



Evolution of MEMS motion sensors and future trends

Soheil Habibi

Business Development Manager

Content

- **Colibrys**
- **Accelerometer markets**
- **Harsh environment application**
- **Motion sensor classification**
- **Product development roadmap**
- **Conclusion**

Colibrys

Is a world-leading supplier of motion sensors based on MEMS technology

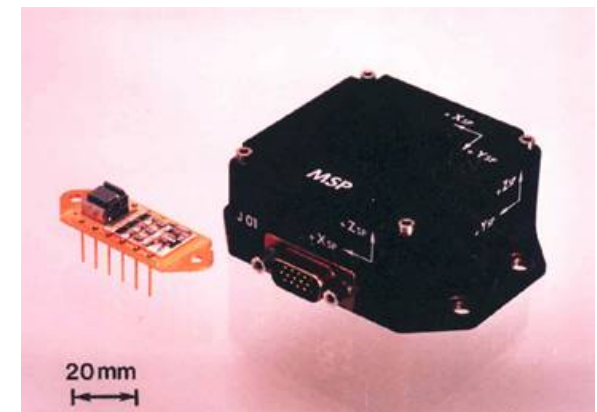
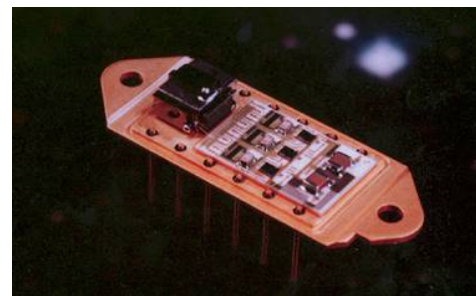
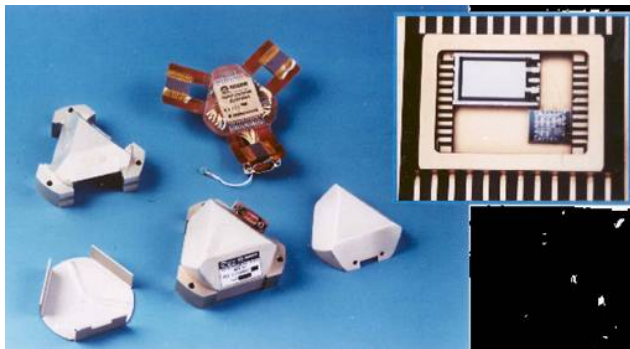
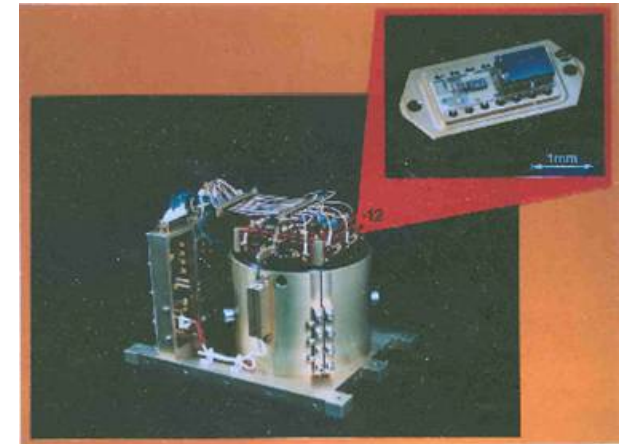
- **Provides unique sensing and actuating solutions for high value-added harsh-environment (defense/aerospace/energy) and industrial (instrumentation, test & measurement) applications**
- **Seeks to exploit applications that demand innovative, high performance, total solutions in small to medium volume quantities**
- **Provides customized products and is dedicated to long term customer loyalty**



Accelerometer for space application

1983-1994 accelerometer development, largely driven by space application

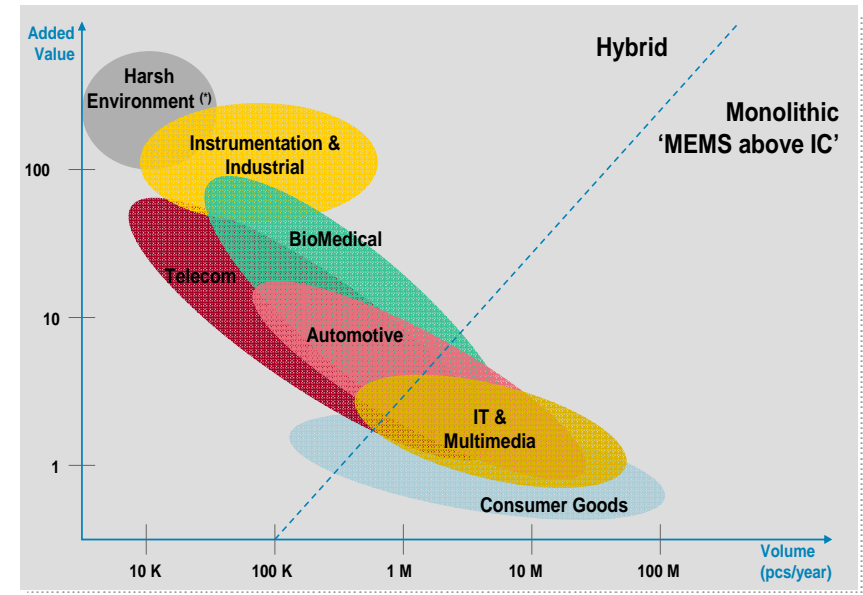
- 1985 : 3 axis systems for parabolic flights
- 1987 : Accelerometer test in a Chinese satellite
(project Matra / CSEM + ESTEC)
- 1988 : Olympus: acceleration measurement box
- 1988–1993 : Active test of accelerometers performances in space
SSMA – experiment (G21)
(project ESTEC / CIR / CSEM)
- 1988–1994 : MMA 3 axis accelerometer for micro-g measurements
Prototypes realized and tested
(project DFVLR / ERNO / CIR / CSEM)
- 1992 : AST-01, 3 axis accelerometer in collaboration with Sagem



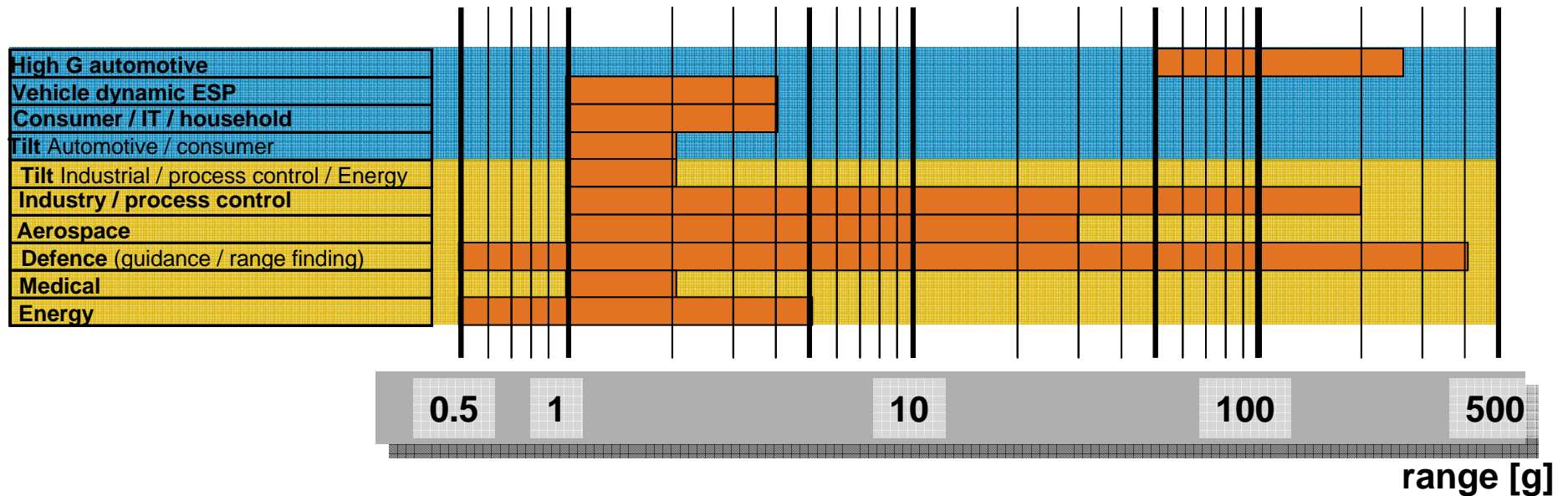
Accelerometer market

- **Market dynamics:**
 - Extensive qualification, fixed design
 - Long term guarantee of supply
 - Export regulations + ITARS
 - Difficult long lead time to design-in
- **Program based**
- **Medium volumes**
- **Product specifications beyond automotive**
 - **Harsh environments.**
 - Temperature range: -55C to +180C
 - Shock: From 5000g to >20'000g
 - Storage lifetime / High Stability: Down to <1mg bias stability
 - **Operation**
 - Higher G-Range: From 0.5g - 500g
 - Bandwidth: From >150 Hz for Inertia to >5 kHz for Vibration
 - Noise: Extreme low noise for UGS to standard noise levels
 - Post shock stability
 - **Small size, light weight**

Beyond Automotive!



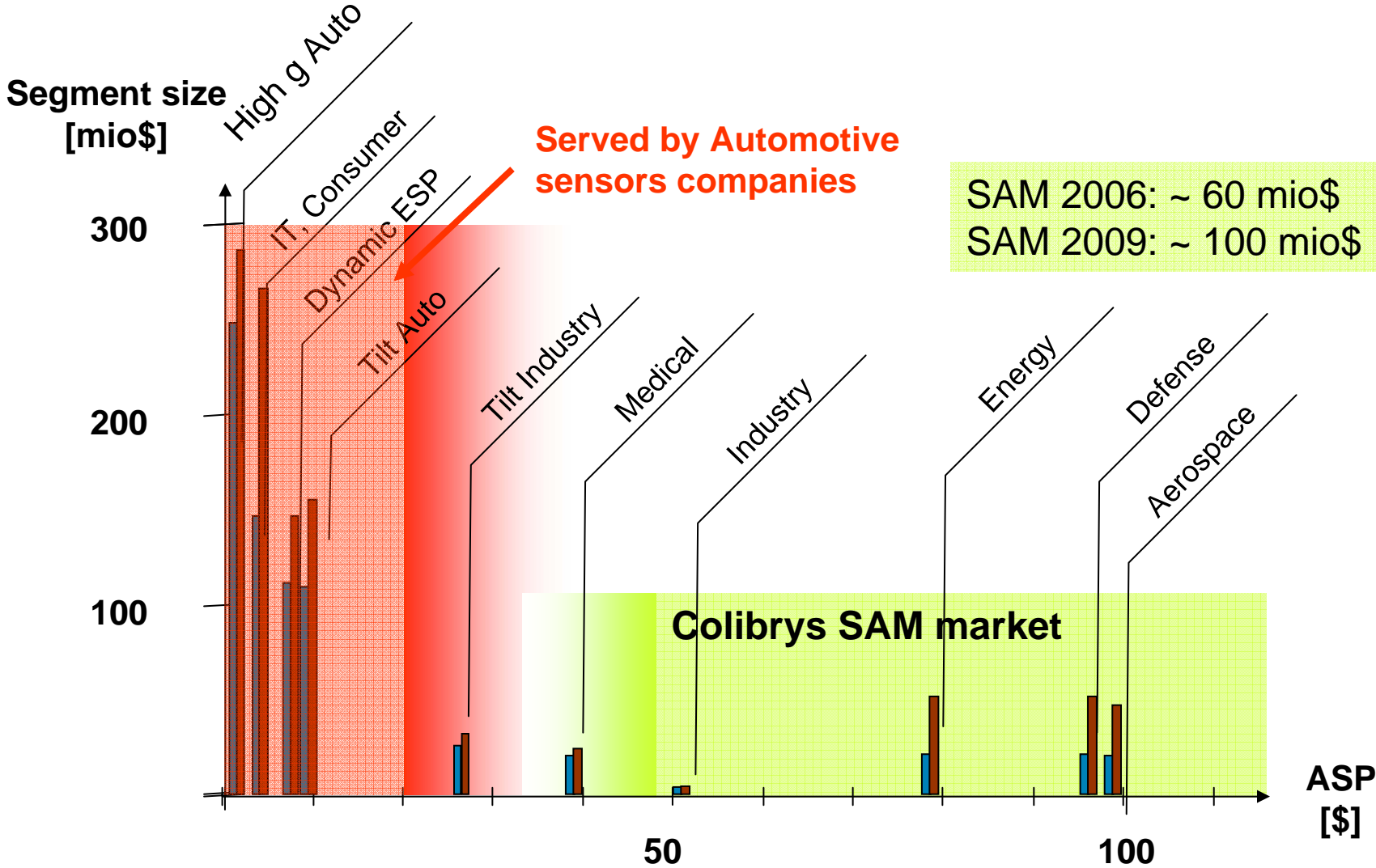
Accelerometer market segmentation



The total accelerometer market is divided in various distinctive segments

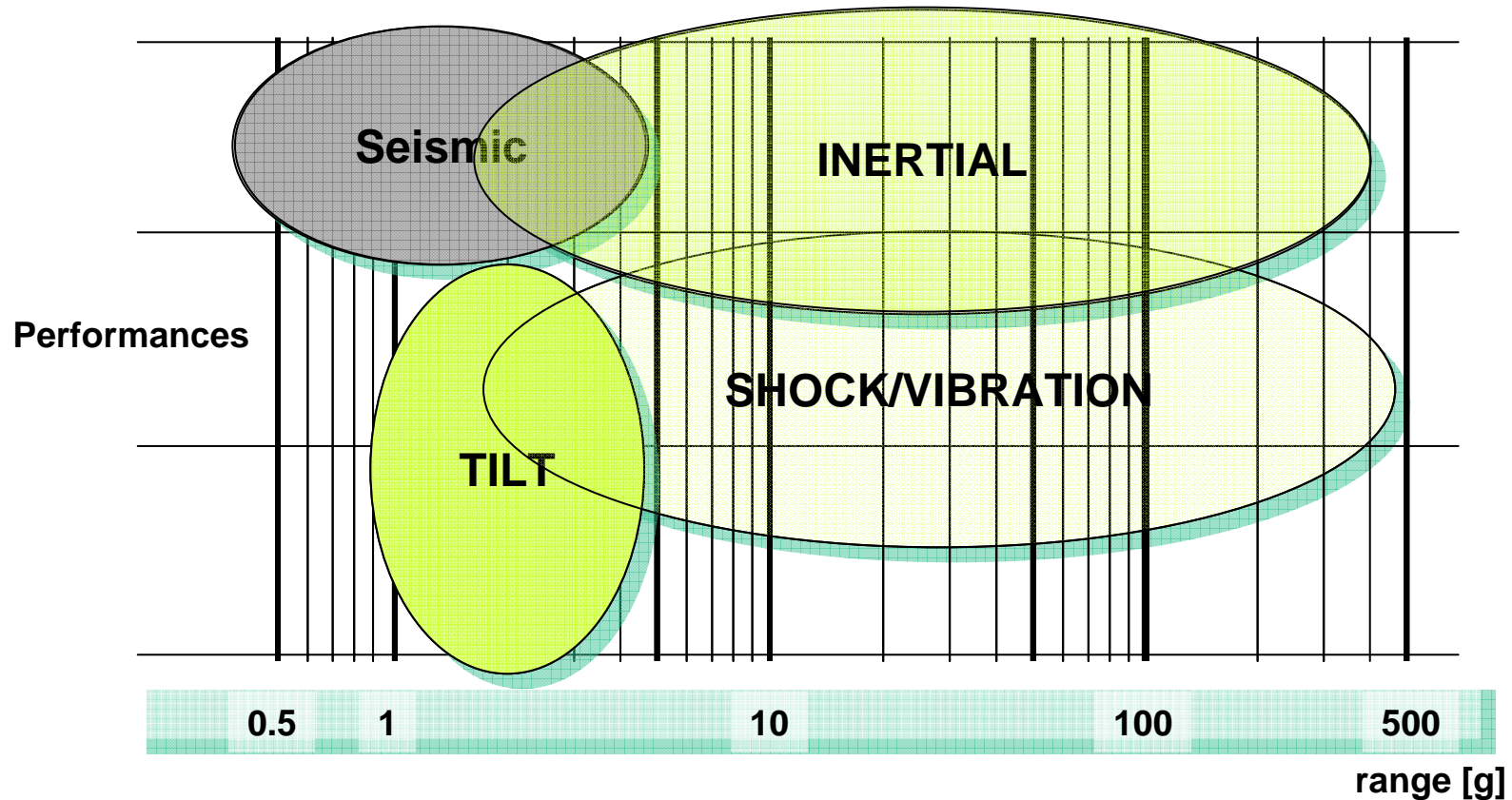
- Clearly 4 dedicated to high volume / low g - low cost
- At least 6 dedicated to medium volume / high added value

Market size vs. ASP / Performances



Accelerometers: Horses for courses

- Accelerometer performance needs to be adapted depending on the specific applications



Motion sensor classifications

Success Drivers

- **Inertial sensing – navigation, dead reckoning**

- High stability at all G levels (1 – 300g)
- Operation in Harsh environment
- Small size, reliability

- **Vibration sensing**

- Maximize bandwidth (2-5 kHz)
- Small size
- Reliability, Shock resistance
- *Signal conditioning (S/N)*
- *Standard system level packaging*
- Low power / passive

- **Seismic sensing – very low frequency**

- Low noise
- Low power / passive
- Harsh environment

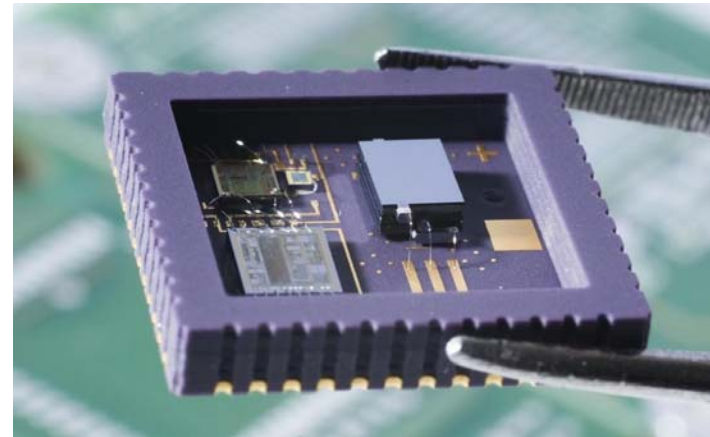
- **Tilt**

- Small size, Reliability
- Precision
- Speed

Inertial sensing

Required features

- Wide range availability
- High stability (temperature, post shock)
- Long term bias stability
- Low VRE (Vibration Rectification Error)
- Suitable for harsh environment



Inertial sensor applications

- **Inertial Measurement Unit (IMU)**
 - Civilian IMU
 - Aerospace
 - Tactical missiles
 - Smart munitions
 - Dead reckoning
 - Directional drilling
- **Attitude Heading Reference System (AHRS)**
 - Civilian aircraft
 - UAV
 - Land Vehicles



SiIMU01 - BAE



AHRS(APIRS) - SAGEM

Tilt Sensing *Measurement of absolute or change in tilt angle*

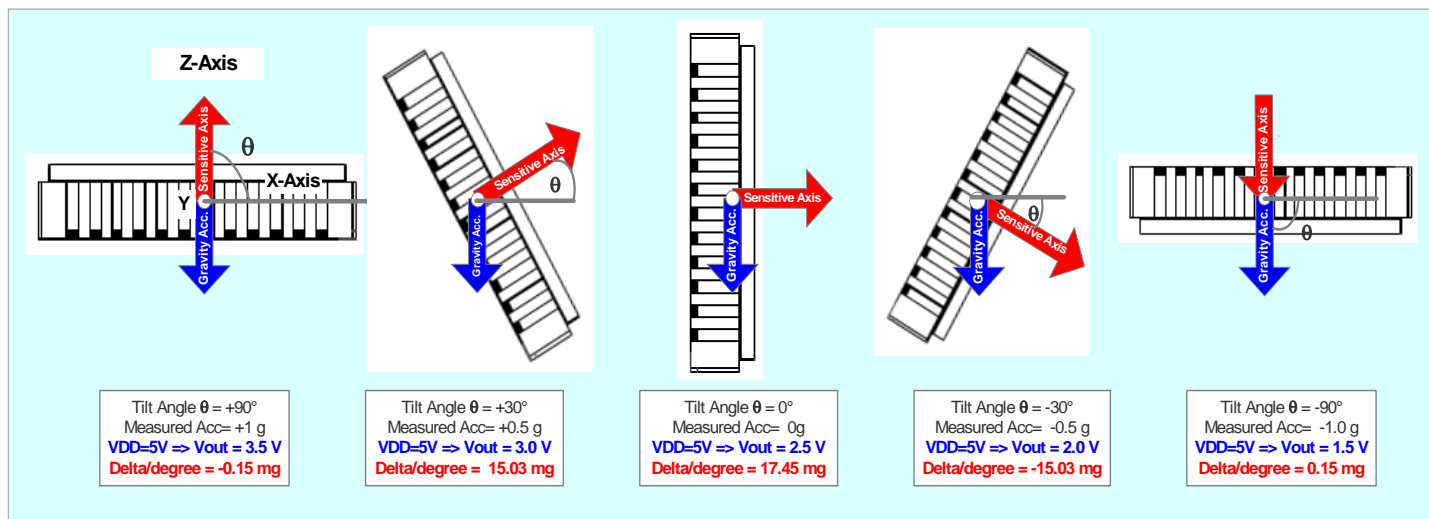
Required features

- Very low frequency response (DC)
- High bias stability
- High resolution /low noise
- Speed
- Small size



Tilt measurement applications

- Range finding (Laser target spotting)
- Fire control (Platform stabilization)
- Antenna stabilization (Mobile satellite communications)



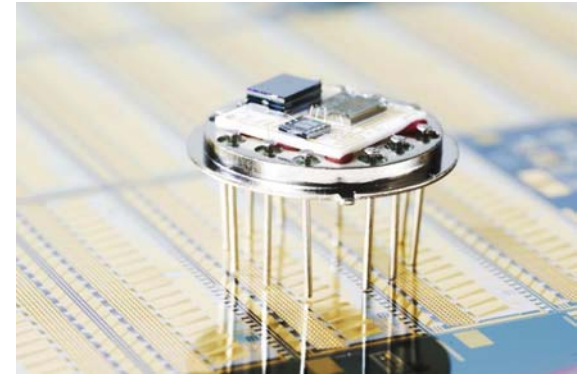
Vibration Sensing

Required features

- Wide range availability
- Large bandwidth (control of resonance frequency)
- High signal to noise ratio
- Flexible packaging solutions

Vibration sensor applications

- **Airborne vibration sensing**
 - Flight testing
 - Flutter testing
 - HUMS (jet engine testing)
- **Ground vibration sensing**
 - GVT
 - Spacecraft Launch monitoring
 - Modal testing
- **Industrial testing**
 - Automotive crash test
 - General lab testing
- **Monitoring & control**
 - Structural monitoring (buildings & bridges)
 - Factory-Facility health monitoring
 - Low frequency machinery
 - Antenna platform stabilization



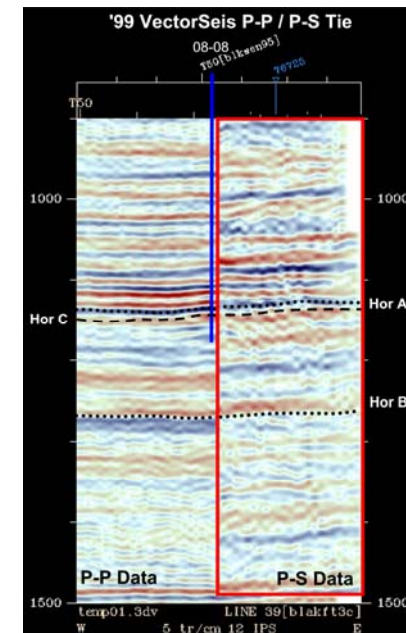
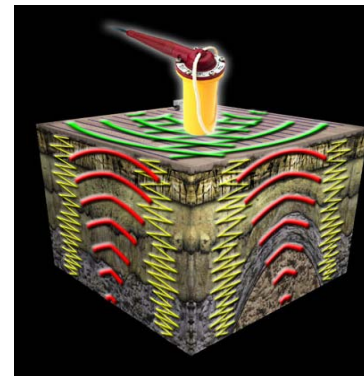
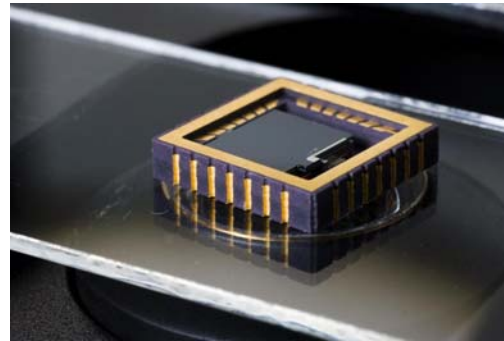
Seismic sensing

Required features

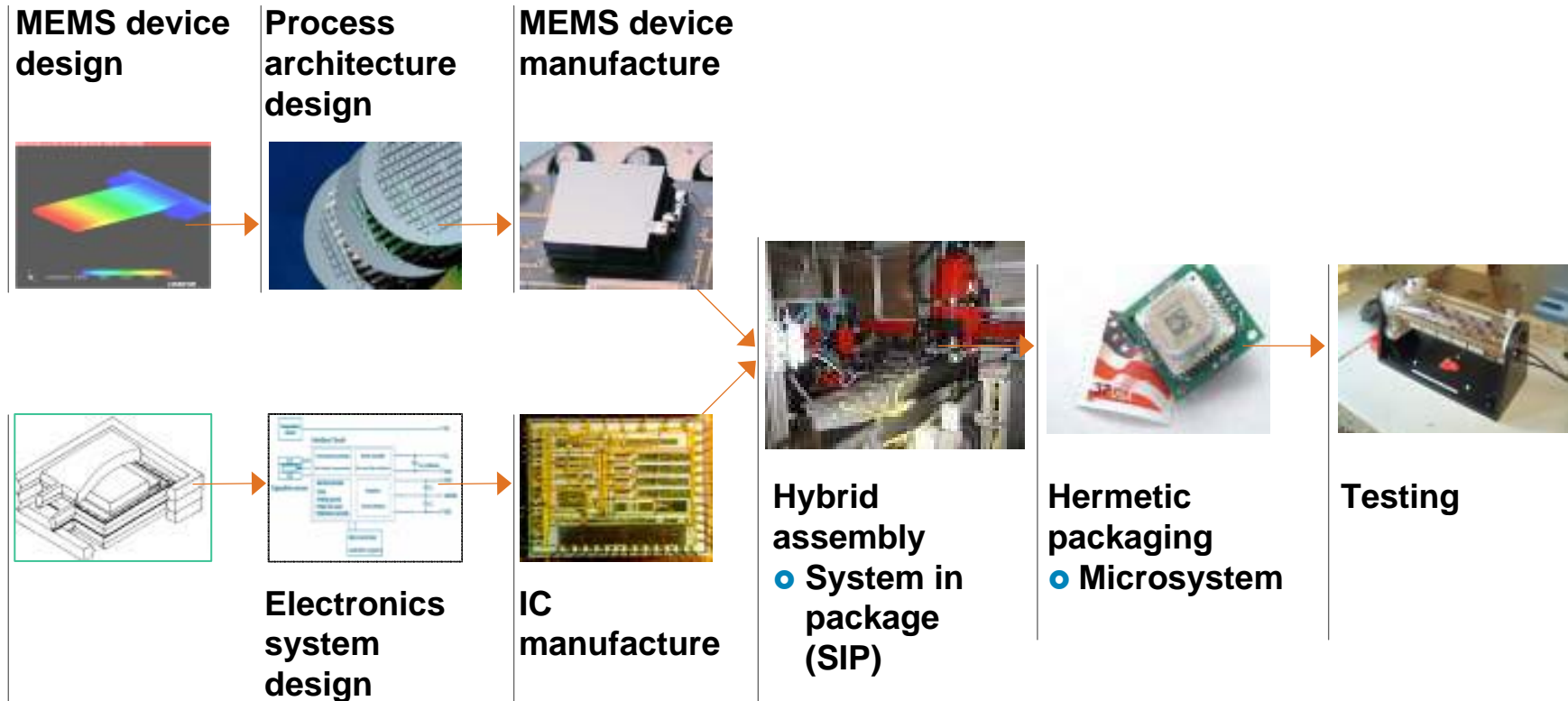
- Adaptable range
- Extremely low noise (nano-g level)
- Suited for harsh environment
- Wide dynamic response

Seismic applications

- **Geophysics**
 - Underground imaging
 - Seismic monitoring
 - Ground motion
- **Homeland security**
 - Perimeter security, border control
 - Nuclear treaty verification
- **Future combat systems (FCS)**
 - Unattended ground sensor (UGS)
 - Land mine detection
 - Unmanned vehicle deployment
 - Towed arrayed sonar (submarines)
- **Monitoring & control**
 - Structural monitoring
 - Road monitoring

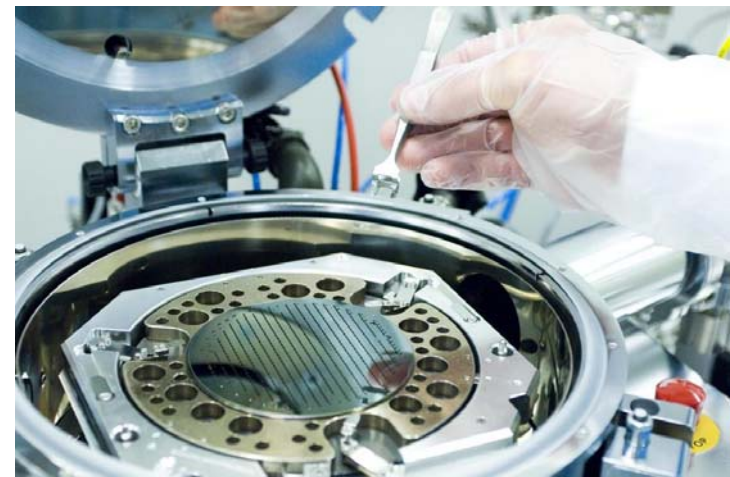


Integration to Systems In a Package (SIP)



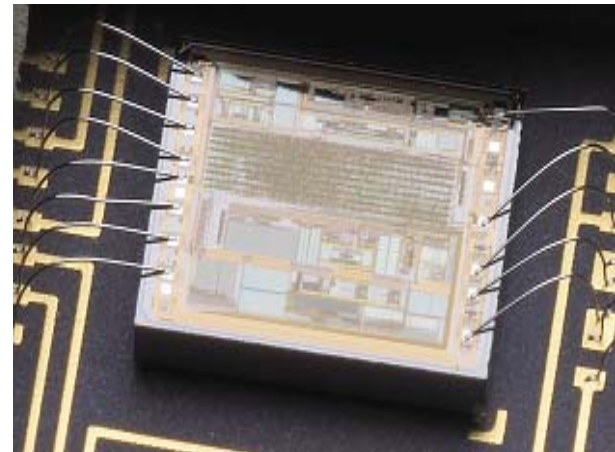
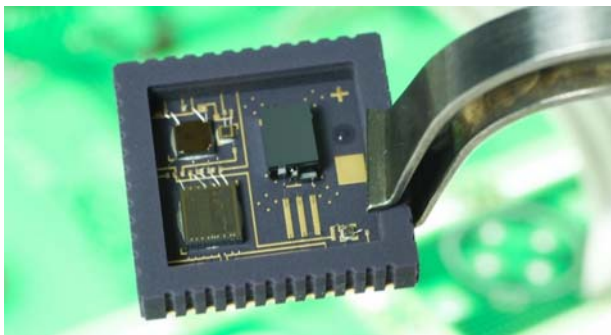
Stacked Wafer Processing Roadmap

- **Process architectures for 50 to 500 μ m thick wafer**
- **Multi wafer materials**
 - Silicon, Quartz
 - SOI to SiC
- **Optimized wet etch technology**
 - Uniformity
 - Repeatability
 - Metrology
- **DRIE etching**
 - 50 to 500 μ m with controlled structuring
 - Controlled critical dimension
 - Increased etching speed – lowering the cost
- **Silicon Fusion / Anodic bonding**
 - Bonding with micron scale alignment tolerance
 - Stack Bonding with nano-scale gap tolerance
 - Controlled pressure



Electronics modeling

- Develop modeling platforms and methodology for the design of sigma delta motion sensors
- Build model with appropriate transfer functions and noise sources
- Implement as analytical model and time domain simulation tool
- Choose adequate model complexity for time simulation
- Define methodology for
 - Loop stability analysis
 - System performance
 - Noise
 - System transfer function (gain offset, linearity, ...)



Assembly & Test technology roadmap

● Soft die attach technology platform

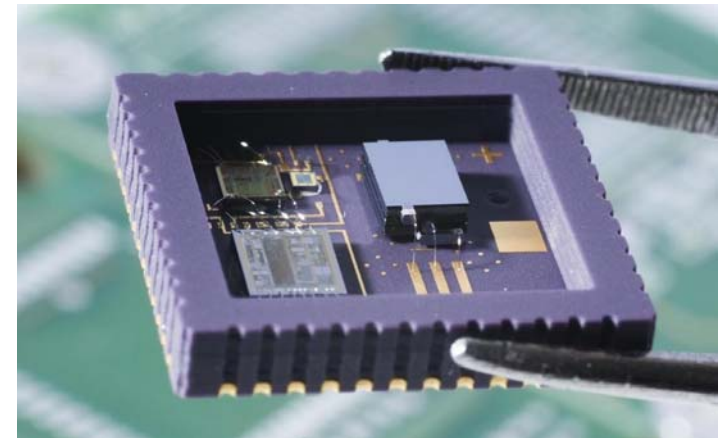
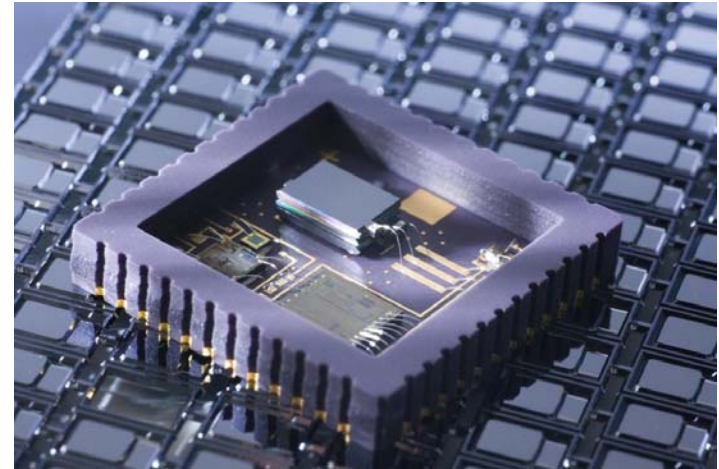
- Glue characteristics
- Limits in shock and vibration
- Intrinsic stress induced in silicon die
- Study potential for new materials

● Packaging

- New multi-layer multi-material packaging
- Systems in Package (multichip stacking)
- Chip / Wafer Scale packaging
- High temperature

● Testing

- Accelerated burn-in and lifetime/stability
- Optimized simulation of high shock
- High temperature measurement
- Low ambient noise
- Error analysis
- Application specific qualification test programming



Concluding notes

- **Space application has been a pioneering driver in development of new acceleration sensors that have been used in many other applications over time**
- **Colibrys has specialized in providing innovative solutions for motion sensing for the harsh environment**
- **Type of application require specific sensor dedicated to**
 - Inertial sensing
 - Vibration sensing
 - Seismic sensing
 - Tilt sensing
- **Key driver in accelerometer further development are higher stability, lower noise, smaller size and weight and reliability over time, temperature and post shock**
- **Having identified these success driver factors, Colibrys is further enhancing its world-class accelerometer performance by following a product development roadmap focusing on MEMS technology, packaging technology and new electronic design**



Thank you for your attention!