

5G MMTc AND IoT PLATFORMS - TECHNOLOGY AND MARKET TRENDS 2021

Market & Technology Report - September 2021

Cellular IoT to get full benefit of 5G starting in 2023 and to reach 900M units a year in 2026.

KEY FEATURES

- Executive summary
- Market forecasts
- System level forecast
- RF component level forecast
- Wafer forecast
- Market trends
- General market dynamics
- Cellular IoT for existing and new applications
- Focus on 4G/5G public frequencies
- Focus on 4G/5G private frequencies
- Focus on ISM unlicensed frequencies
- mMTC 5G IoT cost breakdown
- URLLC, edge computing and AIoT
- General expectations for IoT
- Market shares and supply chain
- Market shares
- Cellular IoT modules market shares
- RF components market shares
- Supply chain
- Ecosystem and technology landscape
- IoT chipset and module makers
- Technology trends
- Transmission module
- RF communication
- Network infrastructure

A LIMITED NUMBER OF POTENTIAL APPLICATIONS

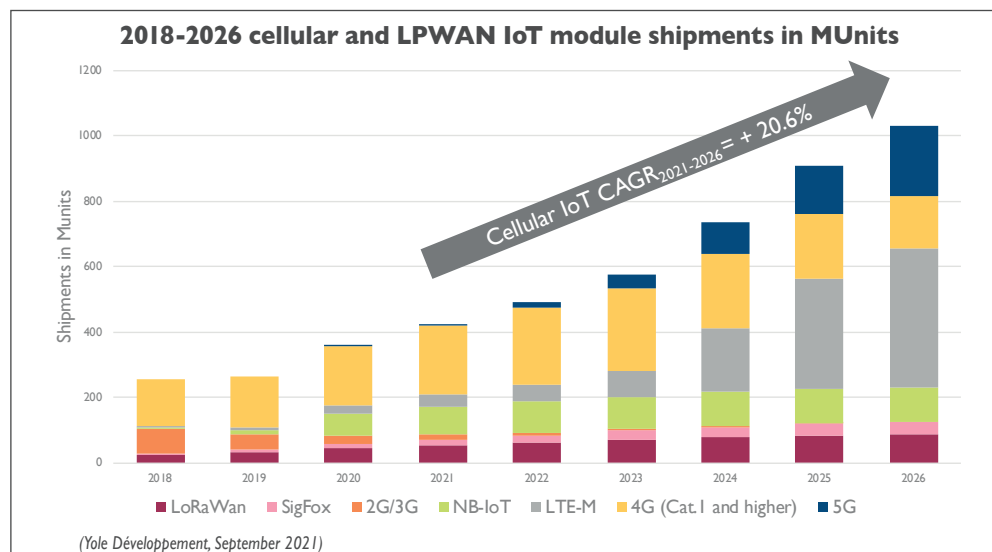
Wireless connectivity of things has stopped being an abstract concept. Today, everyone has their personal experience with connectivity or at least has heard about it. It could be through Bluetooth earphones, a fitness band or the connection of their electric meter to their home Wi-Fi. These applications, often using Wi-Fi or Bluetooth, are referred to as Personal Area Networks or Home Automation. This market, which is based on short-distance, non-critical operations, already exists. Nevertheless, the generalization of the Internet of Things (IoT), connected devices in all aspects of our society and industries, has not fully happened yet.

Multiple approaches have been tried in the past to develop the IoT. They have used unlicensed frequencies, through protocols like the IEEE802.15.4 based Zigbee or Z-Wave, the LoRaWAN and Sigfox protocols, or long-range Wi-Fi. But this has not been a success, mainly due to the general requirement for data reliability and security, meaning confidentiality, integrity, and availability. But this is changing now with cellular protocols aimed at IoT.

These cellular protocols range from the low data rate NB-IoT to the very high data rate, high reliability, low latency 5G Cat20. The latter has finally started to see traction from the industry.

Cellular deployment is expensive, either on a capital expenditure standpoint for private networks or an operating expenditure standpoint when using public networks. But 5G offers unprecedented capabilities in terms of data security, creating a market opportunity for critical applications. These are niche applications, for example, in highly automated industrial environments, where wireless connectivity adds a lot of value. Other applications range from machine vision to autonomous guided vehicle monitoring. They are now motivating investment in 5G deployments, thus opening the market for all other cellular-based deployments to come.

Market volume is expected to reach 900M devices in 2026. It started in 2020 with a volume of 298Mu driven by the replacement of 2G/3G devices like points of sale or telematics. These volumes are still very far from the billions of industrial connected devices anticipated by tech companies several years back. This is mostly due to the niche nature of IoT applications. But this still represents a big market opportunity, reaching \$859M in 2026 from \$257M in 2020 with a 22.3% Compound Annual Growth Rate (CAGR) for 2020-2026 at the radio frequency (RF) front-end component level.



IoT TECHNOLOGICAL LANDSCAPE

Transmission protocols shape the IoT technological landscape. Multiple protocols exist based on different standards. Today, the protocols

of interest are the 5G related protocols, ranging from the now well-known NB-IoT and LTE-M, to the 5G Cat20 protocol, also referred to as

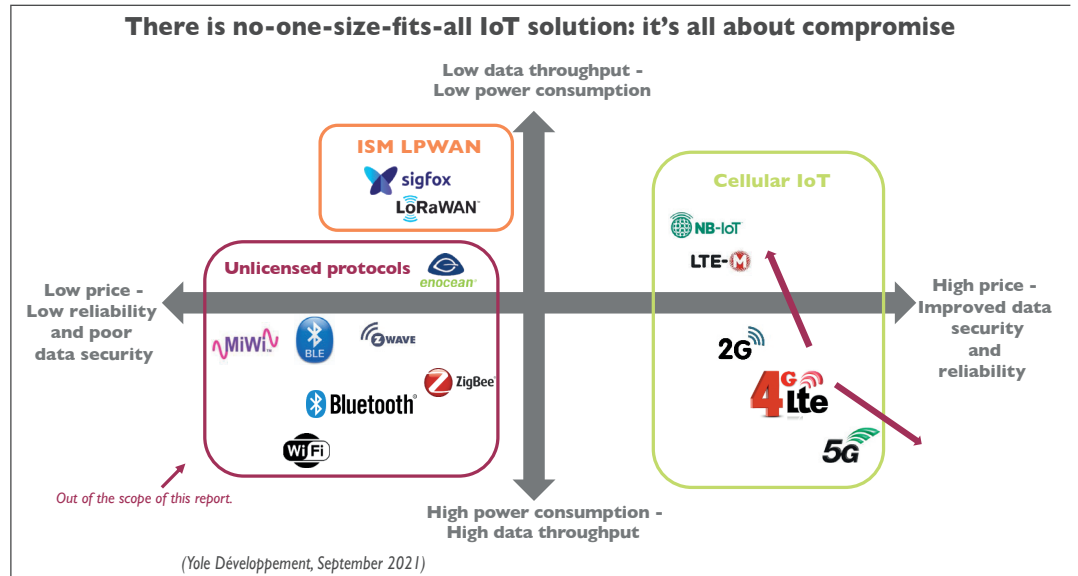
simply 5G. In between these, a wide variety of LTE-based protocols also exist, offering a broad range of solutions, all 5G forward compatible. The most used today are LTE Cat1 and LTE Cat4.

Thanks to the coming 5G stand-alone, these LTE categories will benefit from the expected 5G SA, especially at the network level. Since it will allow for new functionalities such as Network Slicing and the digitalization of the physical network for efficient usage.

In general, cellular protocols are expected to be the go-to solutions for long-range connectivity, and

critical short-range connectivity. The only strong competition is coming from Wi-Fi at short range. All other IoT protocols that have appeared in the past have not managed to launch. We are likely never to see new unlicensed developments in this area, at least none with great market success, in case of cellular IoT worldwide adoption.

If cellular IoT fails for reasons yet unknown and unanticipated, this would once again delay the expected adoption of IoT. Instead, we would be waiting for a convenient, innovative approach, as we have been for more than a decade.



WHAT SHOULD WE EXPECT FROM CELLULAR IOT FIVE YEARS FROM NOW?

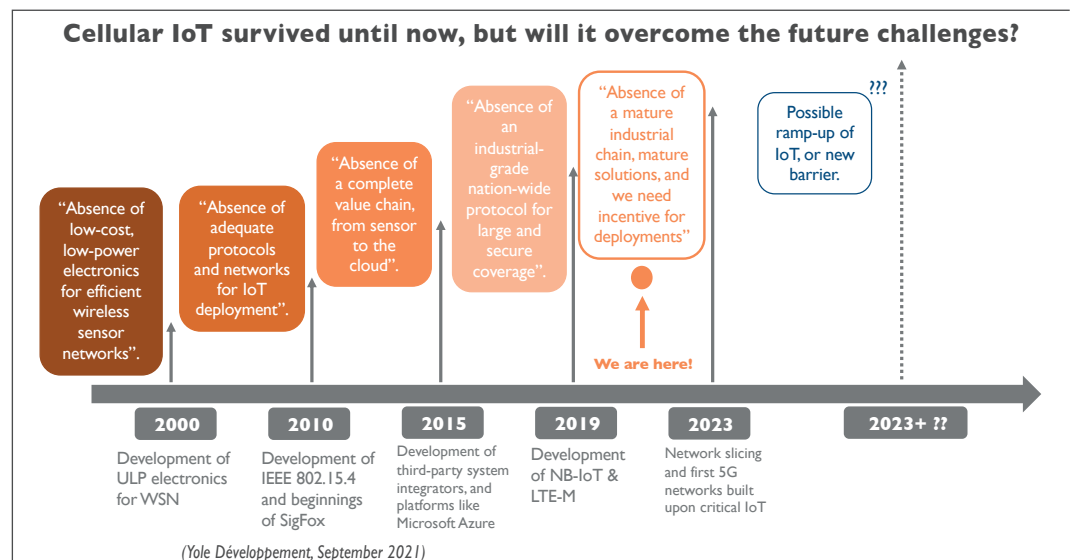
We expect to see increased use of cellular IoT in 2023 thanks to worldwide deployments of true 5G public networks, using standalone 5G, permitting network slicing.

We also expect to see a new RF module offering in 2023, given that today the only solution is provided by Qualcomm at a quite expensive cost. Developments are awaited from other players, like Sequans Communications. Qualcomm will also soon release its second generation of 5G modules, expected at half the price of its

current solution. The IoT industry needs this diversification and strengthening of supply.

By 2023, we will also see more private networks deployments. Whereas today they are starting at pilot level and are meant for high-value applications. But, once deployed, they are expected to be used for lower value IoT applications, especially those using LTE-M or the future NR-Light protocols.

Therefore, the future ramp-up of IoT is expected through the conveniently timed conjunction of



events at public network, devices, and private network levels for 2023. Once this cellular IoT adoption happens, the democratization of the technology will finally take place. It

will be followed by industrial consolidation in the longer term, and ubiquitous use of the licensed radio frequencies for non-consumer purposes.

REPORT OBJECTIVES

There has been a lot of movement in the IoT field with the arrival of 5G. With the development of network slicing, a technology mainly intended for IoT. Moreover, regulators are opening frequencies for private networks that private companies would directly license. Furthermore, new 5G connectivity industrial modules are emerging.

In general, the value chain is starting to mature and now offers convenient solutions for IoT developments using cellular connectivity; It is expected to solve most of the previously seen IoT adoption and development problems.

It also means that the volumes for 5G IoT and cellular IoT, in general, will start their ramp-up quite soon. However, they won't reach the unrealistic advertised volumes.

Indeed, cellular IoT will persist as a combination of niche applications without the awaited expansion into personal area networks, i.e., wearables and consumer electronics.

In this context and following our reports on 5G telecom infrastructure and on RF front-ends for mobile handsets, we decided to publish a report dedicated to Cellular IoT and 5G's impact in this domain. It describes the general market dynamics and offers realistic prospects regarding the market potential at the RF front-end level.

COMPANIES CITED IN THE REPORT (non exhaustive list)

Aarna Networks; Alcatel Lucent; Altair; Aruba; AT&T; Atmel; AWS; Bird; Bosch; British Telecom; CAVLI Wireless; Cheerzing; China Mobile; Cisco; EnOcean; Ericsson; Fibocom; Geotab; HBC; Hisense; Hisilicon; Hewlett Packard; Huawei; IBM; Infineon; Intel; Lierda; LinkLabs; Long Ung; Losant; Mediatek; Meig; Microchip; Microsoft Azure; MobileTek; MuRata; Neoway; NimbeLink; Nokia; Nordic Semiconductor; NXP; Orange; OVH; Pycom; Qorvo; Qualcomm; Quectel; Renesas; Ruijie; Sagemcom; Samsung; Schneider Electric; SemTech; Sequans Communications; Sercom; Sierra Wireless; SigFox; SIMCom; Skyworks; Smarter Micro; STMicroelectronics; Sunsea; Tayo Yuden; Tekelek; Telit; Thales; Tuya; U-Blox; Unisoc; Vanchip; Verizon; Welink; Xiaomi; Yuge Technology; ZTE and more.

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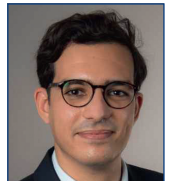
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RELATED REPORTS, MONITORS & TRACKS



- Cellular RF Front-End Technologies for Mobile Handset 2021
- 5G's Impact on RF Front-End for Telecom Infrastructure 2021
- RF Front-End Module Comparison 2021 – Vol. 2 – Focus on 5G Chipset

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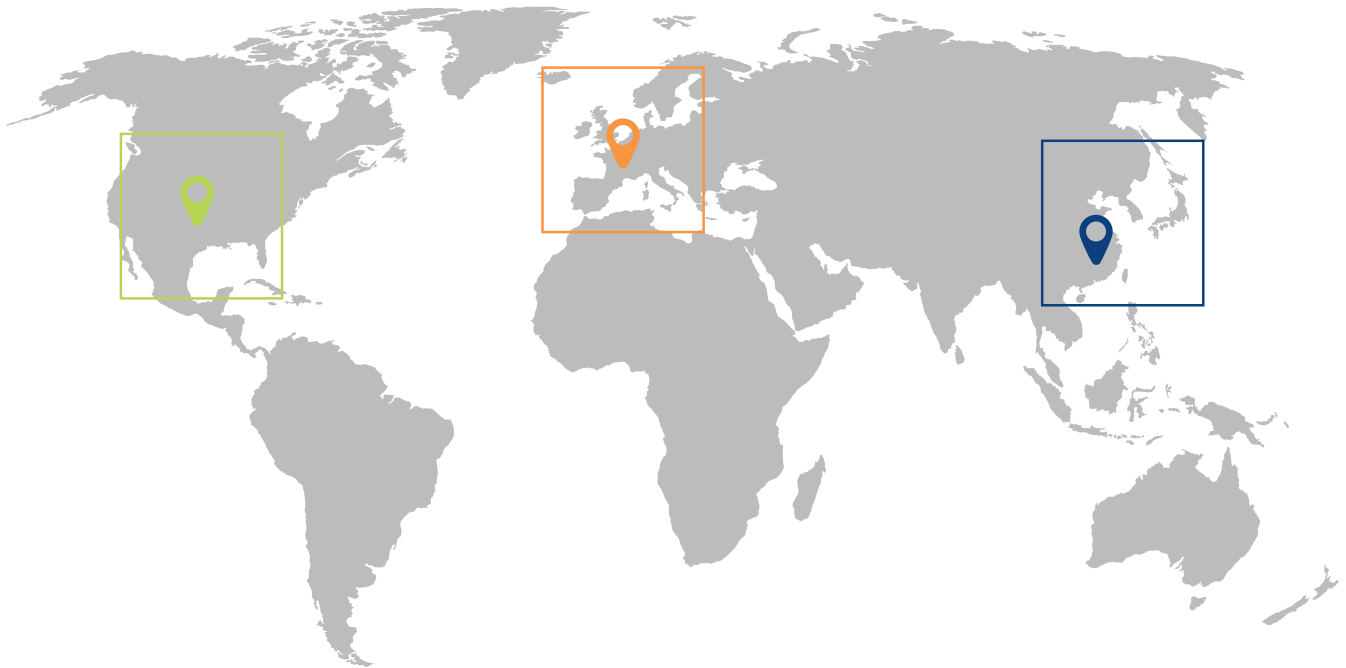
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ABOUT YOLE DEVELOPPEMENT

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.

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- 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)

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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.

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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.

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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:

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- 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.

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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.

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- 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.

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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.

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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.