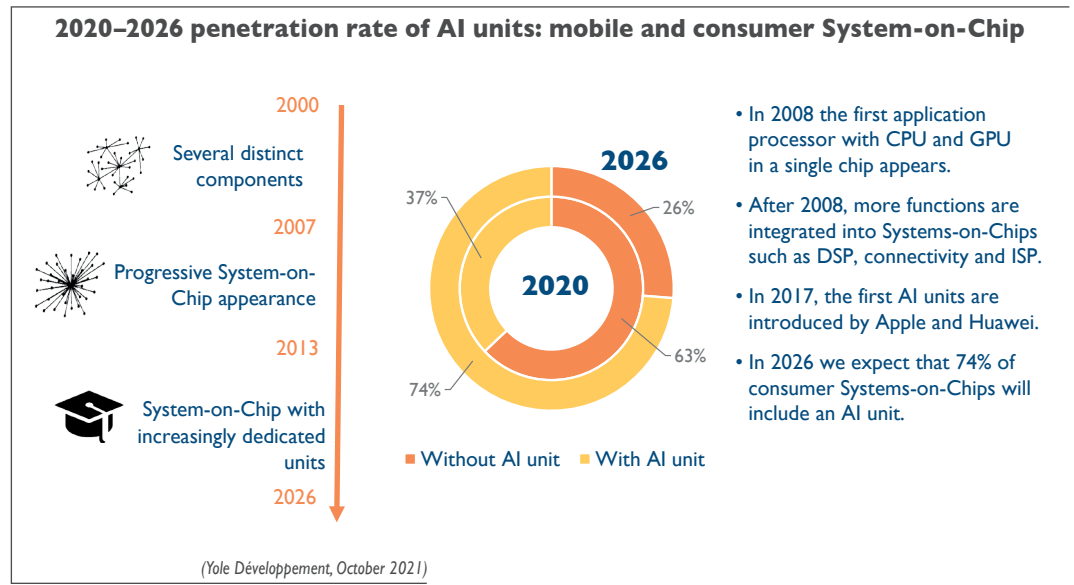
Processors for consumer markets are today mostly Systems on Chips (SoCs). They integrate all the required functions, such as Central Processing Unit (CPU) cores, audio Digital Signal Processing (DSP), and Bluetooth connectivity, rather than having a standalone chip for each function. Other options also exist and are analyzed in this report, but this is the main trend and it also affects AI hardware. Most consumer processor players are directly integrating AI units

into their SoCs to accelerate AI inference. This sector is unlike CPUs and Graphics Processing Units (GPUs), where many solutions from Intellectual Property (IP) players such as ARM contribute. Instead, the processor designers are mostly not using solutions developed by IP companies, such as the new ARM Ethos solution. They prefer developing custom IP, as it is a good way to differentiate themselves from their competition.

BETWEEN SMARTPHONE OEM AND FABLESS PROCESSOR COMPANIES, FEW PLAYERS COMPETE ON HIGH-END TECHNOLOGIES

There are two kinds of processor players. One is the smartphone-making OEMs with processor design capabilities, such as Apple, Samsung, Huawei, and soon Google. The other is fabless

processor companies such as Qualcomm, MediaTek, and UniSoC. Qualcomm and MediaTek are the two biggest fabless processor companies for consumer applications, both



in terms of shipments and revenues. They have products targeting most consumer applications, with either one or the other usually being the leading player. Apple follows a different model, however. It is the third-placed processor maker for consumer markets, but doesn't sell processors to anyone. Processors let Apple control its ecosystem and to adapt its products' hardware to its software. Even if Apple's silicon design activity is just to support its products, it designs top-level processors and frequently drives innovation in this domain. Following a similar strategy, HiSilicon, a Huawei subsidiary, was very dynamic in 2020, following the strong growth of Huawei products. However, following the application of US sanctions, the story will be totally different. We expect HiSilicon to lose almost half of its Application Processor Unit (APU) revenue in 2021. In the short term, the future of high-end HiSilicon products made technology beyond the 14nm lithography node is uncertain.

Smartphone processor designers also lead the race in most other consumer product processor

markets. That is especially true in smartwatches which has the same players, both for end-products and processor. For True Wireless Stereo (TWS) earbuds, the story is different. Big processor players compete with historical processor players specialized in Bluetooth and audio technologies, but also with new players, mainly from China. For example, BES Technic has leveraged the skyrocketing growth of TWS earbuds to become a major player in this market. Smart speaker makers are also different from big smartphone players. They are US and Chinese tech giants, through partnerships with processor players. For example, Amazon and MediaTek make a processor that integrates Amazon's custom AZI Neural Edge processor. Other players include Synaptics, Amlogic, and Allwinner Technologies.

All the big players, and US and Chinese tech giants especially, are very involved in acquisitions of and investment into AI start-ups. This entire dynamic ecosystem is analyzed in detail in this report, including a broad analysis but also specific focuses on wearables and smart homes.

2021 consumer processor ecosystem overview

	Smartphone	Smart TVs	Smart speakers	Home security cameras	Smartwatches	TWS earbuds
Main players (#revenue ranking)	#1 Qualcomm	#1 MEDIATEK	#1 MEDIATEK		#1 Apple	#1 Apple
	#2 MEDIATEK	#2 SAMSUNG	#2 Amlogic		#2 Qualcomm	Qualcomm
	#3 Apple		#3 Apple		#3 MEDIATEK (Only in China)	AIROHA <small>Alibaba Technology Corp.</small>
	SAMSUNG	SONY	Qualcomm	Qualcomm	SAMSUNG	REALTEK
	HISILICON	LG	Synaptics	Ambarella	TOSHIBA	BROADCOM
	UNISOC		Allwinner Technology	Amlogic	HISILICON	Omnivision
			HISILICON	UNISOC	CYPRESS	BES TECHNOLOGIES
			AXIS			UNISOC

Non-exhaustive list of companies
(Yole Développement, October 2021)

REPORT OBJECTIVES

Provide an understanding of computing trends and dynamics for key mobile and consumer applications:

- Market dynamics and segmentation breakdown by application and end-system
- Systems - volume shipment forecast
- Hardware for consumer application - revenue forecast, volume shipment forecast, ASP
- Type of hardware associated with each end-systems, key trends and dynamics

Provide a scenario for AI within the dynamics of the consumer market, and understand AI's impact on the semiconductor industry:

- Hardware for AI - revenue forecast, volume shipment forecast
- Focus on consumer applications with embedded technologies: smartphones, consumer drones, smart speakers, smart TVs, home security cameras, smartwatches, TWS earbuds, AR and VR headsets

Deliver an in-depth understanding of the ecosystem and players:

- Who are the players? What are the relationships inside this ecosystem? What happened in the last three years?
- Who are the key suppliers to watch, and what technologies do they provide?

Offer key technical insight and analysis into future technology trends and challenges:

- Key technology choices
- Technology dynamics
- Emerging technologies and roadmaps

COMPANIES CITED IN THE REPORT
(non exhaustive list)

Airoha, Alibaba, Allwinner Technology, Alphabet, Amazon, Ambarella, Amlogic, AMD, Analog Devices, Anker, Apple, ARM, Asus, ATI, Axis Communication, Baidu, Bes Technic, Bluetrum, Bose, Broadcom, CEVA, Cirrus Logic, Cray, Cypress, Deephi Tech, DeepMind, DJI, DSP Group, Edifier, Facebook, Fossil, Fitbit, Garmin, Greenwaves, Google, Graphcore, Hailo, Hisilicon, Hover Camera, Honor, HTC, Huawei, Huawei, IBM, Imagination, Infineon and more.

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John Lorenz is a Technology and Market Analyst within the Computing & Software division at Yole Développement (Yole). After holding various positions within Micron Technology including engineering, strategic and finance roles, John is daily engaged in the development of market and technology monitors for the logic segment of advanced semiconductors at Yole. John has a Bachelor of Science degree in Mechanical Engineering from the University of Illinois Urbana-Champaign (USA), with a focus on MEMS devices.

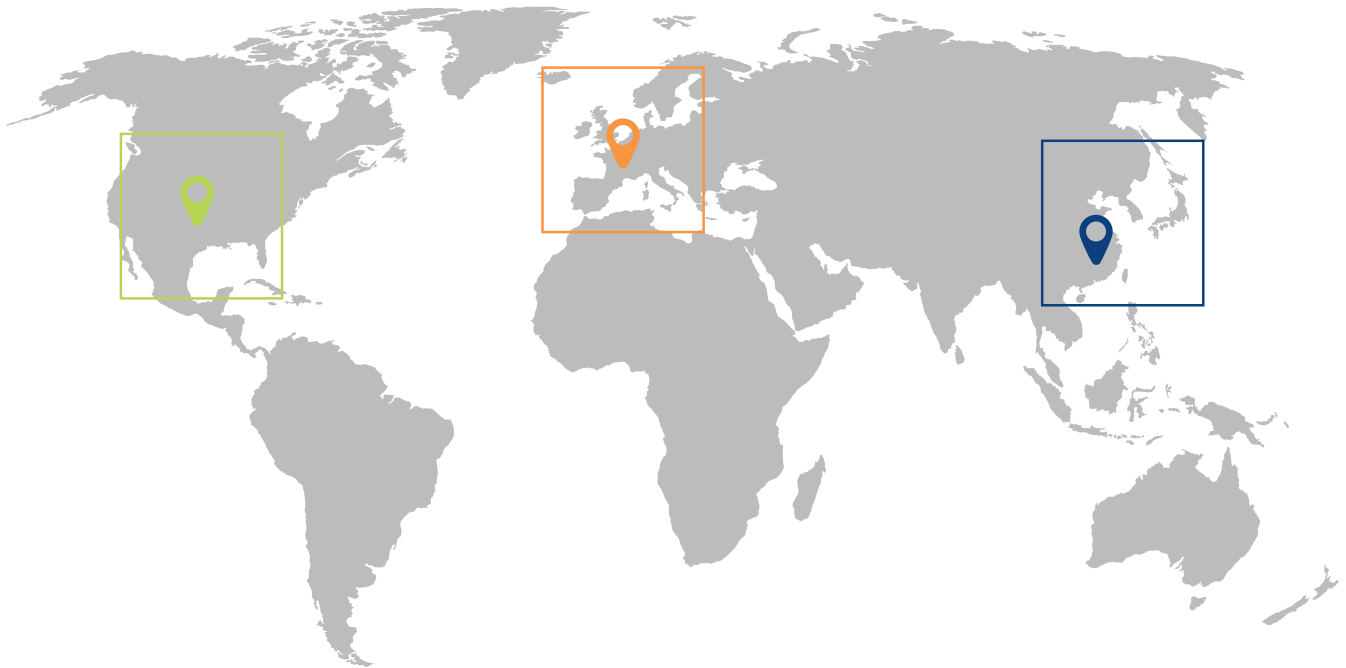
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- Cameras and Computing for Surveillance and Security 2020
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ABOUT YOLE DEVELOPPEMENT

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.

CONSULTING AND ANALYSIS

- Market data & research, marketing analysis
- Technology analysis
- Strategy consulting
- Reverse engineering & costing
- Design and characterization of innovative optical systems
- Financial services (due diligence, M&A)

More information on www.yole.fr

MEDIA & EVENTS

- i-Micronews.com website, application & related e-newsletter
- Communication & webcast services
- Events: TechDays, forums

More information on www.i-Micronews.com

REPORTS & MONITORS

- Market & technology reports
- Market and reverse technology quarterly monitors
- Structure, process and cost analysis and teardowns
- Cost simulation tool

More information on www.i-micronews.com/reports

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- Marketing & Communication: Jean-Christophe Eloy (eloy@yole.fr)

Definitions: **“Acceptance”**: Action by which the Buyer accepts these General Terms and Conditions of Sale in their entirety. It is done by signing the purchase order which states “I hereby accept Yole Développement’s General Terms and Conditions of Sale”.

“Buyer”: Any business user (i.e. any person acting in the course of its business activities for its business needs) placing an order pursuant to these General Terms and Conditions of Sale, with the exclusion of any individual consumer acting for his/her sole personal interest.

“Seller”: Headquartered in Villeurbanne (France), Yole Développement provides marketing, technology and strategy consulting, media and corporate finance services, reverse engineering/costing services as well as IP and patent analysis. With dedicated teams of technology & market analysts, Yole Développement operates worldwide with the key industrial companies, R&D institutes and investors to help them understand the market and technology trends.

“Contracting Parties” or **“Parties”**: The Seller on the one hand and the Buyer on the other hand.

“Intellectual Property Rights” (“IPR”) means any rights held by the Seller in its Products, including any patents, trademarks, registered models, designs, copyrights, inventions, commercial secrets and know-how, technical information, company or trading names and any other intellectual property rights or similar in any part of the world, notwithstanding the fact that they have been registered or not and including any pending registration of one of the above mentioned rights.

“Products”
Our products can be bought either on a unit basis or as a bundled offer (i.e. subscription for a period of 12 calendar months).

“Report”
Reports are established in PowerPoint and delivered in a PDF format with an additional Excel file. 30 min of Q&A session with an analyst/author can be included for all purchased reports (except the ones bought as a one user license). More time can be allocated on a fee basis.

“Monitor”
Monitors are established and delivered in Excel. An additional PDF can also be added. Q&A with an Analyst is possible for each monitor (except where specified otherwise). Frequency of the release vary according to the monitor or service (quarterly and monthly). All monitor products are eligible for a Corporate License.

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Yearly subscription to access a web-based interactive portal to view features and specs of a device or component based on a complete turnaround process.

“License”
For the reports 3 different licenses are proposed. Buyer has to choose one license type:
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1. SCOPE

1.1 Both Contracting Parties undertake to comply with these General Terms and Conditions of Sale.
ANY ADDITIONAL, DIFFERENT, OR CONFLICTING TERMS AND CONDITIONS IN ANY OTHER DOCUMENTS ISSUED BY THE BUYER AT ANY TIME ARE HEREBY OBJECTED TO BY THE SELLER, ARE DEEMED WHOLLY INAPPLICABLE TO ANY SALE MADE HEREUNDER, AND SHALL NOT BE BINDING IN ANY WAY ON THE SELLER.

1.2 These General Terms and Conditions of Sale shall be deemed valid and enforceable between the Contracting Parties after acceptance of an order from the Buyer by the Seller pursuant to Article 1.3 below. For such purpose, the Buyer, when signing the purchase order which mentions “I hereby accept Yole Développement’s Terms and Conditions of Sale” is deemed to have fully and unequivocally accepted these Terms and Conditions of Sale.

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:

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- 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.