AST4-CT-2005-012334

HASTAC

High stability Altimeter SysTem for Air data Computers

Instrument: Specific Targeted Research Projects (STREP)

Thematic Priority: Priority 4: Aeronautics and Space

Publishable Final Activity Report

Period covered: from 2007-01 to 2008-03   Date of preparation: 2008-04-23

Start date of project: 2005-01-11   Duration: 38 months

Project coordinator: SINTEF, Norway

HASTAC
High stability Altimeter SysTem for Air data Computers

HASTAC is a specific targeted research project running under EU's 6th Framework Programme, priority 4 Aeronautics and Space. The project started in January 2005 and is closed in March 2008.

The project will develop a new generation of Barometric pressure sensors and compensated Transducers, which will be used in the building of Air Data Computers (ADC), suitable for fixed wing and rotary wing applications. Such sensor systems will give altitude accuracy capabilities significantly improved over those available today.

SINTEF (Norway) coordinates the project. Memscap AS (Norway), Microelectronica S.A. (Romania), Penny & Giles Aerospace Ltd (United Kingdom), McAlpine Helicopters (United Kingdom) and Farus Grup SRL (Republic of Moldova) are project partners.

www.hastac.biz

Contents

1 Publishable execution

1.1 Background

The project responds to the challenge of ensuring that, irrespective of the growth of air traffic, air transportation will be safer. By this HASTAC contributes to one of the major challenges identified in the Strategic Research Agenda for European aeronautics[1].

HASTAC will contribute to improved safety in different flight situations:
- On board technologies for prevention of controlled flight into terrain
- On board technologies for in-flight and on-ground collision avoidance novel concepts
- Techniques enabling the development of improved aviation safety metrics

1.2 Project Objectives

The main project strategic objective has been to increase the safety in all in-flight situations, particularly low visibility situations. This objective has been met by improving the transducers used in Air Data Computers (ADC) for aircraft applications. The results are relevant in auto pilot situations in the reduced vertical separation minima legislation of 1000ft, as well as in demanding manual flying situations in darkness and low visibility. Used in transponder applications, the project results will increase the reliability in altitude information for manual and automated Air Traffic Control systems. Aircraft Traffic Collision Avoidance Systems will also benefit from more accurate and reliable altitude information, which will allow the automated avoidance instructions to be more accurate and effective.

1.2.1 The Scientific and technological objectives

Our main scientific and technological objectives were:

1. To develop an absolute pressure sensing element with a minimal number of un-identified error sources featuring excellent long term stability and high repeatability in aerospace applications

2. To develop a new hermetic pressure sensor package that does not transfer unwanted forces to the silicon sensing element

3. To develop an optimum altimeter pressure transducer based on the new silicon sensor that will reduce the weight and size significantly, lower the cost, and enable longer calibration intervals.

4. To develop a digital Air Data Computer/Unit that will use the improved accuracy in altimeter barometric measurements from the new transducer and include new digital and software technologies.

5. To increase avionic safety related to flying in low visibility conditions, under rescue operations, and for increased Air Traffic Control safety issues.

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[1]ACARE - Strategic Research Agenda - Executive Summary, Volume 1 & 2 (published in October 2002)

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1.3 Partners in Consortium

SINTEF, research institute, Oslo, Norway
www.sintef.no

Main tasks have been design and processing of silicon MEMS structures in order to make the new barometric sensing element. In addition SINTEF is the Project Coordinator in the HASTAC project

MEMSCAP, Horten, Norway
www.memscap.com

Main tasks have been to characterize the new altimeter sensors and develop the new TP4000 altimeter pressure transducers. MEMSCAP has also the technical management of the HASTAC project.

MICROELECTRONICA, Bucharest, Romania
www.microel.ro

Main tasks have been to develop sensor headers for the new sensor and assemble and environmentally test all the structures in the HASTAC project.

PENNY & GILES Aerospace, Christchurch, England
www.pennyandgiles.com

Main tasks have been to characterize the new TP4000 altimeter pressure transducer and develop a new Air Data Computer based on this new transducer. P&G should also integrate the ADC to the two test helicopters.

McALPINE HELICOPTERS, Oxford, England
www.eurocopter.co.uk

Main tasks was planned to be mounting and verifying the new ADC into the helicopters, and to perform test flights and collect flight data over a certain period of time.

FARUS GRUP, Cristinau, Moldova

Main task has been to develop a ceramic adaptor to be used in the sensor package. They work closely with partner 3, Microelectronica.

1.4 Work performed

1.4.1 Methodologies & approaches employed

The implementation plan for the project is shown below. WP1 to WP4 has defined the different system integration levels progressing from sensing element, to packaged sensor, to transducer and finally integration in an Air data Computer. WP5 should have performed the final performance and validation testing of the technology developed in the project. This activity has been postponed to the follow-up project HISVESTA in FP7.

WP1	WP2	WP3	WP4	WP5
SP83 New Silicon solid State MEMS	Integration into hermetic MIL SPEC package	Transducer development and qualification	Air Data Unit development, test & qualification	Test phase of new concept in real life environments
TASKS:				
Design Modelling Dev.ment Processing	Design Dev.ment Assembly Testing	Design Software Hardware Testing Qualification	Software Hardware Testing Qualification	Training Ground Test Flight Test
PARTNERS:				
SINTEF MEMSCAP	MICROELECTR MEMSCAP SINTEF FARUS	MEMSCAP MICROELECT PENNY & GILES	PENNY&GILES MEMSCAP	PENNY&GILES McALPINE

The project have been managed and documented in a specific HASTAC eRoom.
All relevant documents has been stored there, from application, DoW, Agreements, Budgets, Cost status files, Prepayment overviews, All Technical Reports etc. Each WP responsible has worked according to the project the overall HASTAC Project Plan.

Research and development activities have included material properties studies, alloy compositions of metals and composites, Micromachined MEMS silicone designs, hermetic package development, studies of sensor behavior, thermal compensation techniques and more. State of the art tools like Solid Works FEM analysis, Thermal simulation, MEMS micromachining simulations, High Resolution SEM analysis etc have been used in the HASTAC project.

A large number of hardware sensors were produced and characterized in the project, in order to support the simulation and analysis results from the design phase.

1.4.2 Achievements to the current state-of-the-art

The HASTAC project main target was to develop a new altimetry pressure transducer that should be better than reported state-of-the-art transducers in the marketplace. The target was

to achieve a demonstrated stability better than 0.01% (100ppm) maximum drift error per year. Existing state-of-the-art transducers were reported to be in the 0.02% range.

Based on the HASTAC TP4000 altimeter pressure transducer built and measured for some time in the project, the conclusion is that the project have met the objective, and are outperforming other state-of-the art MEMS transducers. However, we have to keep in mind that due to the delay of the project, only a very limited number of pressure transducers have been monitored, and the time in the stability test is relatively short. The documented results demonstrate a stability better than 0.01% (100 ppm)/year of full scale, which corresponds to a calibrated pressure range of -2000ft to 60,000ft (1150mbar – 50mbarA).

1.5 Results achieved during the project – fulfilment of objectives

The HASTAC project main target was to develop a new altimetry pressure transducer that should be better than reported state-of-the-art transducers in the marketplace. The target was to achieve a demonstrated stability better than 0.01% (100ppm) maximum drift error per year. Previous state-of-the-art MEMS transducers were reported to be in the 0.02% range.

Accelerated tests performed in the HASTAC project, corresponding to more than 20 years of operation in room temperature conditions, indicate that the goal has been met. The statistical data is limited, and additional tests are still ongoing when this report is submitted.

The four (4) transducers which have been on Long Term Stability test, including more than 1000 thermal cycles, all indicate a 0.01% or less drift error per year. The documented results demonstrate a stability better than 0.01% (100 ppm)/year of full scale, which corresponds to a calibrated pressure range of -2000ft to 60,000ft (1150mbar – 50mbarA). Additional transducers are started in tests, and the consortium will continue the data collection and further development in the FP7 project HISVESTA, starting Q3-2008.
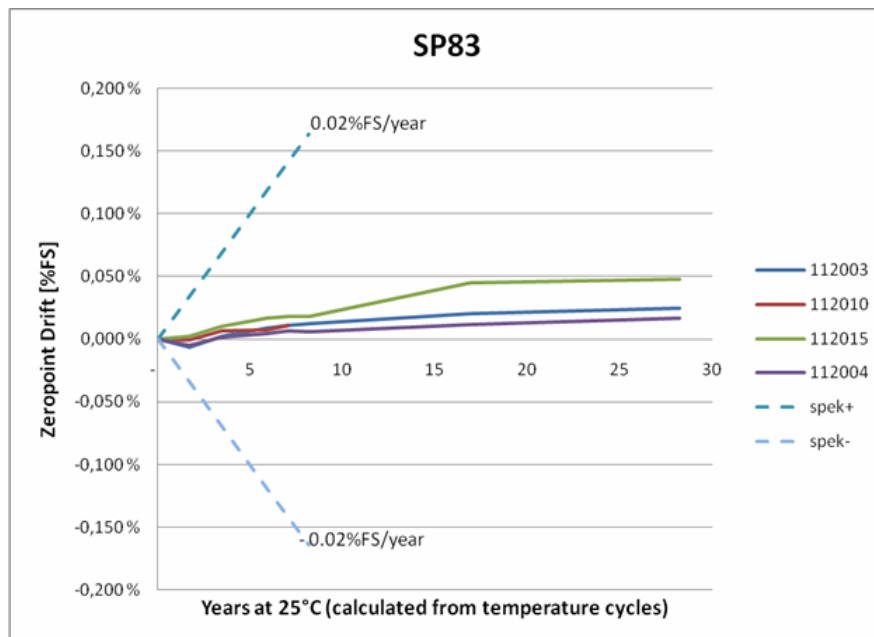

Figure 1 HASTAC SP83 preliminary stability performance compared to current state-of-the-art limit

The HASTAC project has developed more than 800 sensors in 40 different versions, to identify the potential causes for drift mechanisms. The knowledge established is used to make the ideal design for the new SP83 pressure sensor, which is the key element in the TP4000 transducer.

The TP4000 transducer is embedded in a batch of modified Air Data Computers by Penny & Giles, and preliminary performance testing shows very promising results. The lab test data supports the superior results reported from the transducer tests. Test data is still collected when this report is written.
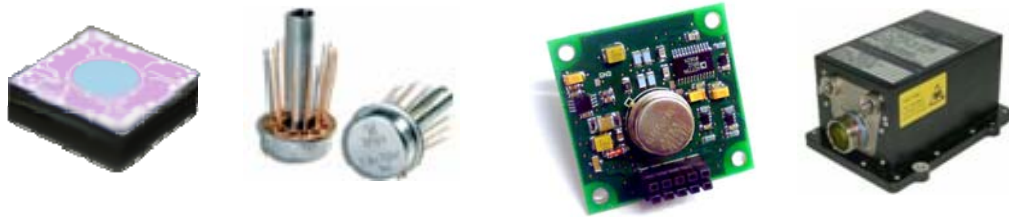

Figure 2 Development in the different work packages (sensing element, sensor package, transducer and air-data unit)

The project has developed a new generation of Altimeter Pressure Sensors (SP83), fully compensated altitude Pressure Transducers (TP4000) and an upgraded version of Air Data Computers (ADC), suitable for fixed wing and rotary wing applications, which have proven altitude long term stability capabilities significantly improved over the traditional types. Aircraft flight testing that was planned performed in the project was cancelled due to delay in the wafer processing task[2], however accuracy and long term stability tests on transducer and Air Data level demonstrates a significant performance improvement. The new generation of transducers with the new MEMS silicon barometric pressure sensor as the key component, will also be available for other application areas, such as transponders and cabin pressure control systems.

The results achieved in the HASTAC project does clearly indicate that TP4000 transducer is capable of performing within the target of 100 ppm (0,01%) altitude shift per year which is a clear target for RVSM altitude sensors. The emerging HISVESTA project in FP7 will benefit from all the results from HASTAC.

In addition, the HASTAC project has resulted in major know how and competence in the MEMS pressure sensor field of the industry, as examples:

1. Increased knowledge within all the HASTAC project partners of silicon MEMS structures for avionic use

2. The basic silicon sensing structures may be used in, or modified to, other demanding aerospace applications

3. The new MEMSCAP SP83/TP4000 barometric pressure sensor will generate more business and will give aircrafts better accuracy in altitude monitoring

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[2] The flight testing will be performed in the next phase of the project (HISVESTA in FP7), see chapter 1.7

4. SINTEF has become an alternative source for avionic grade MEMS wafers

5. MicroElectronica in Romania has become an alternative source for assembly of aerospace grade sensors

6. The TP4000 transducer will be a better alternative than current available state-of-the art-units

7. Penny & Giles Air Data Computer will be one of the most accurate in the market

1.6   Impact on industry and research

The HASTAC project will have a significant impact on the avionic industry. This project will allow manufacturer of Altimetry equipment, Air Data Computers, Auto Pilot systems and Encoding Altimeter Transponders to get better accuracy and stability in their final system products. The ADS-B[3] automated Air Traffic Control system that will be implemented in the near future will also benefit from the results from the HASTAC project. It is highly likely that parts and technology developed in this project will be embedded in the next generation airliners, regional aircrafts and in general aviation.

Research in further enhancement of silicon MEMS structures for altimetry systems will take place. The FP7 project HISVESTA will continue on the research path from HASTAC, to improve functionality even more, and to exploit the usage of the technology also into other segments in Aeronautics and Transport in general.

1.7   Further work

HASTAC will be followed by a new project HISVESTA - HIgh Stability VErtical SeparaTion Altimeter instruments, in the FP7 program (AAT-2007-RTD-1). This project is the next step in solving the remaining RTD challenges after the successful HASTAC project in FP6. The project will further develop the new generation of altimetry module, suitable for fixed wing and rotary wing applications. Air data computer and aircraft flight testing performed in this next phase will demonstrate the effectiveness of the performance improvement.

HISVESTA will also develop the pressure sensor element and sensor package further, expanding the specifications both in respect to pressure ranges and temperature. By improving these parameters, it will be possible to improve the performance of the multifunctional pressure control system in the Full Authority Digital Engine Control systems. This will contribute to a significant reduction of the emission of CO_2 and NO_x in the next generation jet Engines.

Another key target for HISVESTA is to regain the market lead in altimetry and automatic ATC solutions as well as in altitude pressure transducers with best in class long-term stability for the European avionic system industry.

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[3] Automatic Dependent Surveillance - Broadcast

1.8   Project information

Coordinator: SINTEF
                 Strindvegen 4,
                 N-7465 Trondheim, Norway
                 www.sintef.no

Project logo:

Contact persons:

	Mr. Dag Ausen	Mr. Ole Henrik Gusland
	Tel.: + 47 2206 7546	+47-3308 4005
	Fax: + 47 2206 7350	+47-3308 4001
	E-mail: dag.ausen@sintef.no	ole-henrik.gusland@memscap.com

Web-site: www.hastac.biz

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2   Dissemination and use

2.1   Dissemination and exploitation activities

Results from HASTAC have been disseminated widely during the project lifetime. The main activities have been:

1. The Avionics Show, Amsterdam, March 2006/2007/2008
The HASTAC Project has been visible at the Memscap booth and at the Penny & Giles booth with posters and demonstrators, with great interest from a lot of the participants.

2. EUROCAE Altimetry working group 68
EUROCAE has started a workgroup in order to create the next generation of specifications for avionic altimetry. The working group consists of representatives from airframe manufacturers, equipment manufacturers and pressure transducer manufacturers. Representatives from Penny & Giles and Memscap are elected members of the WG68 due to their expertise in Altimetry and Altimetric Sensing solutions. Nick Kidd from Penny& Giles and Ole-Henrik Gusland from Memscap are the representatives. Results and outcome from the HASTAC project are used as input to the EUROCAE WG68. The FAA has a representative in the working group and it is expected during 2008 that the US will become more involved by expanding the working group to become joint EUROCAE and RTCA.

3. Aeronautics Days 2006, Vienna
The project was represented at the conference with a project presentation as part of the conference program and a booth in the exhibition area. Preliminary project results was presented and demonstrated at the booth.[4]

4. Avionic flight magazines
Several Press releases related to next generation of avionic high stability pressure products (Air and Cosmos, France, Avionics Magazine US, Avionics Europe pre-show leaflet 2006, 2007[5], 2008 and several Press releases from Memscap).

5. Gemini article
SINTEF as coordinator has published an article "Teknologi til himmels" ("Technology into Heaven") in the research magazine "Gemini" printed in more than 70.000 copies and distributed in Norway. The article was also available on web[6]. The article presents the project background and main results and communicates this to a general audience. Many newspapers picked up the article, among them "Aftenposten", one of the most important newspapers in Norway

The Gemini article was also translated to English language and spread in Europe through internet. [7, 8] This has resulted in a lot of interests from European companies.

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[4] http://www.dglr.de/veranstaltungen/extern/aerodays2006/sessions/B_Sessions/B7/B72.pdf

[5] http://www.acq.nl/file/Avionics_newsletter..pdf (page 2)

[6] http://www.ntnu.no/gemini/2008-01/16-17.htm

[7] http://www.alphagalileo.org/ - The world's leading resource for European research news

6. Others
- MEMSCAP press releases related to the HASTAC project [9, 10, 11]
- The HASTAC project was presented in a half page article in "the Parliament Magazine" and "Research Review", March editions. [12, 13]
- Sensor+Test Measurement Fair in Nurnberg 2007 and 2008. Memscap displayed poster and samples from the HASTAC project. Approximately 50,000 visitors are at Sensor+Test expo.

2.2   Publishable results

2.2.1   TP2000 Miniature Digital Pressure Transducer – Aerospace Grade

Description
The Memscap TP2000 series digital-output pressure transducer is a fully calibrated, high precision device. The TP2000 contains a Memscap SP82 sensor, Analog to Digital Converter (ADC) and Electrically Erasable Programmable Read-Only Memory (EEPROM) with compensation data. Temperature and non-linearity effects need to be externally compensated for by using data stored in the EEPROM. More than 400 sets of measurements, covering a wide range of temperature and pressure combinations are used as the input to the compensation data. This 'board to board' solution creates an opportunity to use a pre-calibrated sensor that easily can be integrated into a final product.

Market applications
Memscap high-end sensors transducers and switches offer unique performance for your applications. The high proven quality and reliability of our sensors that match Aerospace and Defence standards offer unmatched results in a wide variety of industry applications ranging from Aviation, Meteorology, Instrumentation as well as R/D programs.

Stage of development
Product

IPR granted or published
Product by Memscap AS, Norway
Product data-sheet attached in Appendix 1 – TP2000 data sheet

Contact details
Web: www.memscap.com
Phone: +47-33 08 40 00
Email: sensors@memscap.com

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[8] http://www.innovations-report.de/html/berichte/verkehr_logistik/bericht-106231.html

[9] http://www.memscap.com/dowload/20050511_cessna_en.pdf

[10] http://www.memscap.fr/documents/cp-d-en-48-L-3-GB.pdf

[11] http://www.euronext.com/news/companypressrelease/details_popup/cprDetails-1721-NL.html?docid=97786

[12] http://www.theparliament.com/

[13] http://www.researchreview.eu/

Appendix 1 – TP2000 data sheet

The TP2000 unit from Memscap AS is one visible result from HASTAC, and is already available in the market. This appendix presents the product data-sheet. A user manual and an evaluation kit are also available for customers upon request[14].

TP2000 Miniature Digital Pressure Transducer – Aerospace Grade

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[14] www.memscap.com

M E M S C A P

S E N S O R   S O L U T I O N S

TP2000 MINIATURE DIGITAL PRESSURE TRANSDUCER
AEROSPACE GRADE

Memscap high-end sensors transducers and switches offer unique performance for your applications. The high proven quality and reliability of our sensors that match Aerospace and Defence standards offer unmatched results in a wide variety of industry applications ranging from Aviation, Meteorology, Instrumentation as well as R/D programs.

Brief Description:

The Memscap TP2000 series digital-output pressure transducer is a fully calibrated, high precision device. The TP2000 contains a Memscap SP82 sensor, Analog to Digital Converter (ADC) and Electrically Erasable Programmable Read-Only Memory (EEPROM) with compensation data. Temperature and non-linearity effects need to be externally compensated for by using data stored in the EEPROM. More than 400 sets of measurements, covering a wide range of temperature and pressure combinations are used as the input to the compensation data. This 'board to board' solution creates an opportunity to use a pre-calibrated sensor that easily can be integrated into a final product.

APPLICATIONS

* **Aerospace/Avionics**
* **RVSM Air Data Computers**
* **Standard µC SPI bus**
* **Ground Test Systems, Air Data test sets**
* **RVSM and Standby Altimeters**
* **UAV's/Drones**
* **Multifunctional Probes**
* **Air Speed Instruments**
* **Cabin Pressure Control Systems**
* **Encoders/Transponders**
* **Auxilary Power Units**
* **Navigation systems**
* **Engine Control Systems**
* **Defence**
* **Meteorology**
* **Industrial**
* **Instrumentation**

FEATURES

* **24 bit ADC with SPI & chip select**
* **EEPROM with compensation coefficients**
* **Pressure and temperature output**
* **Available in Absolute, Relative and Diff versions**
* **Board to board configuration**
* **Supplied also as "Plug&Play" evaluation kit**
* **System compliant RTCA DO-178B, level A**
* **Built with Memscap SP82"L" high spec sensor**

BENEFITS

* **Very high accuracy and resolution**
* **Excellent long term stability**
* **Complete Evaluation Kit available**
* **Board to board digital SPI interface**
* **No Software, RTCA DO-178B not applicable**
* **MIL STD 883 compliant hermetic sensor**
* **Operating range from -40 to 80°C (105°C)**
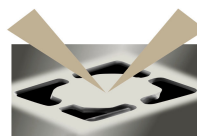
MEMScAP®
The Power of a Small World™

SPECIFICATIONS

Parameter	Min /Typical	Max	Unit
Pressure ranges (absolute, relative or differential)	0 - 0.5	0 - 10	bar
Overpressure	150		% FSO
Power-supply	6.5	20	V
Current consumption	0.75	1.5	mA
Total pressure error (absolute)		±0.05	% FSO
(differential and relative)		±0.1	% FSO
Long term stability (at ambient temp)	±0.03	±0.05	% FSO / year
Repeatability and mechanical hysteresis		±0.005	% FSO
Pressure resolution		<0.00005	
Output noise		±0.002	
Conversion time	22	25	ms
Response time	44	50	ms
Total temperature error		±2	°C
Temperature resolution	<0.0002		°C
Calibration temperature range	-40	80 (105*)	°C
Operating temperature range	-40	105	°C

* Wider temperature range is available on request. This can influence the accuracy.

COMMUNICATION

For detailed description of the communication protocol and commands, please contact MEMScAP for user manual.

The connector is used to power and communicate with the transducer. Table shows the pin functions. A Samtec type: IPS1-105-01-S-D connector is mounted on the TP2000. This board to board connector has 0.76µm gold on contacts and mates with Samtec type: IPT1-105-01-S-D. Versions with cable harness are available on request.

Pin number	Function
1	Power
2	EE_CS
3	EE_WP
4	SCLK
5	MISO
6	VCC_ERR
7	ADC_CS
8	ADC_CLK
9	GND
10	MOSI

Figure 1 – Mechanical dimensions in mm