

3D Non-Volatile Memory

Patent Landscape Analysis – March 2018

*The 3D Non-Volatile Memory field is changing fast.
How the Chinese players can find a place in a crowded space?*

REPORT OUTLINE

- 3D Non-Volatile Memory
- Patent Landscape Analysis
- March 2018
- PDF > 150 slides
- Excel file > 3,400 patents
- €6,490 for a corporate license
- Ref.: KM18003



KEY FEATURES OF THIS REPORT

- **IP trends**, including time evolution of published patents and countries of patent filings.
- **Current legal status** of patents.
- Ranking of **main patent assignees**, their patented technologies, joint developments and IP partnerships.
- **Key patents** and granted patents near expiration.
- **IP position of key players**, and relative **strength** of their patent portfolios.
- **IP profiles** for 6 major companies: SanDisk/Western Digital, Micron Technology, SK Hynix, Toshiba, Samsung, Macronix International.
- **Key Patents** related to 3D NAND devices of key companies: trend of patent publications in China
- IP Analysis of 3D non-volatile memory **types** and **configurations**.
- Focus on **3D XPoint Memory**.
- **Excel database** with all patents analyzed in the report, including technology segmentation.

RELATED REPORTS

[TSV Stacked Memory Patent Landscape 2016](#) (Knowmade)
[Resistive Memory Patent Landscape 2015](#) (Knowmade)
[Emerging Non-Volatile Memory 2017](#) (Yole Développement)

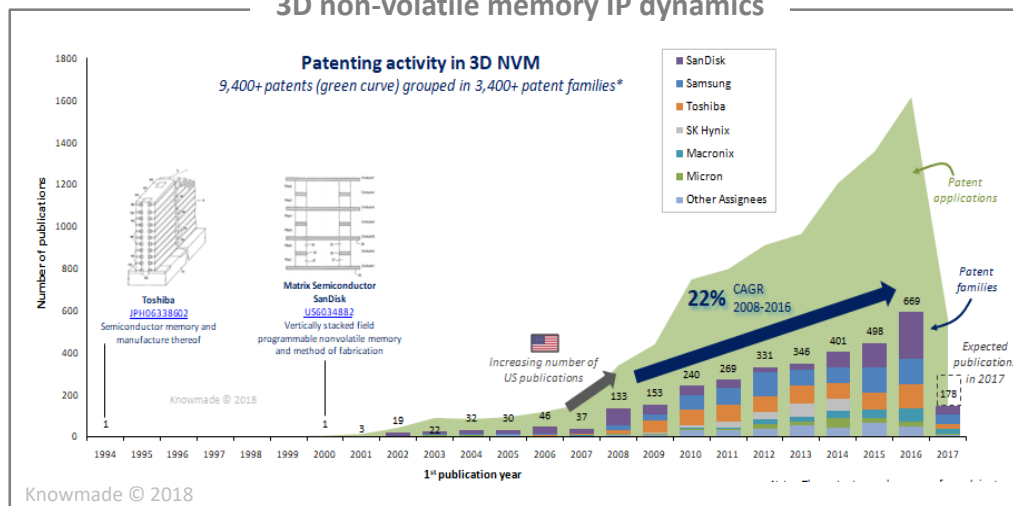
A YOUNG MARKET WITH BIG PLAYERS AND A FAST-MOVING IP LANDSCAPE

3D NAND Flash Memory devices appeared on the market in 2015 with **3D V-NAND – 32L** of Samsung Electronics, followed in 2016 with **3D NAND V2 – 36L** of SK Hynix, **3D NAND – 48L** of Toshiba/SanDisk and **3D NAND – 32L** of Micron/Intel.

In recent times, it happens a lot in the **3D non-volatile memory** (3D NVM) field with the acquisition of **SanDisk** by **Western Digital**, The investments of **Chinese government** in memory, or the Intel announcement of the **Intel/Micron** separation for further development of 3D NAND. We witnessed these evolves in the IP landscape through the recent increase of 3D NVM-related patents filed by **Chinese players** (YMTC/YRST) and the numerous **Samsung's** patents published the latest months in China, USA and Korea, reflecting its willing to strengthen its 3D NVM IP portfolio. Also, we observed **non-practicing entities** (NPEs) like Conversant IP and WiLAN are entering the landscape. The presence of such companies is a tangible sign of the market explodes, heralding **future IP battles** when they will assert their patents to make money.

In this report, KnowMade has thoroughly investigated the patents related to **3D non-volatile memories** and draws a picture of the **current patent landscape and its potential evolution**. SanDisk/Western Digital, Samsung and Toshiba are leading the 3D NVM patent landscape. They hold together more than 65% of the patents, Western Digital and Toshiba signed a JV extension until 2029, and Samsung and Western Digital renewed a patent cross-license agreement until 2024. On the other hand, we witness the emergence of Chinese players in the IP landscape.

3D non-volatile memory IP dynamics



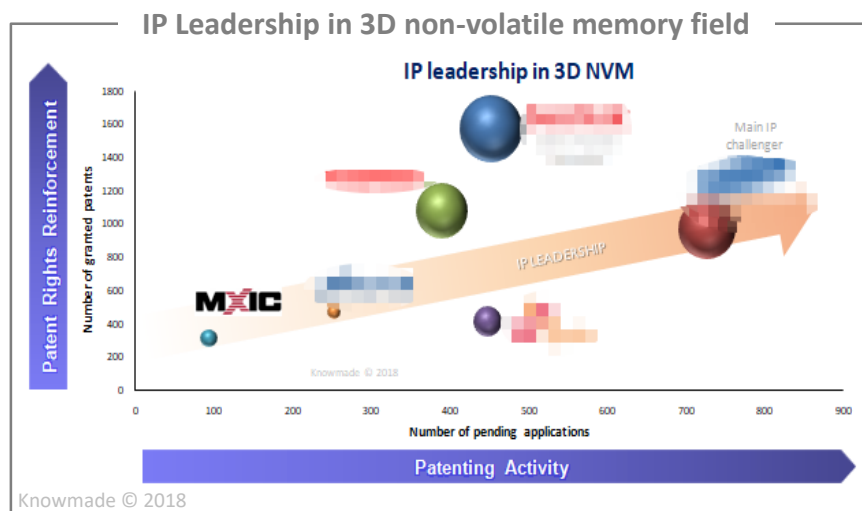
Patent activity related to 3D non-volatile memory (3D NVM) emerged in the 1990s with Toshiba and SanDisk. They signed Joint Venture agreement on Flash Memory in 1999. In the end 2000s, the research and development of 3D architectures appeared with IP related to BiCS (Bit Cost Scalable, SanDisk and Toshiba), TCAT (Terabit Cell Array Transistor, Samsung Electronics) and FG (Floating Gate, SK Hynix). Few years later Micron Technology developed also FG architecture, and Macronix International developed in 2015 SGVC architecture (Single Gate Vertical Channel). Since 2008, the number of patents related to 3D NVM has continuously increased, and today the **3D NVM patent landscape** represents over **3,400 patent families** including more than 9,400 patents. The landscape is very **competitive**, with several **big companies** and the entrance of **Chinese players** these last years.

IDENTIFY KEY IP PLAYERS

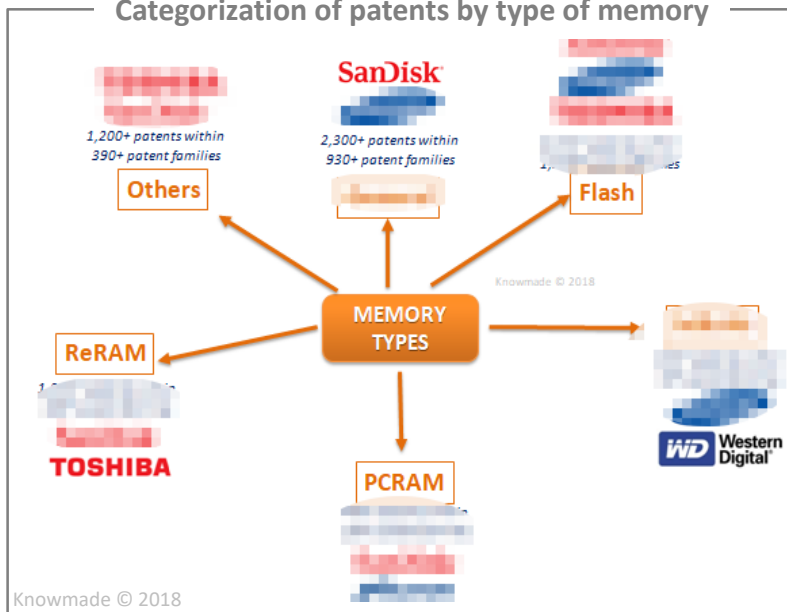
This report reveals the **relative strengths of the top patent owners** derived from their portfolio size, patent citation networks, countries of patent filings, and current legal status of patents. Through this in-depth analysis, each of 6 major **market players are profiled** in this report: SanDisk/Western Digital, Micron Technology, SK Hynix, Toshiba, Samsung, Macronix International. Each profile includes a detailed portfolio analysis with **IP dynamics, IP strategies and key patents** linked to 3D NAND products.

The 3D non-volatile memory patent landscape involves **big companies**, and this closed domain is very **difficult to enter for newcomers**. Nevertheless **Chinese** companies are **entering the landscape** thanks to their financial means and will maybe change the 3D NVM development of further 3D memory layers.

Note that equipment manufacturers like **Applied Materials**, **Tokyo Electron** and **Lam Research** have less than 20 patents related to a 3D non-volatile memory.



Categorization of patents by type of memory



IDENTIFY KEY TECHNOLOGIES

The **3,400 patent families** selected for this study have been categorized by memory types and main architectures.

This report reveals the **IP strategy and technical choices** of patent assignees. We analyzed the current **IP position of key players** regarding the **type of memory** (Flash, MRAM, ReRAM, PCRAM) and the **architecture** (vertical, cross-point). Some companies concentrate on one memory type such as Micron Technology on PCRAM as we expect it with the research on 3D Xpoint Memory. Others like SanDisk are involved in several 3D Non-Volatile Memories.

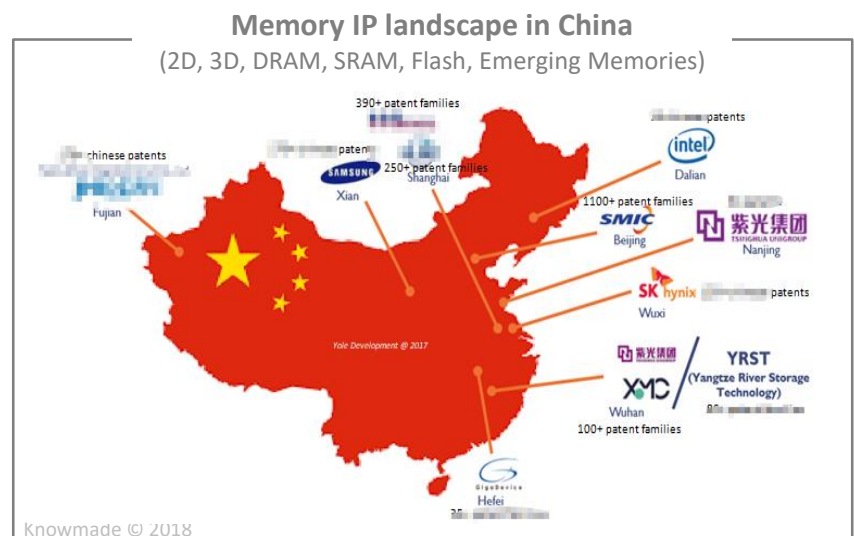
FOCUS ON CHINA

With all the funds invest by Chinese government in Memory, YMTC/YRST developed last year old generation 3D NAND 36L and try to catch up with major companies. However we can ask us, **where do Chinese companies get their IP ?** The China memory-related IP landscape is analyzed (2D, 3D, DRAM, SRAM, Flash, Emerging Memories) in order to understand the **IP trends and technologies owned by Chinese players** such as XMC, YRST, Tsinghua Unigroup, SMIC, etc.

We also investigated what IP do the **major companies involved in China** have like Samsung, SK Hynix or Intel.

USEFUL PATENT DATABASE

This report also includes an **Excel database** containing the **>9,400 patents analyzed in this study**. This useful patent database allows **multi-criteria searches** and includes for each patent its publication numbers, the hyperlink to the original document, its priority dates, title, abstract, patent assignees, memory types/architectures, and current legal status.



COMPANIES AND ACADEMICS CITED IN THIS REPORT (PARTIAL LIST)

Samsung Electronics, Micron Technology, SanDisk/Western Digital, Intel, SK Hynix, Toshiba, 3D Monolithic, SMIC, United Microelectronics, Sino King Technology, YRST/YMTC (Yangtze River Storage Technology), GigaDevice, Rambus/Unity Semiconductor, etc.

TABLE OF CONTENTS**INTRODUCTION** _____ **4**

The authors
Scope of the report
Key features of the report
Objectives of the report
Main patent assignees mentioned in the report

METHODOLOGY _____ **12**

Patent search, selection and analysis
Search equations
Key patents identification
Terminology

TECHNOLOGY OVERVIEW _____ **21**

3D integration memory
Memory types
3D NVM roadmap
3D NAND

PATENT LANDSCAPE OVERVIEW _____ **26**

Time evolution of patent publications
Countries of patent filings
Time evolution of patents publications by country
Main patent assignees
M&A and agreements
Patent litigations
Time evolution of patent publications by assignee
Mapping of main patents owners
Mapping of main patent applicants
Summary of assignee's IP portfolio

IP POSITION OF MAIN PATENT ASSIGNEES _____ **42**

IP leadership of patent assignees
Citations analysis
Impact factor of patent portfolios
IP blocking potential of patent assignees
Key patent families
IP position vs. Remaining lifetime of enforceable patents
Time evolution of patent publications by memory type (flash, MRAM, PCRAM, ReRAM).
Patent assignees vs Memory type (flash, MRAM, PCRAM, ReRAM).
Patent assignees vs Memory architecture (vertical, cross-point).

FOCUS ON CHINA'S MEMORY IP LANDSCAPE _____ **53**

(2D, 3D, DRAM, SRAM, Flash, emerging memories)
Chinese players / Foreign players / Emerging players

FOCUS ON KEY PLAYERS _____ **66**

Western Digital/SanDisk, Samsung, Toshiba, Micron Technology, SK Hynix, Macronix International.
For each players:
3D NVM technology overview
Key patents linked to 3D NVM products
3D NVM IP portfolio and key patents

FOCUS ON 3D XPOINT MEMORY _____ **115**

Key Intel/Micron's patents linked to 3D XPoint

CONCLUSIONS _____ **121****KNOWMADE COMPANY PRESENTATION** _____ **130****AUTHORS****Dr. Audrey Bastard**

Audrey works for Knowmade in the field of Memories and Compound Semiconductors. She holds a PhD in Materials Science from National Polytechnic Institute of Grenoble, France in collaboration with STMicroelectronics, CEA-Leti and CEMES Toulouse. She also holds a Materials Engineering Degree from the Superior Engineering School of Luminy, Marseille, France.
Contact: audrey.bastard@knowmade.fr

**Dr. Nicolas Baron**

Nicolas is CEO and co-founder of Knowmade. He manages the development and strategic orientations of the company and personally leads the semiconductor department. He holds a PhD in Physics from the University of Nice Sophia-Antipolis, and a Master Degree in Intellectual Property Strategies and Innovation from the European Institute for Enterprise and Intellectual Property (IEEPI Strasbourg), France.
Contact: nicolas.baron@knowmade.fr

ABOUT KNOWMADE

Specializing in patent analysis and scientific information, **Knowmade** provides technology intelligence and IP strategy consulting services. The company supports R&D organizations, industrial companies, and investors in their business development by offering them a deep understanding of their IP environment and technology trends.

Knowmade operates in the following industrial sectors: Compound Semiconductors, Power Electronics, RF & Microwave Technologies, LED/OLED Lighting & Display, Photonics, Memory, MEMS & Sensors, Manufacturing & Advanced Packaging, Batteries & Energy Management, Biotechnology, Pharmaceuticals, Medical Devices, Medical Imaging, and Agri-Food & Environment. **Knowmade's** experts provide prior art search, patent landscape analysis, scientific literature analysis, patent valuation, IP due diligence, and freedom-to-operate analysis. In parallel, the company proposes litigation/licensing support, technology scouting, and IP/technology watch services. **Knowmade's** analysts combine their technical and patent expertise with powerful analytics tools and proprietary methodologies to deliver relevant patent analyses and scientific reviews.

ORDER FORM

3D NON-VOLATILE MEMORY

Patent Landscape Analysis – March 2018

Ref.:KM18003

SHIP TO

Name (Mr/Ms/Dr/Pr):

Job Title:

Company:

Address:

City:

State:

Postcode/Zip:

Country:

VAT ID Number for EU members:

Tel:

Email:

Date:

PAYMENT METHODS

Order online for instant download: [Click here](#)

Check

To pay your invoice by check, please mail to the following address:

KnowMade S.A.R.L.

2405 route des Dolines

06902 Valbonne Sophia Antipolis

FRANCE

Money Transfer

To pay your invoice by bank money wire transfer, please contact your bank to complete the process. Here is the information required for submitting payment:

Payee: KnowMade S.A.R.L.

Bank: Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var

IBAN: FR76 1460 7003 6360 6214 5695 139

BIC/SWIFT: CCBPFRPPMAR

Paypal

In order to pay your invoice via PAYPAL, you must first register at www.paypal.com. You can then send money to KnowMade S.A.R.L. by entering our email address (contact@knowmade.fr) as the recipient, and inputting the invoice amount.

RETURN ORDER BY

E-mail: contact@knowmade.fr

Mail: KnowMade S.A.R.L. 2405 route des Dolines, BP 65 06902 Sophia Antipolis FRANCE

PRODUCT ORDER

☐ €6,490 – Corporate license

☐ €5,990 – Single user license*

For price in dollars, please use the day's exchange rate.
For French customer, add 20% for VAT.

All reports are delivered electronically in pdf format at payment reception.

**Single user license means only one person at the company can use the report. Please be aware that our publication will be watermarked on each page with the name of the recipient and of the organization (the name mentioned on the PO). This watermark will also mention that the report sharing is not allowed.*

I hereby accept Knowmade's Terms and Conditions of Sale
Signature:

TERMS AND CONDITIONS OF SALES

Definitions

“Acceptance”: Action by which the Buyer accepts the terms and conditions of sale in their entirety. It is done by signing the purchase order which mentions “I hereby accept Knowmade’s 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) entering into the following general conditions to the exclusion of consumers acting in their personal interests.

“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.

“License”: For the reports and databases, 2 different licenses are proposed. The buyer has to choose one license:

1. Single user license: a single individual at the company can use the report.
2. Corporate license: the report can be used by unlimited users within the company. Subsidiaries are not included.

“Products”: Reports are established in PowerPoint and delivered on a PDF format and the database may include Excel files.

“Seller”: Based in Sophia Antipolis (France headquarters), Knowmade is a technology intelligence company specialized in the research and analysis of scientific and technical information. We provide patent landscapes and scientific state of the art with high added value to businesses and research laboratories. Our intelligence digests play a key role to define your innovation and development strategy.

1. Scope

1.1 The Contracting Parties undertake to observe the following general conditions when agreed by the Buyer and the Seller. 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, SHALL BE WHOLLY INAPPLICABLE TO ANY SALE MADE HEREUNDER AND SHALL NOT BE BINDING IN ANY WAY ON THE SELLER.

1.2 This agreement becomes valid and enforceable between the Contracting Parties after clear and non-equivocal consent by any duly authorized person representing the Buyer. For these purposes, the Buyer accepts these conditions of sales when signing the purchase order which mentions “I hereby accept Knowmade’s Terms and Conditions of Sale”. This results in acceptance by the Buyer.

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 or to the Buyer’s address. In the absence of any confirmation in writing, orders shall be deemed to have been accepted.

2. Mailing of the Products

2.1 Products are sent by email to the Buyer:

- within [1] month from the order for Products already released; 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 Some weeks prior to the release date the Seller can propose a pre-release discount to the Buyer.

The Seller shall by no means be responsible for any delay in respect of article 2.2 above, and including in cases where a new event or access to new contradictory information would require for the analyst extra time to compute or compare the data in order to enable the Seller to deliver a high quality Products.

2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in article 3.

2.4 The mailing is operated through electronic means either by email via the sales department. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that it 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 to 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 information to the Seller, even in case of delayed delivery. Any Product returned to the Seller without providing prior information to the Seller as required under article 2.5 shall remain at the Buyer’s risk.

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 expressed to be inclusive of all taxes. The prices may be reevaluated from time to time. 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 Knowmade, PayPal or by electronic transfer to the following account:

Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var

BIC or SWIFT code: CCBPFRPPMAR

IBAN: : FR76 1460 7003 6360 6214 5695 139

To ensure the payments, the Seller reserves the right to request down payments from the Buyer. In this case, the need of down payments will be mentioned on the order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except in the case of a particular written agreement. If the Buyer fails to pay within this time and fails to contact the Seller, 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. Our publications (report, database, tool...) are delivered only after reception of the payment.

3.4 In the event of termination of the contract, or of misconduct, during the contract, the Seller will have the right to invoice at the stage in progress, 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 choosing the Products and for the use and interpretations he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

4.2 The Seller shall only be liable for (i) direct and (ii) foreseeable pecuniary loss, caused by the Products or arising from a material breach of this agreement

4.3 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 or inability to use the Seller's website or the Products, or any information provided on the website, or in the Products;

b) any claim attributable to errors, omissions or other inaccuracies in the Product or interpretations thereof.

4.4 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.

4.5 All the Products that the Seller sells may, upon prior notice to the Buyer from time to time be modified by or substituted with similar Products meeting the needs of the Buyer. This modification shall not lead to the liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

4.6 In the case where, after inspection, it is acknowledged that the Products contain defects, the Seller undertakes to replace the defective products as far as the supplies allow and without indemnities or compensation of any kind for labor costs, delays, loss caused or any other reason. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 5 below.

4.7 The deadlines that the Seller is asked to state for the mailing of the Products are given for information only and are not guaranteed. If such deadlines are not met, it shall not lead to any damages or cancellation of the orders, except for non-acceptable delays exceeding [4] months from the stated deadline, without information from the Seller. In such case only, the Buyer shall be entitled to ask for a reimbursement of its first down payment to the exclusion of any further damages.

4.8 The Seller does not make any warranties, express or implied, including, without limitation, those of saleability and fitness for a particular purpose, with respect to the 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 the 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, labor difficulties, equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not 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 the Product, or any part of it to any other party other than employees of its company. The Buyer shall have the right to use the Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use the 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 the Product.

6.3 The Buyer shall be solely responsible towards the Seller of all infringements of this obligation, whether this infringement comes from its employees or any person to whom the Buyer has sent the Products and shall personally take care of any related proceedings, and the Buyer shall bear related financial consequences in their entirety.

6.4 The Buyer shall define within its company point of contact for the needs of the contract. This person will be the recipient of each new report in PDF format. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company.

7. Termination

7.1 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 borne by the Seller, following this decision.

7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

8. Miscellaneous

All the provisions of these Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.

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

The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

9. Governing law and jurisdiction

9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract (orders) entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Grasse, which shall have exclusive jurisdiction upon such issues.

9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.