High-End Inertial Sensors for Defense, Aerospace & Industrial Applications

Market and Technology Report 2020
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<th>Acronym</th>
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<td>AHRS</td>
<td>Attitude-Heading Reference System</td>
<td>LAV</td>
<td>Light Armored Vehicle</td>
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<td>ASP</td>
<td>Average Selling Price</td>
<td>M&amp;A</td>
<td>Merger &amp; Acquisition</td>
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<td>AUV</td>
<td>Autonomous Underwater Vehicle</td>
<td>MAV</td>
<td>Medium Armored Vehicle</td>
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<td>CAGR</td>
<td>Compound Annual Growth Rate</td>
<td>MEMS</td>
<td>Micro-Electro-Mechanical System</td>
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<td>DTG</td>
<td>Dynamically Tuned Gyroscope</td>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>FOG</td>
<td>Fiber Optical Gyroscope</td>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<td>HRG</td>
<td>Hemispheric Resonator Gyroscope</td>
<td>RLG</td>
<td>Ring Laser Gyroscope</td>
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<td>IC</td>
<td>Integrated Circuit</td>
<td>ROV</td>
<td>Remotely Operated Vehicle</td>
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<td>IMU</td>
<td>Inertial Measurement Unit</td>
<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
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<td>Inertial Navigation System</td>
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<td>Inertial Reference Unit</td>
<td>UUV</td>
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</table>
TABLE OF CONTENTS

- Glossary and definition 2
- Table of contents 3
- Report scope 4
- Methodologies & Definitions 7
- About the authors 8
- Companies cited in this report 9
- Why this report? 11
- What we got right, What we got wrong 12
- 3-page Summary 14
- Executive Summary 18
- Context 46
- Market forecasts (value & units) 69
  - Industrial
  - Commercial naval & offshore
  - Commercial Aerospace
  - Defense & Military
- Market trends 100
  - Industrial & commercial naval
  - Commercial Aerospace & Space
  - Defense
  - Robotic applications & new mobility
- Market shares and supply chain 154
  - Players’ overview
  - Player market shares by technology (FOG, RLG, HRG, Si-MEMS, Q-MEMS, DTG & others)
- Technology trends 226
  - Gyroscopes (FOG, RLG, HRG, Si-MEMS, Q-MEMS, DTG & others)
  - Accelerometers
  - Inertial R&D concepts
- Cost & manufacturing 295
  - Gyroscope cost per axe and per IMU (FOG, RLG, HRG, Si-MEMS, Q-MEMS, DTG & others)
  - Accelerometers
  - Cost evolution
- Conclusions 325
- Reverse Costing® - Structure, Process and Cost analyses 331
- Related reports 337
- Appendix 338
  - Application description, key specifications, main players, techno trends,main drivers
- How to use our data? 366
- Yole Corporate Presentation 367
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SCOPE OF THE REPORT

Technology

- Accelerometer
- Gyroscope
- IMU
- INS

Markets

- Commercial Maritime
- Commercial Aerospace

Applications

- Agriculture
- AUVs
- Freight transport ship
- High speed train
- Inclinometers
- Oil drilling heads
- ROV
- Satcom antenna stab
- Platform stabilization
- UGVs
- Vibration monitoring
- Structural health monitoring
- Machine health monitoring
- Business Jets
- Civil aircraft
- Civil helicopters
- Civil and paramilitary UAVs
- General aviation
- Satellites
- Space crafts & rockets
- Defense ships
- Defense transport aircraft
- Defense UAVs
- Guided munitions
- Soldier navigation
- LAV/Artillery Guns
- MAV/Tanks
- Military & special mission helicopters
- Military fighters
- Military submarines
- Nuclear missiles
- Vibration monitoring
- Structural health monitoring
- Machine health monitoring
- Business Jets
- Civil aircraft
- Civil helicopters
- Civil and paramilitary UAVs
- General aviation
- Satellites
- Space crafts & rockets
- Defense ships
- Defense transport aircraft
- Defense UAVs
- Guided munitions
- Soldier navigation
- LAV/Artillery Guns
- MAV/Tanks
- Military & special mission helicopters
- Military fighters
- Military submarines
- Nuclear missiles
- Short, medium and long range missiles

Trends

- Forecasts

Players and ranking

- Units

Contact us for a custom:

Yours needs are out of the report’ scope?
Yole’s market forecast model is based on the matching of several sources:

- **Comparison with existing data**
- **Monitoring of corporate communication**
- **Using other market research data**
- **Yole analysis (consensus or not)**

**Top-to-bottom approach**
- Aggregate of market forecasts
  - @ System level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of all players’ revenue
  - @ System level

**Market**
- **Volume (in Munits)**
- **ASP (in $)**
- **Revenue (in $M)**

- **Information Aggregation**
  - Primary data
    - Reverse costing
    - Patent analysis
    - Annual reports
    - Direct interviews
  - Secondary data
    - Press releases
    - Industry organization reports
    - Conferences

**Preexisting information**
- **Top-to-bottom approach**
  - Aggregate of market forecast
  - @ Semiconductor device level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of key players’ revenues
  - @ Semiconductor device level
« High-performance » inertial sensors

- With regard to the applications: we consider all inertial sensors except for the consumer / mobile and automotive applications.
- We take into account industrial, aerospace, defense applications (even industrial applications are considered as “high-performance” applications, as opposed to consumer ones).
- In some cases: « consumer-grade » MEMS gyroscopes (for instance few °/s bias stability) are used in industrial applications.

To simplify representation, performance has been divided into 4 segments:

- The only parameter which is considered is the bias stability:
  - >5°/h range: « industrial » grade (but it doesn’t mean that this is an industrial application: for instance, often missile and bomb guidance require moderate bias stability and fall in this category) → ability to get data on angular rates / on motion.
  - 0.1-5°/h range: « tactical » grade → possibility to get angles.
  - 0.01-0.1°/h range: « mid-term navigation » grade → possibility for mid-term navigation (for GPS outage) and azimuth detection.
  - <0.01°/h range: « high-end navigation & strategic » grade → ability to navigate.

- Day to day bias stability is considered for navigation grade; this is the most significant parameter in characterizing a navigation system.
- In-run bias stability is used for industrial and tactical grade because:
  - In the past 20 years, MEMS have appeared and delivered performance in terms of « in-run » parameters.
  - Use of inertial sensors is now frequently used in conjunction with GPS, meaning that day-to-day bias repeatability is no longer significant (for tactical / industrial grade).
  - Other parameters may need to be considered as well, depending on the application. Parameters such as angular random walk or scale factor may be more important than just bias stability.
COMPANIES CITED IN THIS REPORT


Non-exhaustive list
This report is an update of Yole’s best-selling “IMU Markets” report, which was first released in 2008. This latest edition is an updated version with some major changes since the last edition:

- The market is quantified for each gyroscope technology, and each company’s yearly shipments are estimated.
- Market metrics are provided for each grade of gyroscopes: each application is positioned according to performance level and corresponding market size.
- Applications are described in a synthetic way in order to provide rapid access to key information (functions, specification, technical solution, geography, trends, and market evolution) and graphical representation of the industrial chain.

The high-end inertial business is a tough market, between the different technologies, the different level of integration, at different performances and the numerous applications of major markets which lead to a complex description of this broad market. Added to that, as we deal with critical applications (defense & aerospace), the availability of various data is limited since many players are reluctant to discuss and disclose information about these sensitive markets.

Therefore, the data that you will find in this report is the best available data according to our hypotheses. If you have other arguments and want to react to something, or have an open discussion, please feel free to contact us.

This report combines the best of Yole’s knowledge in the high-performance inertial sensor industry. Yole regularly participates in industry conferences and tradeshows worldwide and has close relations with most market leaders. This report synthetizes the status of the 2019 inertial sensor industry in a thorough manner.
GYRO TECHNOLOGY OVERVIEW

Gyroscopes are based on 3 sensing technologies:
- Mechanical/Vibration based gyroscopes (Coriolis force)
- Optical gyroscopes (Sagnac effect)
- Resonating gyroscopes (Resonating mass)

7 types of gyroscopes have been identified:
- Mechanical/Spinning Mass gyroscopes
- Electric Suspension (electrostatic) Gyroscopes (ESG)
- Ring Laser Gyros (RLG)
- Fiber Optical Gyroscopes (FOG)
- Hemispherical Resonator Gyroscopes (HRG)
- Quartz gyroscopes (non-MEMS)
- Micro-machined gyroscopes (MEMS): vibrating quartz or vibrating silicon
- Old technology is mechanical dynamically tuned gyro also called dynamically tuned gyro (DTG)

Dominant technologies:
- It uses the action of the Coriolis force to sense the rotation.
- Gyroscopes can be activated by:
  - High speed rotation
  - Vibration
- It uses a stationary mass where a stationary resonance wave is maintained electronically.
- It uses the Sagnac effect to measure the rotation rate by measuring the phase shift of two counterpropagating light beams in an interferometer.
ACCELEROMETER DETECTION CLASSIFICATION

There are two main families (and a smaller one) of linear acceleration sensing technologies:

- Pendulous/Translational Mass displacement/rebalance
  - Electrical Restraint
  - Rotational Restraint
  - Elastic Restraint
- Resonant Element Frequency
  - Vibrating String
  - Vibrating Beam
  - Double Ended Tuning Fork
- Thermal

5 types of accelerometers have been identified:

- Pendulous Rebalance Accelerometers (particularly PIGA)
- Force Rebalance Accelerometers
- Resonant Element Accelerometers
- Thermal Accelerometers
- MEMS Accelerometers

This has been divided in 2 sensing categories for the market detailed in this report:

MEMS: Resonant Silicon / Pendulous - Lateral Silicon + some Resonant Quartz accelerometers are counted here (e.g. Honeywell RBA-500 which uses quartz resonator, but metal flexures and is integrated in HG1700, HG1900…)  
Electromechanical, piezo & others: Pendulous - PIGA / Pendulous Force Rebalance / some Resonant Quartz Acc.
An even evolution of inertial technologies can be found by analyzing different stages of development of several technologies. Indeed, every 20 years, some change seems to appear in the market, and in the coming years, HRG could be the next technology to mature and bring enhanced performance in a compact SWAP. MEMS could follow the same path within 10 years?
PERFORMANCE CLASSES OF VARIOUS GYROS

MEMS could eat up the FOG market in the future if similar performance is achieved at lower price (due to batch manufacturing). HRG, particularly from Safran, is well positioned as costs are decreasing.

*Cost is indicative for comparison purposes
HIGH END INERTIAL MARKET SEGMENT VALUE

~$3.24B

~$1,300M
~$800M
~$550M
~$600M

2019

~$1,550M
CAGR +3%

~$1,000M
CAGR +4.5%

~$700M
CAGR +3%

~$950M
CAGR +10.5%

~$4.26B
CAGR +4.7%

~$1,000M
CAGR +4.5%

~$950M
CAGR +10.5%

~$700M
CAGR +3%

~$1,550M
CAGR +3%

~$1,300M
~$600M
~$800M
~$550M

Total high end inertial industry
- Defense & military
- Commercial naval
- Commercial aerospace
- Industrial

PLAYERS IN THE HIGH END INERTIAL FIELD AND GEOGRAPHIC DOMINANCE

Non-exhaust list of companies

USA
$2.24B

Europe & Middle East
$0.65B

Asia, Russia & RoW
$0.35B

~$3.24B
2019
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**Players’ Mapping per Technology (1/3)**
### Inertial Landscape

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<th>Technologies portfolio</th>
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## Inertial Landscape

### PLAYERS’ MAPPING PER TECHNOLOGY (3/3)

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PLAYERS IN THE FIELD AND RANKING – MARKET VALUE

Revenues for each player regrouping stand-alone accelerometers (1/2/3-A), gyroscopes (1/2/3-A), IMU, INS

Top 3:
- Honeywell
- Northrop Grumman
- Safran

2019 High-end inertial revenues market share - % and $M

$3.24B
Only slight changes are expected, with RLG losing some market share due to the increasing popularity of FOG and HRG, which are approaching RLG performances and will increasingly meet the requirements in various applications.
SUMMARY OF AXIS COST STRUCTURE (PER TECHNOLOGY)

Axis cost structure (USD$) (Per technology)

- 0.001°/h HRG Axis
- 0.01°/h HRG Axis
- 0.1°/h RLG Axis
- 1°/h FOG Axis
- 1°/h QMEMS Axis
- 10°/h MEMS Axis

Sensing part, electronic board, assembly, test and calibration represent the highest extra costs of a gyro inertial axis.

ASP (USD$)

GYRO TECHNOLOGY BREAKDOWN – PER BIAS STABILITY CATEGORIES

2019 High-end Inertial Market - Technology breakdown

- Industrial >5°/h
- Tactical 0.5-5°/h
- Mid-term Nav 0.05-0.5°/h
- LT Nav/Strategic <0.05°/h
A global CAGR of 4% expected. Market value is expected to reach $4.2B by 2025.
Vibrating silicon MEMS pushes FOG and RLG to be very competitive on the very high-end market
YOLE GROUP OF COMPANIES RELATED REPORTS

System Plus Consulting

Honeywell HG1120CA50 9-Axis MEMS Inertial Sensor

Honeywell HG4930CA51 6-Axis MEMS Inertial Sensor

Safran Colibrys VS1000 Series

Analog Devices ADIS16460 IMU

Tronic GYPRO3300 Angular Rate Sensor

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