Barry C. Breen, Vice President-Conferences
Iraun J. Weinstien, Associate Vice President-Conferences

**AESS MEETINGS & CONFERENCES**

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<tr>
<td>3-10 March</td>
<td>2007 IEEE Aerospace Conference</td>
<td>Big Sky, MT</td>
<td>D. Warren, (818) 726-8228</td>
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<tr>
<td>16-18 April</td>
<td>2007 IEEE International Conference on System of Systems Engineering (SoSyS)</td>
<td>San Antonio, TX</td>
<td>M. Jamshidi, (203) 459-3074</td>
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<tr>
<td>17-20 April</td>
<td>IEEE Radar Conference 2007</td>
<td>Boston, MA</td>
<td><a href="mailto:info@radar2007.org">info@radar2007.org</a></td>
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<td>18-19 April</td>
<td>AESS Bolt Meeting</td>
<td>Boston, MA</td>
<td><a href="mailto:rtan@ieee.org">rtan@ieee.org</a></td>
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<tr>
<td>4-8 June</td>
<td>2007 International Waveform Diversity &amp; Design Conference</td>
<td>Lisbon, Portugal</td>
<td>W. Wang, (818) 726-8228</td>
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<td>14-16 June</td>
<td>1st International Conference on Recent Advances in Space Technologies RAST 2007</td>
<td>Istanbul, Turkey</td>
<td>H. Tan, (818) 726-8228</td>
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<tr>
<td>18-21 June</td>
<td>DOCSIS 2007 Forum</td>
<td>Abilene, TX</td>
<td>A. Austin, (818) 726-8228</td>
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<tr>
<td>9-12 July</td>
<td>2007 9th International Conference on Radar, Remote Sensing and Image Processing (RASIP)</td>
<td>Quebec, QC, Canada</td>
<td>W. Wang, (818) 726-8228</td>
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<tr>
<td>13-20 September</td>
<td>AESS Meetings 2007</td>
<td>Baltimore, MD</td>
<td>H. Tan, (818) 726-8228</td>
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<td>10-12 October</td>
<td>2007 European Radar Conference (EURAD)</td>
<td>Munich, Germany</td>
<td>W. Bieger, (818) 726-8228</td>
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<tr>
<td>15-18 October</td>
<td>IEEE Radar Conference 2007</td>
<td>Lisbon, Portugal</td>
<td>W. Wang, (818) 726-8228</td>
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<td>17-18 October</td>
<td>AESS Bolt Meeting</td>
<td>Edinburgh, UK</td>
<td>A. Austin, (818) 726-8228</td>
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<td>4-9 November</td>
<td>International Workshop on Human-Computer Interaction and Adaptive Multimedia Interfaces (HUMI)</td>
<td>Ottawa, Canada</td>
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**OTHER SOCIETY MEETINGS OF AESS INTEREST**

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<tr>
<td>20-23 March</td>
<td>2007 International Conference on System of Systems Engineering and Modeling (SoSyS)</td>
<td>Haifa, Israel</td>
<td>V. Bleu, (972) 629-4449</td>
</tr>
<tr>
<td>14-16 June</td>
<td>2007 International Conference on Recent Advances in Space Technologies RAST 2007</td>
<td>Istanbul, Turkey</td>
<td>Y. Choi, (972) 629-4449</td>
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Send all corrections and omissions to Barry C. Breen at his address on the inside back cover.
For latest information: http://www.ohm.ieee.org/occ/AESS/conferences.html
This Month’s Cover...

is of Eli Brooker visiting a nearly 5000-year-old pyramid, the first built in Egypt. They were constructed as an Egyptian Pharaoh's eternal life to be enshrined. In his lectures, Dr. Brooker pointed out that this is—in reality—an era with a forty-faced phased array (Radar Antenna)?.

Directory of IEEE-EEAS Personnel

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In This Issue - Technically

Moving Towards a More Electric Aircraft
The latest advances in electric and electronic aircraft technologies from the point of view of an “all-electric” aircraft are presented herein. Specifically, we describe the concept of a “More Electric Aircraft” (MEA), which involves removing the need for on-engine hydraulic power generation and bleed air off-takes, and the increasing use of power electronics in the starter/generation system of the main engine. Removal of the engine hydraulic pumps requires fully-operative electrical power actuators and mastery of the flight control architecture. The paper presents a general overview of the electrical power generation system and electric drives for the MEA, with special regard to the flight controls. Some discussion regarding the interconnection of nodes and safety of buses and protocols in distributed systems is also presented.

Textile Antennas: Effects of Antenna Bending on Input Matching and Impedance Bandwidth
How the performance of wearable textile antennas is affected on the antenna bending is described herein. We will focus on the resonance frequency fluctuation and input-match bandwidth variation due to the antenna bending. The results are given for three different antennas, namely, a conventional patch, EBG, and dual-band U-slot antennas.

Theater Battle Management Core System Lessons for Systems Engineers
The difficulties encountered during development of the Theater Battle Management Core System (TBMCS) provide lessons for systems engineering of large-scale, software-intensive systems. The absence of formal requirements and oversight, coupled with strong pressure for rapid deployment, caused the program to fail its first operational tests and actually delayed its deployment to the field.

The lack of measurable requirements and the need to integrate multiple third-party products and systems made it impossible to establish a system baseline and to test TBMCS in realistic conditions. Thus, significant problems manifested themselves only during official government tests. Moreover, despite nominal authority, the lead contractor had little or no control over the government-furnished elements and commercial off-the-shelf products that TBMCS was to incorporate.

Experience with TBMCS leads to several conclusions. First, the more complex a system, the greater the need for rigor and discipline in engineering processes. Second, well-defined requirements are essential. Third, mandating the incorporation of specific third-party hardware or software may create severe problems for system development. Other lessons highlight the importance of open standards in a heterogeneous information technology environment and of layering with well-defined interfaces to facilitate integration and system evolution.

Keys to Automate Supply Chains with Smart Labels
RFID technology is a popular research topic for both academia and industrial practitioners in recent years. However, most published articles focus on the technology itself and seldom discuss the implementation issues of RFID-based systems. This article sets out to fill this gap by proposing some key aspects to automate RFID-enabled systems, in particular supply chains.

Onboard Trajectory Equipment Measurements
In past years, the onboard trajectory measurements complex (OTMC) was found in flight tests of flight vehicles (FV). The quick-release small-sized complex makes registration of the information of onboard systems, definition of trajectory parameters of FV, the information synchronization of onboard systems, and trajectory parameters. OTMC is used for the solution of the whole set of different tasks on estimation of the characteristics of FV and its onboard equipment. With the help OTMC in flight tests there solved the tasks of estimation: operation and accuracy characteristics of air navigation computing systems, inertial navigational systems, integrated navigational systems; SNS receivers, landing radio engineering systems, accuracy of flights under the standard takeoff patterns and landing, take-off and landing characteristics, accuracy characteristics of radars, corrections of high-altitude, fast-track parameters, systems of early warning of ground proximity etc.

Railway Track Inspection Using INS-BINS-N
The results of an integrated strap-down inertial system development and tests are presented. The system includes laser gyro and accelerometers and is intended for measuring railway track angular parameters. To raise the accuracy of angles and distance measurements the inertial system is integrated with a GPS receiver and an odometer. Test results showed that BINS-N accuracy is better than the accuracy of an issued system.
Moving Towards a More Electric Aircraft

J.A. Rosero, J.A. Ortega, E. Aldabas, & L. Romeral

ABSTRACT

The latest advances in electric and electronic aircraft technologies from the point of view of an “all-electric” aircraft are presented herein. Specifically, we describe the concept of a “More Electric Aircraft” (MEA), which involves removing the need for on-engine hydraulic power generation and bleed air off-takes, and the increasing use of power electronics in the starter/generation system of the main engine. Removal of the engine hydraulic pumps requires fully-operative electrical power actuators and mastery of the flight control architecture. The paper presents a general overview of the electrical power generation system and electric drives for the MEA, with special regard to the flight controls. Some discussion regarding the interconnection of nodes and safety of buses and protocols in distributed systems is also presented.

INTRODUCTION

Conventional aircraft architectures used for civil aircraft embody a combination of systems dependent on mechanical, hydraulic, pneumatic, and electrical sources. The resulting conventional equipment is the product of decades of development by system suppliers.

In a conventional architecture (Figure 1 is a basic schematic) fuel is converted into power by the engines. Most of this power is used as propulsive power to move the aircraft. The remainder is converted into four main forms of non-propulsive power [1]:

- **Pneumatic power**, obtained from the engines’ high-pressure compressors. This kind of energy is conventionally used to power the Environmental Control System (ECS) and supply hot air for Wing Anti-Icing (WAI) systems. Its drawbacks are low efficiency and a difficulty in detecting leaks.

- **Mechanical power**, which is transferred (by means of the mechanical gearboxes) from the engines to central hydraulic pumps, to local pumps for engine equipment and other mechanically driven subsystems, and to the main electrical generator.

- **Hydraulic power**, which is transferred from the central hydraulic pump to the actuation systems for primary and secondary flight control; to landing gear for deployment, retraction, and braking; to engine actuation; and to numerous ancillary systems. Hydraulic systems have a high power density and are very robust. Their drawbacks are a heavy and inflexible infrastructure (piping) and the potential leakage of dangerous and corrosive fluids.

- **Electrical power**, which is obtained from the main generator in order to power the avionics, cabin and aircraft lighting, galleys, and other commercial loads (such as entertainment systems). Electrical power does not require a heavy infrastructure and is very flexible. Its main drawbacks are that conventionally it has a lower power density than hydraulic power, and results in a higher risk of fire (in the case of a short circuit).

Each system has become more and more complex, and interactions between different pieces of equipment reduce the efficiency of the whole system. A simple leak in the pneumatic or hydraulic system may lead to the outage of every user of that network, resulting in a grounded aircraft and flight delays. The leak is generally difficult to locate and once located it cannot be accessed easily.

The trend is to move towards “all-electric” aircraft, which means that all power off-takes from the aircraft are electrical in nature, thus removing the need for on-engine hydraulic...
power generation and bleed air off-takes. The removal of bleed air off-takes requires new high-voltage electrical networks and new solutions, such as air-conditioning, wing ice protection, or electric engine start-up. Removal of the engine hydraulic pumps requires fully-operative electrical power actuators and a mastery of flight control architecture.

The “all-electric” aircraft is not a new concept: the concept of an electric aircraft has been considered by military aircraft designers since World War II [2], although until recently the lack of electrical power generation capability, together with the volume of the power conditioning equipment and the advanced control required, rendered the approach unfeasible – especially for commercial and civil transport applications.

Since the early 1990s, research into aircraft power system technologies has advanced with the aim of reducing or eliminating centralized hydraulics aboard aircraft and replacing them with electrical power. Several programs have been started with the aim of driving the research on this field [3], such as Totally Integrated More Electric Systems (TIMES), devoted to use previously developed systems into electrical aircraft, US Air Force MEA Program that investigates for providing more electrical capability for fighter aircrafts, and Power Optimized Aircraft (POA), which tries to optimize the management of electrical power on aircraft in order to reduce non-propulsive power and reduce fuel consumption, while increasing the reliability and safety of onboard systems and reducing maintenance costs.

Nowadays, novel ways of generating, distributing, and using power onboard are examined at the aircraft level. Hybrid or bleed-less air conditioning systems, “More Electric Engines” (MEEs), fuel cells, variable frequency generators, complex embedded digital systems and distributed system architectures are just a few of the technologies vying for space on forthcoming aircraft; the concept is known as “More Electric Aircraft” (MEA) as presented in Figure 2.

Recently, worldwide research into the future development of commercial aircraft has given rise to more advanced approaches to on-board energy power management and drive systems (Figure 3). These are now being carefully considered, and it is believed that electrical systems have far more potential for future improvement than conventional ones regarding energy efficiency.

![Fig. 1. Schematic of conventional power distribution](image)

![Fig. 2. Current trends toward the MEA](image)

![Fig. 3. Schematic of MEA Power Distribution](image)
loads. Also, reliable high integration and safety of the electrical power system leads to the use of distributed generation and control architecture.

The advantages of More Electric systems are not confined to aircraft. Other transport systems, such as marine propulsion, are also moving in this direction [4].

The next sections briefly discuss a general overview of the electrical power generation system and electric drives on the MEA, especially with regard to the flight controls. A brief introduction to the safety aspects of the flight controls has also been included.

**ELECTRONIC POWER SYSTEMS**

The first factor to take into account is the large amount of power electronics for power conversions and power users that MEA will involve: at least 1.6 MW for a next-generation 300 pax aircraft. The development of efficient and secure power electronics technologies is a great challenge. However, not only are power electronics necessary, but also efficient control of the electronics must be developed.

One major evolutionary technological advance that has contributed greatly to the feasibility of an electric aircraft non-propulsive power system has been the development of reliable, solid-state, high power-density, power-related electronics. Generator power control units, inverters, converters, and motor controllers consist of state-of-the-art silicon-based power semiconductor switching devices that include integrated gate bipolar transistors (IGBTs). It is expected that advanced composition, high-performance multi-layer ceramic capacitors will dramatically improve the power density of future inverters, converters, and motor controllers. Improved, high-efficiency electric circuit topologies are also the subject of on-going research.

Some of the higher power level equipment is actively cooled through the use of oil circulation or forced air convection. The extent of the use of active, fluid-based cooling systems is extremely application-specific and is yet to be determined. Lightweight, simplified, passive (non-pumped fluid-based) thermal management techniques are also a focus of research and will be used, wherever feasible, to maintain high reliability.

Power Distribution and Management Systems (PDMS) provide fully automatic monitoring, control, protection, and switching of aircraft electrical loads under normal and emergency conditions with load management, including automatic load shedding and restoration, to make best use of available power. These systems comprise the Primary Power Buses, located close to the generators, with high power contactors and circuit breakers, and the Secondary Power Distribution Buses, located in the avionics bay, which provide the monitoring and control of the system, and contain some same circuit breakers and remote power switches.

The use of programmable solid-state devices and switching power devices in place of traditional electromechanical circuit breaker technology provides benefits to the aircraft in terms of load management, fault isolation, diagnostic health monitoring, and improved flexibility to accommodate modifications and system upgrades.

With these advancing technologies, it will be feasible to use high power-density electrical power components to drive the majority of aircraft subsystems. These will become easier to maintain (supported by less equipment and manpower), more durable, lower in cost, and higher in performance.

The engine primarily provides thrust, but it also produces all other power (Figure 1). In a MEA, current engine accessories that derive power from gearbox mounted pumps will be replaced with electronically-driven electrical machines. Vibration resistance, electromagnetic compatibility, and size constraints are key design challenges of embedding electrical machines into the engine. The integration into a harsh environment of engine off-takes for aircraft systems will not significantly affect engine performance but is also a difficult task.

By deleting off-takes, virtually the only requirement the engines have to satisfy is to provide electrical power. Whilst the hot-air bleed ducts and the pre-cooler are removed, several other integration issues arise, such as generator thermal management, mechanical integration, new electric starting requirements, and electrical power conversion, (whether the chosen solution is a conventional gearbox-mounted generator or an embedded power-optimized generator).

Conceptually, electrical power for an MEA would be produced by a starter/generator directly driven by the gas generator spool of the main engine. Power is transferred out of the engine through wires that feed into a fault-tolerant electrical network to drive the aircraft subsystems. Electronic power converters would transform the electrical power and no accessory gearboxes would be necessary. Elimination of gearing and associated gear separation forces enhances the use of advanced magnetic bearing systems [5], which could be integrated into the internal starter/generator for both the main engine and auxiliary power units.

For many years, electrical power for aerospace applications has been generated using a variable ratio gearbox-mounted wound-field synchronous machine to obtain a three-phase 115 V AC system at a constant frequency of 400 Hz. This machine is known as a Constant Frequency Integrated Drive Generator (IDG), and today it is still the most commonly used. However, operating experiences under the new requirements of lower cost, increased reliability, easier maintenance, and higher operating speed and temperatures have shown that a replacement for the gearbox using power electronics has obvious advantages. A high quality three-phase AC-DC conversion plus subsequent DC-AC conversion is one of the steps involved in achieving these objectives. The resulting system is known as variable speed constant frequency (VSCF) system, and it results in promising technology that meets these requirements.

Figure 4 shows a typical block diagram of a VSCF system. In the motoring mode, the constant frequency system
supplies the machine through the power converter, and the system acts as a starter for the aircraft engine. In the generating mode, the main engine moves the machine, providing electrical power at a variable frequency which is transformed into a constant frequency by the power converter.

The bidirectional power converter can be built using a DC link in a back-to-back topology—a mature technology in use in civil aircraft (Boeing, MacDouglas, etc.) or by using a direct AC-to-AC converter. This is a new technology that is increasingly used in military fighter aircraft.

The matrix converter [6] is a clear alternative to any other AC-to-AC converter for aerospace applications. The converter consists of nine bi-directional switches arranged as three sets of three so that any of the three input phases can be connected to any of the three output lines. The switches are then controlled in such a way that the average output voltages are a three-phase set of sinusoids of the required frequency and magnitude. Some of the advantages of the converter that make it a promising technology for the near future are as follows:

- A higher power ratio with a lower size and weight.
- Unity power factor control.
- It is free from bulky reactive components (especially large electrolytic capacitors).

Electromagnetic interferences due to large currents and voltages high frequency switching are the main disadvantage of power electronics supplying actuation systems. These interferences can be alleviated by reducing the length of electrical cables supplying power and even more by integrating the matrix converter into the motor-actuator system. Moreover, the ability of matrix converter to supply almost sinusoidal currents helps to reduce these interferences as well.

Application of higher voltages is also investigated, which allows reducing the weight for the power used. 230/400 VAC 400 Hz could be relevant for some electrical subsystems because of its lighter weight generator system. 270 VDC is commonly used as DC link bus voltage, whereas the motor controllers can use even higher level. 540 VDC.

Another solution to generate electrical power for the aircraft consists of variable-frequency (VF) power generation, which allows designers to discard the complex and difficult-to-maintain equipment necessary to convert variable-speed mechanical power produced by the engines to constant-frequency electrical power traditionally used by aircraft systems. By this way, variable-frequency power generation increases reliability of the whole system. Of course, aircraft’s systems such as fuel and hydraulic pumps and EHA/EMA actuators have to be designed to be compatible with VF generation and distribution.

Fig. 4 VSCF Starter/Generator System

Variable-frequency power generation is now coming for large aircrafts, and it is expected that power generation reliability will be increase by about 50 percent, although the challenges related to advanced electromagnetic technology, high-speed electronic voltage regulation and system protection to maintain high-level power quality over the wide output range have to be solved.

The switched reluctance machine is very promising as an integral starter/generator system in future aircraft integral engines. The simple rotor construction and high power density of the machine permit high speed and high temperature environment operation. The possibility of direct-driving and, hence, the elimination of gearboxes and hydraulic accessories in the aircraft may give it an advantage over the classical synchronous and induction machine technologies.

Reduction of an aircraft’s multiple secondary power subsystems to a single electric subsystem is another challenge under development. There are numerous generator and distribution choices to be made for this architecture, such as ECS and Electro-Thermal WAI, but careful application of the necessary system integration must be done, and analysis tools to design and verify the integrity of the new hardware- and software-based systems are necessary.

Apart from generators and loads, other elements are needed for the control and management of high-power electrical energy. Power electronics and control are seen as the major and most crucial technologies for an MEA, which faces the challenges of reduced package size, higher power capability, reduced acquisition cost, and high efficiency.

**ELECTROMECHANICAL ACTUATORS**

Subsystems of the MEA include power electronics, power controllers, converters, inverters, and associated components, which have a direct impact on the viability of the MEA, especially in the case of control actuators. The basic building blocks for control actuators are solid-state power electronics and variable speed motor drives. Fully fault-tolerant Control Management and communications for decentralized systems are also required to link and control the wide range of variables used.

In the area of Actuation Systems, alternative architectures incorporating electro-hydrostatic, hybrid and
electromechanical actuation for primary and secondary flight control (as well as new landing gear, braking, nacelle actuation, and horizontal stabilizer architectures) are being examined. A large number of actuators have been studied, most of them electromechanical except flight control actuators due to the showstopper jamming case.

In the last decade, a lot of research has allowed Electro-Hydrostatic Actuator (EHA) technology to be mastered. One result of this on new aircraft such as the Airbus A380 or Boeing B787 is the replacement of the hydraulic circuits by EHA networks. These are used as a back-up for other hydraulic systems, although there is increasing interest in the use of electric drives to substitute hydraulics and electro-hydraulic systems in aircraft. In such systems, an electric motor directly drives a pump, a fan, or an actuator.

![Diagram of Direct Drive Architecture for EMA]

Fig. 5. Direct Drive architecture for EMA

In fact, the next step from the present hydraulic or electro-hydraulic actuation (EHA) in a centralized system, to the use of Electromechanical Actuators (EMAs) in de-centralized systems (while maintaining the same level of safety) is today of major importance for aeronautics. The objective is to reduce production and maintenance costs. Furthermore, these highly safe and reliable EMA technologies, which are jamming free, will help to satisfy the social demand for sustainable transport.

EMAs technologies are already being used in aeronautics, but for safety reasons they are limited to Secondary Flight Controls or military aircraft [7]. Their application to Primary Flight Controls will allow reductions in the weight of drives, gas consumption, and polluting emissions. The major step in moving from EHAs to jam-free EMAs is the prevention of potential jamming cases by appropriate technology and monitoring, thus giving the system aircraft availability for dispatch and failure sizing cases.

Electromechanical Actuators are based on a Direct Drive architecture built up by an electric motor, (usually a Permanent Magnet Synchronous Motor, PMSM) directly connected to the roller-screw that moves the actuator (Figure 5). The power stage can be built up either by standard inverters or by new matrix converter architectures. The complete control block diagram for an EMA drive includes the position, speed, torque and flux controls, and also the supervisory and communication systems.

From the previous statements, it is clear that not only power electronics, but also electric machines, are becoming more and more important in the general electric aircraft power system, both for generation and load control. Specifically, the PMSM is increasingly being used for actuator drives, due to its high efficiency throughout the full speed range, high power ratio, and ease of refrigeration, compared to classical wound machines [8].

The drive operating the flight control must ensure a continuous operation even in the case of a fault. Dual redundant power drive electronics providing motor drive, speed closed-loop, and control management can help to overcome this issue. With more electronics in the actuators, it is also possible to predict how long an actuator will last, introducing the predictive maintenance instead of preventive maintenance today used by airlines.

The drive should also be able to diagnose and report the nature of the fault. The system must also have the following general characteristics [9]:

- **Testability**, to make verification and real-time check-out easier.
- **Reduced complexity and low maintenance costs**, by the decomposition of the main CPU into smaller distributed controls for every EMA, many of them consisting of identical hardware.
- **Intelligent software** running in every control node, which must be able to exchange information by means of standard interfaces.

To achieve the above specifications, control and diagnosis of the EMA needs to rely on modern electronics. As in other fields, digital computer control systems have been incorporated into aircraft avionics system design. Digital systems are more reliable, lighter and more adaptable to change or modifications, as well as providing self-test capability. For these reasons, embedded digital control systems are going to be extensively used in the aeronautical industry.

The growth of electronics has also led to drive-by-wire control systems in which there are no physical connections (mechanical, pneumatic, or hydraulic) between sensors, controls, and actuators. Similarly, a fly-by-wire (FBW)
aircraft has no physical connections between the pilot’s stick and the aircraft’s control surfaces, including the Primary Flight Controls. Moreover, advanced digital systems make automatic checking for faulty signals easier, which allows damaged channels to be identified and disconnected before they can jeopardize the safety of the whole aircraft – although control redundancy is needed to ensure sensor and actuator control even under fault conditions.

Additional advantages concern redundant equipment. In current systems, general flight controls are usually implemented by fault tolerant centralized redundant systems, which are built up by complex and expensive Central Power Units. The new distributed EMA architectures allow us to work on a completely different basis by enabling the isolation of any faulty equipment from the full actuator network by means of a simple switch. The benefits of such an arrangement include power source redundancy and an increased margin of safety, resulting from the introduction of the electric dissimilarity in the power sources.

Finally, we should make mention of the interconnection of nodes in such a distributed system. The topology for the interconnection may be a physical broadcast bus, a star-coupled system, a ring system, or any combination of these. As is easily seen, the backbone comprising the communication subsystem is a critical component for distributed control systems.

As regards flight controls, the actuator nodes are connected via a communication bus to which sensor and cockpit nodes are also connected. Actuators alone need at least half of the total communication bandwidth of the bus. For safe operation, the physical architecture of the bus must not affect the interconnected system in the case of a failure, either in the bus itself or in the node. The damage to the bus must also be immediately detected and a redundant system must be turned on.

Redundant channels are often used for protocols aimed at achieving fault tolerance against more bus failures. If these redundant channels are combined with redundant nodes, it is possible to increase the reliability of the whole system. Currently, new buses and protocols are being validated and verified for these purposes [10], and there are significant on-going efforts to establish standards for future safe communication protocols, particularly for fly-by-wire systems.

However, a variety of mature technologies are in use today. The common goal is low-cost, high-performance and safe electrical power components.

Based on rapidly evolving technology in ultra-reliable, miniaturized, high-efficiency, and affordable power electronic components, embedded control electronics, fault tolerant electrical power distribution systems, and electric primary flight control actuator systems, the “more electric” focus will also permit us to reduce the number of power transfer system functions and use the potential of ultra-reliable miniaturized power electronics, fault tolerant electrical distribution systems and electric generators/motors and drives/actuators to increase performance, and reduce Ground Support Equipment (GSE) and Operation and Support (O&S) costs.

For the first time in aeronautics history, the MEA approach may dramatically reduce or eliminate the need for centralized aircraft hydraulic power systems and replace them with an electrical power system with greatly improved reliability, and maintenance and support potential, as well as the possibility for significant improvements in terms of weight, volume, and system complexity. Some of the expected advantages are:

- A significant reduction in the fuel burn.
- A reduction of maintenance costs.
- 50% fewer unexpected delays due to failures in the power systems.
- A power electronics weight reduction of about 50%.
- Enhanced competitiveness, production improvement, and technology validation.

The advantages of More Electric Systems are not confined to aircraft. Other sustainable transport systems can also take advantage of the advances in this area.

ACKNOWLEDGMENTS

This work was supported by the Spanish Ministry for Science and Technology (Research Project DPI 2004-03180) and by the Alban Programme (the European Union Programme of Postgraduate Level Scholarships for Latin America) scholarship No. E04D027632CO.

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Future Architecture of Flight Control Systems,

On Communication Requirements for Control-by-Wire Applications,
Textile Antennas:  
Effects of Antenna Bending on Input Matching and Impedance Bandwidth

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**ABSTRACT**

How the performance of wearable textile antennas is affected on the antenna bending is described herein. We will focus on the resonance frequency fluctuation and input-match bandwidth variation due to the antenna bending. The results are given for three different antennas, namely, a conventional patch, EBG, and dual-band U-slot antennas.

**INTRODUCTION**

The importance of the individual soldier as an information link will increase in modern warfare [1-2]. The development trends for new systems emphasize the future soldier’s role as a link in a local surveillance net and the importance of communication between soldiers and other units of the modern battlefield including armoured vehicles and unmanned aerial vehicles (UAVs). Therefore, the soldier’s personal equipment should include head-mounted displays, GPS, digital radio, video sight, etc. All these together will enhance the situation awareness, Figure 1. It is obvious that in these systems the textile antennas will play a paramount role in optimizing system performance.

In wearable systems, flat antenna surfaces cannot be provided in general [3]. Therefore, antennas should properly function even if they are bent. This paper will discuss the effects on input-matching and impedance bandwidth of three different textile antennas, namely, a conventional patch antenna, a dual-band antenna, and an EBG antenna [4-6].

*Fig. 1. System concept*

The test setup includes two plastic cylinders with diameters of 70 mm and 150 mm. These dimensions are typical for the human body, e.g., arm, leg, and shoulder. Antennas are bent around the cylinder along two principal planes xz and yz (E- and H-planes, respectively) and the $S_{11}$ is measured for comparison purposes. The results for all three antennas are presented in this paper.

**EBG ANTENNA**

Figure 2 shows the geometry of a two-layer EBG textile antenna for WLAN. Since in this design the metallic vias are not used the structure can also be referred to as a patch loaded dielectric slab. It has 6-by-6 EBG embedded patches without vias on top of the first dielectric layer of thickness 4 mm. The side length of each embedded patch is 26 mm and spacing between each is 2 mm. On top of embedded patches is the next dielectric layer of thickness 4 mm and the main
radiating patch is on top of this layer. The dielectric material is conventional felt fabric with a dielectric constant of 1.1. The previously mentioned conventional patch has the same structure except the embedded EBG patches are removed and the main radiating patch size is increased. A coaxial SMA connector was provided for the antenna feed. The feeding pin is not in contact with the embedded patch surface. The feed was located at a distance of 4 mm from the top radiating patch edge in order to provide a good match. In actual applications, however, the SMA connector could be replaced by a more appropriate connector, such as microstrip line.

Conductive parts, i.e., embedded patches, radiating patch, and ground plane are made out of copper tape. Figure 3 shows the photo of a measured prototype. The main patch size is 44 mm × 38 mm and 52 mm × 46 mm for EBG (embedded patch structure) and without EBG (no embedded patch structure), respectively. This means that the area of the EBG antenna is less than 70% of that of a conventional patch antenna because the EBG structure can be “hidden” inside the clothing. The second observation is that the embedded patch structure can be considered as an artificial textile material. In this example, the equivalent dielectric constant is 1.4, which is shown in Figure 4 as well. It is clear that in this context the words “embedded patch” are more suitable than “electromagnetic bandgap (EBG);” however, in current literatures these definitions are sometimes used interchangeably.

The test setup, shown in Figure 5, includes two plastic cylinders with diameters of 70 mm and 150 mm. These dimensions are typical for the human body, e.g., arm, leg, and shoulder. Antennas are bent around the cylinder along two principal planes xz and yz. The coordinates system is shown in Figure 2. Figures 6 and 7 show the results for the patch and EBG antennas, respectively for both bending diameters.

Table 1 summarizes the results of Figures 6 and 7 in terms of resonance frequency and input-match bandwidth deviation due to antenna bending. It can be observed that yz-plane bending has minor effect on antenna performance compared to xz-plane bending. This is due to the fact that xz-plane
Table 1. Comparison of the bending effect of patch and EBG antennas

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<td>yz (70 mm)</td>
<td>2.51</td>
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<tr>
<td>xz (150 mm)</td>
<td>2.59</td>
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<tr>
<td>yz (150 mm)</td>
<td>2.55</td>
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<tr>
<td>Bandwidth (MHz)</td>
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<tr>
<td>Patch</td>
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<tr>
<td>Flat (0 mm)</td>
<td>212</td>
</tr>
<tr>
<td>xz (70 mm)</td>
<td>287</td>
</tr>
<tr>
<td>yz (70 mm)</td>
<td>237</td>
</tr>
<tr>
<td>xz (150 mm)</td>
<td>262</td>
</tr>
<tr>
<td>yz (150 mm)</td>
<td>212</td>
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bending affects on the antennas’ resonance length. The more the antenna is bent, i.e., around smaller diameter, the more resonance length is reduced, and thus it is shifted up. This is observable for both antennas. However, yz-plane bending affects on the resonance frequency of the conventional patch antenna as well. In terms of resonance frequency stability due to the bending, EBG antenna performs better than the conventional patch antenna. Therefore, the EBG antenna is easier to place within clothing, such as a sleeve, when antenna’s xz-plane is aligned with the sleeve length. Similar observations can be made for input-match bandwidth. The input-match bandwidth of patch antenna varies remarkably when the antenna is bent. However, the EBG antenna clearly outperforms the patch antenna, and the bandwidth deviation is notably smaller.

DUAL-BAND ANTENNA

Figure 8 shows the geometry and the dimensions in millimeters of the U-slot patch antenna mounted on the surface of a 3.5 mm thick fleece fabric. The constructed prototype is shown in Figure 9. The length and width of the ground plane are 110 mm and 130 mm, respectively. The measured relative permittivity of the substrate is 1.1. The conducting surfaces are made out of copper tape with a thickness of 0.075mm. The dimensions L and L1 are the critical antenna dimensions. The dimension L2 is approximately λ/2, where λ is determined by the higher resonant frequency. The antenna length L determines the lower resonant frequency. Therefore, L is approximately λ/2 without the presence of the U-slot. However, the presence of the U-slot lowers the resonant frequency by 5%. In this study, the effect was about 200 MHz. Hence, the L needed to be shortened. The size of the ground plane was selected to be large enough to achieve acceptable performance with dimensions 110 mm × 130 mm.

Similar experimental study for the dual-band antenna was carried out as described in previous sections for the conventional patch and EBG antennas. The coordinate system, shown in Figure 8, coincides with the coordinate system described previously. The dual-band antenna was
bent along the both principal planes with 70 mm and 150 mm diameter cylinders. The measured results are shown in Figure 10. and in Table 2. Again, it can be observed that bending along the xz-plane, i.e., E-plane changes the resonance frequency. However, the deviation from the flat case is minimal. In the both frequency bands the xz-plane bending increases the resonance frequency, as was shown in the previous section. The same deduction can be adopted here, the resonance length decreases when the antenna is bent along the xz-plane. yz-plane bending does not affect on the resonance frequencies of the antenna.

Antenna bending has minor effect on the input-match bandwidths of both frequency bands. Bending along the yz-plane, however, increases the input-match bandwidth on the lower frequency bands, and decreases at the upper frequency band. One possible reason could be that the U-shaped slot effective dimensions are slightly modified, which in turn detune the antenna input-matching. For the lower frequency band the detuning gives better matching, while for the upper band slightly mistuned matching. In either case, the resonance frequency and input-matching stability during the bending is extremely good.

**DISCUSSION**

In the previous sections we have shown that bending along the dimension, which determines antenna’s resonance frequency, has the most dominant effect on the antenna performance. Similar trends were observed for both the single and the dual-band antennas. The examples presented previously, the center frequency was determined with
antenna element dimension coinciding with the xz-plane in our coordinate system. Based on these results, we can make a generalizing assumption that if the antenna is bent along the dimension determining the resonance frequency, the center frequency will shift upwards. However, this assumption needs to be proven right or wrong in the future.

If we consider as an example of circular polarized antenna, such as GPS, for wearable applications, the antenna bending can destroy the antenna's circular polarization characteristics. This happens with patch antennas, since they commonly employ structures, where both the antenna's length and width are in resonance with +90° phase shift. One possible solution to this problem is that one should design the antenna having an elliptical polarization. When this kind of antenna is bent along its longer dimensions, the result would be circular polarized characteristics. Of course, the extra length in one dimension should have a relation with the bending radius.

As the second example if we consider a dual polarized antenna. They usually employ both side lengths of the patch antenna, if the same antenna element is designed to function as a dual polarized antenna. Similar chain of thoughts can be applied as in circular polarization case. It should be also noticed that the antenna placement on the clothing has a major impact on the antenna performance. There exist quite many locations where the bending can be minimized. Accordingly, antenna rotation with respect to the bending axis should be looked carefully. For example, the cases with circular or dual polarization, the antenna could be rotated ±45° with respect to the bending axis to reduce polarization mismatch or the effect of bending. For the cases presented in the previous sections, the antenna could be aligned so that the yz-plane coincides with the bending axis. In this case the antenna functions as designed with flat case, i.e., without bending.

CONCLUSIONS

This paper has focused on the effects of wearable textile antenna bending. Here, we selected two interesting parameters, input-matching and impedance bandwidth performance. These are the two most important parameters to be studied prior to focusing the bending effects on the radiation characteristics, which is left for future focus. In this paper, three different antennas were selected for comparison, namely, conventional patch, an EBG, and a dual-band antenna. It was shown that xz-plane bending, i.e., E-plane, has the dominant effect on the antenna performance. This result holds for all three antenna candidates. In summary, it can be stated that when the antenna is bent along direction, which determines its resonance length affects the most on the input-matching and impedance bandwidth.

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Theater Battle Management Core System

Lessons for Systems Engineers

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ABSTRACT

The difficulties encountered during development of the Theater Battle Management Core System (TBMCS) provide lessons for systems engineering of large-scale, software-intensive systems. The absence of formal requirements and oversight, coupled with strong pressure for rapid deployment, caused the program to fail its first operational tests and actually delayed its deployment to the field.

The lack of measurable requirements and the need to integrate multiple third-party products and systems made it impossible to establish a system baseline and to test TBMCS in realistic conditions. Thus, significant problems manifested themselves only during official government tests. Moreover, despite nominal authority, the lead contractor had little or no control over the government-furnished elements and commercial off-the-shelf products that TBMCS was to incorporate.

Experience with TBMCS leads to several conclusions. First, the more complex a system, the greater the need for rigor and discipline in engineering processes. Second, well-defined requirements are essential. Third, mandating the incorporation of specific third-party hardware or software may create severe problems for system development. Other lessons highlight the importance of open standards in a heterogeneous information technology environment and of layering with well-defined interfaces to facilitate integration and system evolution.

INTRODUCTION

The Theater Battle Management Core System (TBMCS) is an integrated air command and control (C2) system that enables an air component commander to plan, direct, and control all theater air operations and to coordinate with land, maritime, and special operations elements. It encompasses hardware, software, communications links, spares, personnel, training, and other resources. The system is currently deployed worldwide at both the operational and tactical levels and is actively supporting Operation Enduring Freedom and Operation Iraqi Freedom. Figure 1 depicts the operational theater and the interaction among the TBMCS components. A detailed history of TBMCS development can be found in [1].

The TBMCS concept responded to user demand for a more streamlined process to generate the Air Tasking Order than that used in Operation Desert Storm. Although the target system would necessarily be highly complex, the Air Force sought to minimize fielding time by eliminating requirements to build to military standards, reducing government oversight, and mandating adoption of best commercial practices. The lead contractor, Lockheed Martin (LM), was designated as the system integrator and was given Total System Performance Responsibility (TSPR). The Air Force System Program Office (SPO) was instructed to provide insight rather than oversight and, in essence, free LM to find its own path toward producing the system. The ability to reuse software applications across a common infrastructure also became a key program/design driver.

While highly laudable in theory, these approaches ignored the realities of building complex systems for deployment in a combat environment, and had serious consequences for TBMCS. The repercussions affected all aspects of system development, from architectural design to testing. Two aspects had an especially strong impact: the lack of a formal requirements baseline and the mandate to integrate components from multiple sources into an operational system.
REQUIREMENTS

Although the Air Force led the program, TBMCS involves significant joint service participation; thus, the requirements came from many sources. Figure 2 shows the organizations involved in the TBMCS requirements process in the year before TBMCS underwent its first operational test (OT). Over time, the operational user community fed requirements into TBMCS from the top down, while various functional components simultaneously drove requirements from their existing implementations back into the system.

The Air Force intended TBMCS to integrate the functions of three systems: the Contingency Theater Automated Planning System (CTAPS), which was under development, the Wing Command and Control System, and the Combat Intelligence System [2]. Because it was considered simply a modernization of existing legacy systems, TBMCS did not undergo the usual formal joint requirement approval process.
[3]. The user, the Air Force Command, Control, Intelligence, Surveillance, and Reconnaissance Center (AFC2ISRc), believed that TBMCs would not need its own Operational Requirements Document (ORD), because the ORDs for the legacy systems would remain valid and TBMCs requirements could evolve from them. TBMCs would therefore avoid the bureaucratic delays involved in the normal Department of Defense requirements generation and review process and in accreditation as a joint program. However, the ORD specifies the performance and related operational parameters for a proposed concept or system, and the lack of such a baseline proved highly detrimental to TBMCs.

TBMCs also lacked an overarching concept of operations (CONOPS) to define how the system would actually be used in the field. Again, AFC2ISRc believed that the CONOPS for CTAPS would suffice for TBMCs, and therefore tasked The MITRE Corporation to generate a Technical Requirements Document that provided a top-level description of how the system might be employed [4]. The tacit guideline was that TBMCs functionality and performance should be at least equal to those of the legacy systems. As a result, the system architecture was defined at too high a level, which had a tremendous impact on system design and development.

The system development team attempted to cope with this lack of guidance by breaking down the requirements provided and performing an initial analysis of the candidate solutions based on specific factors, such as the commercial off-the-shelf/government off-the-shelf (COTS/GOTS) products mandated from above. The technical leadership of the program then attempted to create a system definition to meet these requirements. The fully harmonized approach of the TBMCs integration and development team proved essential to gathering the information needed on all of the products involved in TBMCs, but did not overcome the inherent problems of contradictory user demands and a fluid baseline.

The lack of an ORD and a CONOPS for TBMCs also had serious implications for the testing community. The loose requirements process made managing expectations extremely difficult. The criteria for assessing system performance became somewhat subjective and left room for interpretation. The formal, documented performance was not agreed to until the OT plan was approved. Moreover, the requirements continually changed depending on which product the government wanted LM to incorporate into the baseline – a critical problem in itself. The implications affected performance at the system-of-systems level because changes in the lower-level requirements did not flow back up to the system-level baseline and allow LM to determine their overall impact. In one case the impact only became evident in OT, which revealed a major problem in the intelligence database that resulted in an eight-month schedule slip.

Pressure from the operational community prompted the government to force early operational testing, even though both LM and the Air Force knew the system was not ready.

The tests that LM had performed did not exercise concurrent processes at the system-of-systems level to assess overall performance, and did not involve nearly as many simultaneous users. The Air Force leadership therefore wanted the first official tests merely to assess system maturity, but the joint test community insisted that this test be a pass/fail Operational Test and Evaluation (OT&E).

SYSTEM INTEGRATION AND INTERFACES

TBMCs involved four types of integration: internal interfaces and subcomponents, third-party applications, external interfaces, and databases. Fully 90% of TBMCs consisted of third-party products or government-furnished equipment (GFE), and a majority of the software was third-party: GOTS or COTS. TBMCs incorporated 76 applications, 64 point-to-point external system interfaces, and 413 segments involving over 5 million lines of software, as well as two commercial relational databases. The system had two hardware baselines, and the communications infrastructure was run by the Defense Information Systems Agency. In the abstract, the requirement to use the DI2 COE as the common software infrastructure represented a worthy goal; unfortunately, the infrastructure could not keep pace with commercial information technology, making integration difficult and expensive. The most extensive integration in TBMCs involves data interoperability, and the two primary TBMCs databases – the Air Operations Data Base and the Intelligence Server Data System – follow different standards and are updated at different intervals. The government also mandated the use of specific hardware, which varied depending on the service branch that would use TBMCs.

This situation led to severe difficulties. The SPO tasked the contractor to integrate disparate legacy capabilities by using open standards with a common user interface. The architecture should allow flexibility for new capabilities to evolve. In theory, LM was the system integrator and had TSPR; in practice, third-party integration meant that LM had little control over the configuration of TBMCs. Determining the quality of a third-party product and coping with hidden design flaws during execution proved highly problematic (and remain problems today). This forced the government to broker changes to the product when problems arose and often resulted in delays and increased cost.

Integrating immature third-party applications also demanded extremely high levels of resources. A particular application requested by the user might be very difficult to integrate into the system either because it did not fit into the DI2 COE or because its COTS infrastructure was more current than that of TBMCs. This led to extensive overruns in integration cost and schedule. Occasionally, LM had to reduce applications in functionality or replace them with other products to achieve integration and operational capabilities.

Thus, program synchronization was exceedingly hard to achieve. Many of the mandated systems were undergoing parallel development while TBMCs was being created.
which meant that all stakeholders had to achieve a reasonable current baseline of the products that would be stable long enough to allow LM to integrate them into the larger TBMCS. For example, at one point TBMCS was based on Solaris 2.5.1, while Sun had already released Solaris 2.8 (a.k.a. Solaris 8). The move to these new releases of the Sun operating system was delayed by dependencies on COE products and by the sheer cost of a massive upgrade of COTS products to match this new baseline.

LM did not have the capability to conduct a live test of the external system interfaces in-plant. Each interface was tested with known inputs and outputs to ensure it was working properly, but simulation did not always reflect performance under realistic conditions, and this led to failures during the actual test.

RESULTS

Not surprisingly, TBMCS failed its first OT in March 1999. As a result, the Air Force established a new baseline for TBMCS and more government oversight was brought to bear, including mandatory oversight by the Office of the Secretary of Defense (OSD). The SPO and LM adopted joint systems engineering processes to help manage the risk, and developed a bottom-up schedule based on the maturity of the system. In addition, the SPO–contractor team established a serial test process with entrance and exit criteria for each test event. In September 1999, the user community reduced the Key Legacy Functions (KLFs) that TBMCS had to perform to five essential capabilities.

The program was then able to move forward by modifying more traditional engineering processes. The SPO–LM team adapted an existing engineering process of design/development with periodic reviews to succeed in an environment where LM lacked direct control over the component products. A System Design Review that bridges the operational and engineering activities has been held for each release since the release of the core baseline (V1.0.1).

Despite these changes, the second OT, which began in January 2000, was suspended because of a problem that prior tests had failed to reveal because the system had never been exercised in a true battle rhythm. At this point, the SPO chief system engineer assumed responsibility for the technical integrity of the system. With LM help, the SPO developed performance tests that reflected a realistic operational battle rhythm. These became part of the formal developmental test (DT) process that TBMCS would have to pass before proceeding to Multi-Service Operational Test and Evaluation (MOT&E).

These new processes, coupled with the reduced number of requirements, enabled TBMCS to pass its MOT&E in July 2000. TBMCS Version 1.0.1 received a favorable fielding decision in October 2000. The following year, the user community approved a TBMCS CONOPS. Shortly thereafter, the Air Force decided that TBMCS should become Web-enabled and migrate from a UNIX platform to a personal computer (PC) end-user (client) device. The Air Force also adopted a new development methodology under which the SPO delivers spirals of capability, and produced a TBMCS ORD, which the Joint Requirements Oversight Council approved in February 2002. The ORD defined the objective TBMCS with the understanding that TBMCS would field spirals with increasing capability, which would eventually produce the objective system.

To support this strategy, the Air Force designed a new requirements process, still in use today, that established a Requirements Planning Team (RPT) and created an on-line database to house all TBMCS requirements. The database provides a central focal point that allows all stakeholder representatives to take part in the process. The program also adopted Air Force Instruction (AFI) 63-123 for spiral development and stood up a Spiral Development Integrated Product Team (SDIPT) comprising users, testers, program managers, and system engineers [5]. The SDIPT uses prioritized requirements generated by the RPT to produce a spiral plan that covers capabilities, cost, and schedule for LM. In addition, LM and the SPO established a System Engineering Integrated Product Team that is responsible for the architecture and performs the requirements analysis for the spiral plan.

The lessons learned from the difficulty in fielding V1.0.1 had a positive impact on the program’s current systems engineering environment. The requirements process for TBMCS has now matured into a relatively disciplined and repeatable process tied to a specific spiral of capability. While the government controls the requirements, it shares most roles and responsibilities with LM. The SPO and the contractor manage each upgrade jointly, and test is factored into the planning process.

TBMCS performance in Operations Enduring Freedom and Iraqi Freedom demonstrates the success of the current approach. The program is producing its fourth spiral in five years and leads the way in delivering the latest in Web and information services technologies as TBMCS evolves to support network centric warfare.

ANALYSIS: LESSONS LEARNED

Experience with TBMCS provides a comparison to the modern systems engineering theory and practices taught in leading universities today and leads to several conclusions.

The lessons learned from TBMCS apply directly to other software-intensive programs that require the integration of vast numbers of third-party products with GFE, such as hardware and communications.

REQUIREMENTS

The requirements process for TBMCS V1.0.1 was profoundly flawed from the start. The acquisition community had a utopian vision of a single modern, integrated, joint C2 system, but had no operator requirements to support it and no CONOPS that described how the system would work as
single integrated capability. It took five years to complete the initial TBMCS baseline; in fact, the SPO never established a firm baseline until after TBMCS failed its first major OT. As a result, the test community and the other military services found it difficult to determine what capabilities TBMCS would provide and how the system would be used.

The strategy for developing and fielding TBMCS capabilities was predicated on evolutionary acquisition, but spiral development does not obviate the need for a rigorous and disciplined requirements process. The government wanted to field capabilities to the operator quickly by delivering capability over three increments, culminating in an OT. However, for such an incremental approach to succeed, a program must first establish a baseline from which the system can evolve. TBMCS lacked such a robust baseline, and this had tremendous impact on cost, schedule, and performance.

Initially, TBMCS did not even establish a vision that the program could follow. Three years after contract award, the government finally agreed that TBMCS needed such a vision and a roadmap to achieve it. Jointly, the government and LM designed a target architecture that provided the framework to guide the evolution of TBMCS from the V1.0.1 baseline to its current state. LM’s chief architect now ensures that the proposed design is consistent with the defined architecture, which serves as a communications tool and is integral to the planning process for subsequent releases.

THIRD-PARTY INTEGRATION

It seems intuitively obvious that assigning TSPR to a contractor when over 90% of the program content was GFE and was a flawed strategy. Contractors cannot be held accountable for performance unless they control all of the system components that affect performance. In theory, the government gave the contractor free rein; in practice, it dictated to the contractor what to do and what equipment to use. The government’s mandate for software reuse and use of commercial software products were contradictory and problematic, although the layered system architecture designed by LM did support system evolution and migration to modern technologies. The decision to leverage legacy applications with modern information technologies created a dichotomy: some of the mandated products did not directly scale for Air Force operations, others proved incapable of operating over the austere communication channels used by the Marines and the Navy. The significant GFE requirements for both physical equipment and other crucial system components meant that LM always needed government support to deliver TBMCS increments.

Software reuse was less straightforward than originally envisioned. Air Force requirements varied from those of the other services and had direct impact on the overall design, especially as it related to the DII COE. The TBMCS software infrastructure changed sufficiently to warrant a separate baseline. Moreover, the plan to use common products as the system infrastructure was flawed and very restrictive, because the COTS upgrade cycle was always at least two versions ahead of the TBMCS baseline. The application baseline was also affected, which led to extensive overruns in integration cost and schedule. This illustrates the importance of using open standards, rather than specifying particular commercial products as the software infrastructure.

It is also essential to understand the maturity of the third-party products specified in a system design. Unfortunately, proof-of-concept demonstrations and user-developed applications did not always transition into production-quality products, and the process and schedule did not permit such an assessment. Development programs must build in an assessment process that allows the integrator either to build the software application or to replace a required product with another if the third-party product does not integrate well—meaning that it takes more time and money than the budget allows.

The government must provide stable interfaces and an environment that allows the contractor to test them. External interfaces must be fully tested in a real-world environment at both the functional and technical levels. If a program’s schedule slips, any system that releases an update to the interface must be backward compatible.

SCHEDULING

Schedules, requirements, and budgets must be realistic. A fast-paced engineering process can work well for prototypes where an opportunity exists to revisit decisions and rework the product, but TBMCS was attempting to define a relatively large system of systems. Months after contract award, the government diverted LM from developing TBMCS and instead directed the contractor to fix and field the legacy system CTAPS. This led to a three-year schedule slip and consumed 70% of the budget allocated for TBMCS. TBMCS never recovered. The remaining resources were devoted to testing and fielding TBMCS V1.0.1 on an accelerated schedule.

SYSTEM INTEGRATION AND TEST

The government did not concern itself with the suitability of TBMCS and its components for formal testing. The System Segment Specification that governs testing never really reflected the baseline; instead, it lagged behind the current program requirements. In addition, the government continually changed the allocated baseline with mandated third-party products, which did not always reflect the agreed-to requirements. Continued pressure from the user community to field V1.0.1 resulted in a failed OT and later basically forced relaxation of test criteria. The program was forced to review and rework some areas based on the results of formal tests instead of feedback from internal activities.

External interfaces must be fully tested in a real-world environment at both the functional and technical levels. The contractor did not have the capability to conduct a live test of the interfaces in-plant, and simulation was not always a good
indicator of performance. Having the contractor test the system in an operational setting is essential.

TBMCS’s two failures in OT and the subsequent remedial actions indicate that the SPO must take ownership in managing the risk for DT and OT. System engineering must play a major role in planning the tests and managing technical risks; again, there is no substitute for a well-defined requirements baseline. Obtaining user agreement on the pass/fail performance criteria was a Herculean effort. Moreover, testing is a building block process that must be run in a serial mode with well-understood entrance and exit criteria. For TBMCS, schedule considerations overruled the test planning process, so that LM was performing integration tests while the government was running development tests.

Finally, system developers must understand how the system will be employed. Again, a detailed CONOPS and a corresponding concept of system employment are essential. For TBMCS, not testing the overlapping processes involved in building and managing air operations prior to an OT was a major mistake, and violated the fundamental systems engineering principles of effective test planning, risk assessment, and definition of external system boundaries.

TBMCS has made several improvements to the test planning since V1.0.1, and the SPO continues to take a proactive role in managing risk. The processes are now serial, with well-understood entrance and exit criteria. Stress testing during DT reflects the real operational load, to include interaction among cells and live testing of interfaces. Finally, field test is part of the contractor and DT testing prior to operational test.

CONCLUSION

Rather than serve as an exemplar for reduced oversight and relaxed standards, TBMCS teaches the lesson that nebulous requirements demand especially rigorous systems engineering processes. The Air Force’s well-intentioned attempt to reduce bureaucratic burdens on system development proved inappropriate to a complex system-of-systems integration program. In the case of TBMCS, external influences drove a relaxation of discipline and rigor in the systems engineering process. In fact, the need for a detailed and accountable process increases when a program lacks sufficient detail in the requirements, architecture, and system design, or when the contractor and government underestimate the complexity of software reuse and third-party integration.

The lessons learned from the difficulty in fielding TBMCS V1.0.1 had a very positive impact on the program’s current systems engineering processes, which have evolved to become mature and repeatable. The demonstrated success of TBMCS in Operations Enduring Freedom and Iraqi Freedom testifies to the success of the current approach, as does the contractor’s ability to field four subsequent releases since the release of V1.0.1.

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Keys to Automate Supply Chains with Smart Labels

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ABSTRACT

RFID technology is a popular research topic for both academia and industrial practitioners in recent years. However, most published articles focus on the technology itself and seldom discuss the implementation issues of RFID-based systems. This article sets out to fill this gap by proposing some key aspects to automate RFID-enabled systems, in particular supply chains.

INTRODUCTION

It could be foreseen that Radio-Frequency Identification (RFID) technology will appear in many facets in supply chains in the next few years. It is an enabling technology which could offer substantial economic benefit by monitoring the flow of goods in an accurate and efficient manner. In fact, the RFID technology is not new: it was used in military applications during World War II [1]. It is believed that some previous hidden areas of business operations can now be made visible with the help of this technology, in particular in the fields of logistics management and supply chain management [2]. The technology is able to “collect product, place, time, or transaction data quickly and easily” electronically and automatically [3]. The rationale behind this technology is due to the fact that non-contact reading without line of sight restriction is made possible in these wireless or radio frequency systems. This benefit is effective in manufacturing and some other hostile environments where its predecessor (and also it’s competitor), bar code, could not be competed with.

It is still unclear that whether RFID technology is useful in mass industrial applications or not. This is due to the fact that little successful case studies could be found to support RFID investment in the industry. In fact, most reported research focuses on the ability of the technology, but little literature could be found to address implementation issues. In this connection, this article aims at suggesting how to implement an RFID-based project.

ATTRIBUTES OF RFID TECHNOLOGY

Egea-Lopez et al. [4] classify RFID technology under the category as “Automatic Identification and Data Capture.” According to their definition, this is the “identification and/or direct collection of data into a microprocessor controlled device without the use of a keyboard” [4]. Generally, RFID-based systems consist of three core components:

- **Tag**: a small label (not necessarily in paper label form) which incorporates a microelectronic device to store data, and an antenna to receive and send radio frequency signals;

- **Reader**: a tool to communicate with tags by using radio frequency signals; and

- **A data processing system** to handle the collected data, and convert it to useful information for distribution. Figure 1 shows some commercially-available RFID tags, readers, and its applications.

Table 1 summarizes some key variables of RFID-based systems, although it is not an exhaustive list. In fact, knowing the attributes is just the beginning of an RFID-based project implementation. RFID technology is a tool to enable information systems in monitoring product movement and capturing data more efficiently. In order to use these data effectively, companies need associated information systems to process the collected data, and may need to feed it to any enterprise systems accordingly. There is a need to develop solutions to cope with the large volume of data that RFID systems generate. However, the infrastructure from suppliers is often incompatible [5]. Therefore, if a company would like to deploy RFID-based projects successfully, it needs to be

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Refereeing of this article was handled by P. Ekelinen  
Manuscript received April 7, 2005; revised August 19, 2005.

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deployed as an integrated system in order to capture, move, and process essential information to and from any points in the business process.

PROCEDURES TO IMPLEMENT RFID-BASED SYSTEMS

Although RFID technology is not new, its application in industry is still in its infancy. If you do not know the direction on how to implement any RFID-based systems, they would probably result in failure. In fact, RFID technology itself is nothing more than a data collection tool. The only way we can fully utilize the RFID capability is to find suitable means of processing the collected information. A complete RFID-based project should consist of relevant information systems to analyze the large volume of collected data, so that automation in the supply chains is made possible.

In this connection, implementation of RFID-based systems, just like implementation of typical information systems, the following steps are crucial steps to go through in order to make sure the implementation has a high chance of success: problem exploration, feasibility study, analysis, design, construction and testing, conversion, and evaluation and maintenance. This set of procedures is sometimes called the life-cycle approach [6]. This section will discuss the key issues under these headings from the RFID technology perspective. Figure 2 depicts the procedures or flow chart for implementing an RFID-based information system. Details can be found as follows:

Problem Exploration

In this stage, the question: “Why should a RFID-based project be considered?” and “What are the purposes it is to serve?” should be clearly answered. You should clearly understand what objectives you are trying to achieve, or what problems you are trying to fix at the very beginning. It is advisable to examine the whole business processes carefully in order to define which part of the processes can be facilitated by the RFID technology. Another important factor is to devise a proper method or measuring system to judge if the project is a success. Once you understand the nature of the problem, it is easier for you to estimate whether the RFID technology could provide a solution or not. After this stage, the scope and objectives of development projects are formally established as next stages’ input.

Feasibility Study

After defining the scope of an RFID-based project, alternative feasible solutions should be found and studied in order to select the most appropriate. This stage will involve discussions with various interested parties, including vendors, and exploring the current way in which the organization operates. By examining current business practices carefully, it is easy to identify whether the benefits that RFID technology could provide (e.g., improvement in inventory visibility) are justified for a new investment. To name a few factors to be considered include financial, technical, organizational, and legal implications of the RFID-based system proposal. It is important to remember that usually there will be more than one possible way to proceed, and careful evaluation is needed to determine which approach is the best with which to proceed.
Table 1. Attributes of RFID Projects

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Options</th>
<th>Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of operations</td>
<td>Low frequency (125 kHz or 134 kHz)</td>
<td>Short transmission range, low system cost</td>
</tr>
<tr>
<td></td>
<td>High frequency (13.56 MHz)</td>
<td>Medium transmission range, cost effective for most applications</td>
</tr>
<tr>
<td></td>
<td>Ultra-high frequency (300 MHz to 1 GHz)</td>
<td>Long transmission range, the highest systems cost</td>
</tr>
<tr>
<td>Types of tags</td>
<td>Passive</td>
<td>No power source (power up by induced magnetic energy) and low cost</td>
</tr>
<tr>
<td></td>
<td>Active</td>
<td>Carries it own power source and higher cost, can send information voluntarily, more flexible</td>
</tr>
<tr>
<td>Programmability</td>
<td>Read only</td>
<td>Status does not need to be updated (e.g. consumer goods for sales recording only)</td>
</tr>
<tr>
<td></td>
<td>Read/Write capable</td>
<td>Status needs to be updated (e.g. an item goes through a series of process to be identified.</td>
</tr>
<tr>
<td>Reading mode</td>
<td>Single item</td>
<td>Reading individual items, e.g. for sales recording</td>
</tr>
<tr>
<td></td>
<td>Multiple items</td>
<td>Reading a bulk packed items, e.g. counting how many goods on a pallet</td>
</tr>
<tr>
<td>Standards</td>
<td>ISO 18000-6</td>
<td>Depends on the usage.</td>
</tr>
<tr>
<td></td>
<td>EPCglobal Generation 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Others (e.g. not need a standard for internal process control)</td>
<td></td>
</tr>
</tbody>
</table>

Analysis

At the analysis stage, potential areas for improvement should be examined in details. It is also necessary to identify the physical characteristics of the environment under study. This investigation will start with understanding the as-is information processing processes. From this point an abstract view of what is currently done can be established. This is then revised to meet the new requirements in terms of as-if information processing processes. Then a new system could be developed at the abstract level, including the new features that are added in the as-if system. If the objective of retailers is to achieve long-term benefits, then “they will need to undertake a strategic review of their business processes and of their relationships with suppliers and distributors” [7]. The output of this stage is the system specification which is used as the input to the next stage (i.e., design stage).

Design

At this stage, detailed specifications for the new as-if system will be produced. This requires various operational decisions to be made such as how many readers should be installed and where a tag should be placed. A number of alternatives may come up and they have to be evaluated in order to come up with the best solution at the moment. Coyle [8] claimed that “new users to RFID often make the fundamental mistake of hearing performance claims from one vendor and assuming this performance is standard across the industry.” The reality is that there is no “standard” RFID-based system because different companies definitely have different business requirements. In short, in the design phase, the output of this stage is the consequences of understanding and figuring out your design requirements (e.g., what items you want to read).

Construction and Testing

This stage concerns the actual development of various components required for the new RFID-based system. The specifications that are developed in the design stage will be implemented. During the construction process, various components will need to be tested individually as well as in an integrated manner. Modifications on the specifications may be encountered. In such case, various interested parties (i.e., all stakeholders) should get involved in discussion on the required modifications and get a consensus on the final modifications that are required.

Testing is usually carried out at the laboratory (or testing bench) at the early stage of RFID-based projects, which is fine. However, it is advisable to set up a testing system where
tags are actually being scanned in the actual environment before pilot studies are carried out. The purpose is to check whether the tags in the final configuration (e.g., on a certain side of a carton) could be read successfully as expected. Only testing the systems in the actual environment can evaluate the technical performance, and hence assess the economic benefits. Under most circumstances, the laboratory or testing environment, cannot be used to simulate the actual environment in which the RFID-based systems are exposed.

**Conversion**
This would probably be the most critical period for most RFID-based systems. In general, a firm can replace an existing system by the newly developed system directly. However, it is also the most risky approach to changeover a system. Since RFID-based projects are usually an improved version of the existing system, it is suggested that the new system can be run (or more precisely, tested) in a pilot run in parallel with the existing system. In such way, the performance of the new system can be compared with the existing system. In addition, new value added features of the new system can be validated against the existing system. If it is possible, implementing should be done incrementally. On the other hand, even if you succeed with a pilot run, it does not mean you are guaranteed a smooth conversion with the rest of the system.

**Evaluation and Maintenance**
This stage applies throughout the remaining life cycle of the new system as continuous improvement. It is important that new systems should be reviewed or evaluated periodically to ensure that they are performing as expected or are still meeting the specifications. A critical evaluation may become the starting point for a whole new cycle of development. This is indicated by the link as the top unfilled arrow in Figure 2. However, regular evaluations usually

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**Fig. 2. Procedures to implement RFID-based Information Systems**
result in some minor changes and amendments to a system only, which is known as maintenance. Some of these changes are intended to correct faults in the developed system, so-called corrective maintenance, or to provide or improve features that should have been specified but were not, so-called perfective maintenance [6]. In some cases, changes are required to meet changed requirements and this is known as adaptive maintenance.

CONCLUSION

Only technical issues about implementation of RFID-based projects have been discussed. Other aspects to make sure the implementation becomes a success, such as human factors, how to overcome employees resistance, etc., are not addressed. New set of trainings regarding the introduction of RFID-based systems is certainly a must for employees, and a company’s suppliers and customers. In other words, a sociotechnical approach, which “combines technical solutions and social solutions so that the alternative that best meets both social and technical objectives is selected” [6], is expected to produce an information system that takes both technical efficiency and human needs into consideration. Therefore, careful planning on preparation works is a need. One way to accomplish this objective is general education to staff. In addition, specific training to users is equally important. A firm must explain to the employees why a new system is needed and explain how it will work so that every staff member could easily identify their role during the course of the development.

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Onboard Trajectory Equipment Measurements

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ABSTRACT

In past years, the onboard trajectory measurements complex (OTMC) was found in flight tests of flight vehicles (FV). The quick-release small-sized complex makes registration of the information of onboard systems, definition of trajectory parameters of FV, the information synchronization of onboard systems, and trajectory parameters. OTMC is used for the solution of the whole set of different tasks on estimation of the characteristics of FV and its onboard equipment. With the help OTMC in flight tests there solved the tasks of estimation: operation and accuracy characteristics of air navigation computing systems, inertial navigational systems, integrated navigational systems; SNS receivers, landing radio engineering systems, accuracy of flights under the standard takeoff patterns and landing, take-off and landing characteristics, accuracy characteristics of radars, corrections of high-altitude, fast-track parameters, systems of early warning of ground proximity etc.

THE REALIZATION OF FV FLIGHT TESTS TOOL

In the middle 1990s in FSUE “Gromov Flight Research Institute” the quick-release small-sized onboard trajectory measurements complex (OTMC) was developed [1, 2].

The complex is intended for definition of airplane trajectory parameters and registration of onboard systems parameters. The exterior of the onboard unit OTMC is shown in Figure 1. The definition of trajectory parameters makes on the basis of instrumentation signals of satellite navigational systems (SNS) and both complex information processing SNS and onboard inertial navigational system. At updating and registration of the flight-navigation complex systems parameters the value of Greenwich Time is shaped in OTMC, which is used for an estimation of the tested navigational equipment accuracy characteristics. OTMC has passed ground and flight of the OTMC unit State official tests. The list of tasks solved with the help of OTMC in flight tests heavy and light airplanes is broad enough. With appearance of OTMC instrumentation the technology of estimation of onboard navigational systems and characteristics both heavy and maneuverable FV has changed in flight tests.

Fig. 1. The exterior of the OTMC unit

ESTIMATION OF OPERATION AND ACCURACY CHARACTERISTICS OF THE AIR NAVIGATION COMPUTING SYSTEM

The information of the air navigation computing system (ANCS) is registered in OTMC. In actual time the code words are unsqueezed, and the ANCS operational mode is determined. The data of independent operational mode built-in in the onboard unit of the SNS receiver are received for real values of trajectory parameters at formation ANCS parameters errors. The errors of the ANCS navigational parameters definition are evaluated in flight and are mapped in a graphic view on the display of a notebook, bound with the OTMC unit. In Figure 2 it is shown the behaviour of the ANCS latitude and longitude errors in a mode of correction

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Based on a presentation at the 2006 St. Petersburg Navigation Conference.
0885/8985/07 USA $25.00 © 2007 IEEE
on radio engineering beacons VOR/DME. The tag of corrections marked in Figure 2 with marker in the shape of a triangle, at correction ANCS on VOR/DME is equal to 1. Automatically in a mode of correction the statistical characteristics of an error are evaluated: expectation M and standard deviation σ.

**INERTIAL NAVIGATIONAL SYSTEMS ESTIMATION**

The information of onboard inertial navigational systems (INS) goes in OTMC. In OTMC the complex information processing INS and built-in in the unit of the SNS receiver is made. During the flight the INS navigational parameters errors are evaluated. In Figure 3 the dependence of INS latitude and longitude errors from time is figured. In post-flight processing of materials of flight tests the INS instrumental errors are evaluated.

**SNS RECEIVERS ESTIMATION**

The onboard SNS receivers evaluate navigational parameters of FV – latitude, longitude, altitude, northern, east and vertical component of speed vector – with enough split-hair accuracy. For their estimation the high-precision values of FV trajectory parameters are required. The estimation of onboard SNS receivers operation and accuracy characteristics on all flight segments, including maneuverable ones with large bank angles or pitch, is implemented in post-flight processing of materials of flight tests. As real values of FV trajectory parameters the data of a differential mode on phase measurements of the SNS receiver built-in in OTMC and complex information processing onboard INS.
and differential mode SNS undertake. It is carried out the calculation of the SNS receiver navigational parameters errors, graphics image of errors, calculation of the errors statistical characteristics.

ESTIMATION OF LANDING RADIO ENGINEERING SYSTEMS AND AUTOMATIC CONTROL SYSTEM

For estimation of landing approaches in the OTMC unit is registered the information of onboard course and glidepath radio engineering means of landing. In post-flight processing of flight tests materials the data of a SNS differential mode are enumerated in top centric coordinate system, which center is placed in an end face of a runway (RW), and the axis X is directed along a runway center line. The qualitative estimation of flight on a glide path is given under the OTMC data; the errors of landing radio engineering means are evaluated. In Figure 4 for example is shown the lateral deviation of FV from a glide path under the SNS data and data of a landing course radio engineering means. On an abscissa axis the values of distance up to an end face of runway are postponed. The FV flight happened in the party of decreasing of coordinate X. The signals of a course radio engineering means are transformed to deviations in meters from zero value appropriate to flight on a glide path. Considered Figure 4 landing approaches was executed in an automatic mode.

FV TAKE-OFF AND LANDING CHARACTERISTICS ESTIMATION

At estimation of FV take-off and landing characteristics the data obtained with the help of OTMC, are used for definition of distances, separation, and contact a landing gear of runway moments, the conditional altitude of a hindrance reaching moments, speed in the reference moment of take-off and landing, lateral deviation from a runway center line. At realization of flights, in which the take-off and landing characteristics are evaluated, on modes of take-off and landing in OTMC the registration frequency of an onboard INS parameters number is automatically augmented up to frequency of their updating (as a rule, up to frequency of 100 Hz). As real values of trajectory parameters the data of complex information processing (CIP) of a differential mode SNS and onboard INS undertake. The data SIP are shaped on the moments of INS parameters updating and are enumerated in top centric coordinate system with the beginning in a point on a runway center line. The contact a landing gear of runway moment is determined, for example, on Qualitative change of behaviour of vector acceleration component and vector angular rate component of FV. In Figure 5 the behaviour of a longitudinal acceleration of FV on landing is figured. On an abscissa axis are postponed the values of coordinate X – deleting from a distant end face of runway. The flight happened in the party of coordinate X decreasing. In behaviour of acceleration two reference moments are marked: the moment of contact a back landing gear of runway (X ~ 4460 M) and moment of contact of a forward undercarriage leg of runway (X ~ 3590 M). In the reference moments the amplitude of an acceleration noise component changes and average value of acceleration varies.

THE HIGH-ALTITUDE, FAST-TRACK PARAMETERS CORRECTIONS DEFINITION

For developing of the high-altitude, fast-track parameters corrections in OTMC are registered the air signals system data, experimental pressure transducers, onboard INS. The
Fig. 5. Behaviour of a longitudinal acceleration of FV on landing

processing of flight tests materials happens after fulfilment of flights. As real values of trajectory parameters the data of a built-in SNS receiver differential mode undertake. To developing of the corrections are applied barometric and fast-track methods. In case of a barometric method the values of a flight geometric height under the data of a SNS differential mode are used. The corrections are evaluated in all operational altitude band, speeds, Mach numbers.

At usage of a fast-track method in specially executed pair modes of flight with mutually opposite course angles with holding of speed and the altitudes determine true air speed on measured values of ground speed projections under the data of a SNS differential mode. The true static pressure at the altitude of flight is determined on values of full pressure, temperatures of inhibiting action, and true air speed. Both in case of fast-track method, and a barometric one, the error of perception of static pressure is determined by matching measured values of static pressure with true values of pressure.

RADAR ACCURACY CHARACTERISTICS DEFINITION

For the accuracy characteristics definition of a radar in an air - air mode on each of two FV, used in flight tests, is established the OTMC unit. The usage of OTMC instrumentation has enabled to make straight lines of radars parameters estimation. On FV with radar tested makes data record of radar with updating frequency of their values. The radar characteristics estimation is made in post-flight processing of flight tests materials. The data of SNS differential mode for each of two FV are shaped, and on them the real values of parameters, giving by radar are evaluated: distance up to the purpose, relative closing velocity, lateral angle, and angle of a place of the purpose. The obtained errors of radar are handled by statistical methods.

CONCLUSIONS

Usage of OTMC instrumentation has allowed to decide a lot of the tasks arising during FV flight tests, in which the definition of FV trajectory parameters, and parameter estimation of onboard systems are required. The OTMC application has allowed essentially to lower costs of realization of FV flight tests and to reduce terms of tests realization and processing of flight tests materials.

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IEEE A&E SYSTEMS MAGAZINE, MARCH 2007 29
Railway Track Inspection Using INS-BINS-N

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“PIC Progress” AG

ABSTRACT

The results of an integrated strap-down inertial system development and tests are presented. The system includes laser gyro and accelerometers and is intended for measuring railway track angular parameters. To raise the accuracy of angles and distance measurements the inertial system is integrated with a GPS receiver and an odometer. Test results showed that BINS-N accuracy is better than the accuracy of an issued system.

INTRODUCTION

Last year, the means and methods of inertial navigation along with traditional fields find application in new fields. Strap-down techniques have opened new opportunities of inertial means use. One important application is railway track inspection.

The actuality of this problem is defined by a necessity to keep an essential level of a railroad traffic safety. To solve the problem one should with a higher degree of authenticity and energy appraise an accordance of actual railway track parameters with prescribed traffic speeds, reveal some improper railway track maintenance limiting the traffic speed, and find track sections that are in need of repair and correcting the track geometry. Usually these operations are implemented with the help of equipment mounted at the railway-measuring car.

Fig. 1.

Fig. 2.

This contribution was originally presented at the 13th Saint Petersburg International Conference on Integrated Navigation Systems, Saint Petersburg, Russia, May 2006, appeared in the Proceedings of the conference, and is reproduced herein with the kind permission of the Copyright owner, the State Research Center of Russia “Keldysh”, 2006. IEEE AESS has been one of the co-sponsors of this conference for many years.

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Based on a presentation at the 2006 St. Petersburg Navigation Conference.
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A feasible method of determining geometrical parameters of a railway track is to continuously measure the car angular attitude. The measurements are used in repair operations.

As an example, let’s consider a curvilinear section of a railway track. To ensure safe train traffic the curvilinear section should be maintained in a near-designed attitude. The shape of the curvilinear section is determined by the radius of turn, by the length and smoothness of passages between curvilinear and straight sections of track and by the elevation of the outer rail relative to the inner rail over all the length of the curvilinear section. During the railway operation all the parameters mentioned change their values owing to the exposure to weather factors and dynamic loads. Train cars while moving along distorted curvilinear sections are exposed to extra dynamic loads, too.

Figure 1 shows diagrams of radius of turn in plan and rail elevation changes along the curve before a scheduled repair of the track. The third diagram shows calculated permissible values of centripetal acceleration acting on a train moving along the curvilinear section of a track (so-called unextinguished acceleration).

Figure 2 represents the same parameters obtained for the curvilinear section after the railway track has been repaired. The result is that the track attitude is close to the designed position. One can see that the plan R became smoother. Level h is raised to the designed mark of 50mm.
The third diagram of Figure 2 shows that permissible centripetal acceleration values increased and correspondingly an admissible velocity for a train and traffic safety rose. So railway track geometric parameters should be accurately measured over all the length of the track.

Today’s state-of-the-art requires knowing the geometry of a railway track with the accuracy of 1...3 mm. It means that an angular error should not exceed 1 arc. min. for a measuring car base length. It is a rather complicated technical problem to make angular measurements with the accuracy mentioned above when the car is moving at speeds up to 200 - 300 km. per hour.

To solve this problem a strap-down inertial system (SINS) is incorporated into railway track measuring complex. The system is a sensor measuring car body angular position relative to a supporting coordinate system. However autonomous strap-down inertial systems do not provide the necessary accuracy of angular measurements (0.02 deg).

To cope with this task “NAVTECO” in cooperation with “PIC PROGRESS” developed a laser gyro strap-down inertial navigation system BINS-N integrated with GPS receiver and odometer. In the course of 2004-2005 two prototype BINS-N systems were manufactured and tested.

A block diagram of functional algorithms of BINS-N is shown at Figure 3. It has the following distinctions from the block diagram considered in [1]:

- an autonomous inertial loop is introduced operating simultaneously with an integrated loop;
- instrumental errors of sensors are continuously estimated and corrected and status vector for the system errors includes accelerometers biases.

The system outputs inertial and integrated data via ARINC-429 channel. Additionally integrated data together with horizon, azimuth, and instrumental errors estimates are transmitted via RS-232 channel.

BINS-N was tested as a part of measuring and computing complex of a railway track inspection car. The tests were conducted in two stages.

In the first stage, 19 - 20 May 2005, the system was tested autonomously and then from 21 - 31 May 2005, and from 4 - 12 November 2005, it was tested as a part of an
issued equipment of the track measuring car TSNII-4 that inspected railway tracks.

The system errors estimates that were received during the tests are shown at Figures 4 - 11.

From the point of view of the angular measurements accuracy the most interesting are horizon errors estimates for the integrated mode. Figure 4 illustrates two typical realizations of the horizon errors estimation process in real-time. During the tests a program version of the system was used that once every 10 minutes corrected attitude, velocity, coordinates, and instrumental errors by estimates obtained with the aid of Kalman filter. Therefore horizon and velocity errors estimates diagrams (Figure 5) are notched.

Horizon error value is not more than 0.015 degree. It is confirmed by the fact that at the end of 10-minute periods of estimation the velocity errors do not exceed 3.5 km/h.

The same estimates were received in all the tests and this fact confirms that BINS-N meets the requirements of angular measurements accuracy for railway track inspection car.

Figures 6 - 11 show diagrams for inertial loop parameters. The estimates for these parameters were obtained by post-processing. Diagrams of Figures 6 and 7 present latitude and longitude errors estimates for 10 runs. Maximum duration of one of the runs was 18 hours.

Each of the diagrams for velocity errors estimates (Figure 8) and horizon errors estimates (Figure 9) presents two typical realizations. The diagram of Figure 9 demonstrates that in inertial mode errors of the system exceeds an admissible level of the errors in measuring railway track geometry.

As a whole the autonomous inertial loop accuracy corresponds to the instrumental errors estimates that are illustrated by Figures 10 and 11.

In conclusion let's consider an accuracy of measuring railway track profile with the aid of BINS-N in a comparison with the issued system aboard TSNII-4 car.

Railway track profile construction is based on the continuous measuring pitch angle of the inspection car. Track slope is calculated along the base of the car using pitch values. Track profile is calculated as an integral of the slope over the track length. To correct the divergence of this integral design marks are used.

To meet the requirement to determine the elevation with an errors not worse than 10 sm over 1 km of a path (10^-4) design marks for an issued system of the inspection car should be placed after every 5 km. And it is a problem. As to integrated strap-down system it meets the requirements of elevation measurement accuracy if a distance between design marks is even 50-70 km.

Figure 12 shows track profile calculated from data of three routes between Bologoe and Moscow, with the distance between design marks equal to 50 km. One of the marks is situated near 565 km point. Two upper curves are measuring data of BINS-N. The maximum divergence between two curves near the point of 590 km is 1.4 m that corresponds to a relative errors of 2.8.10^-4 (tolerance is 10^-4).

The third curve relates to an issued system of the inspection car. The maximum divergence of the third curve near the point of 590 km is 6 m that corresponds to a relative error of 1.2. 10^-4 and increases farther.

So test results of BINS-N shows its measurements are more accurate and repeatable in comparison with an issued system. Besides BINS-N employment reduces labor input in railway track inspecting operations.

Since 2006 BINS-N is included in TSNII-4MD railway track inspection station equipment and will be mounted aboard new and repaired inspection cars. BINS-N characteristics permit to use it as navigation means for different objects.

REFERENCES


The Opening Address at the 2006 International Carnahan Conference on Security Technology is presented herein for the benefit of non-attendees at this successful IEEE-AES conference on a subject that affects everyone of us.

2006 Carnahan Conference Opening Address

Lexington, Kentucky

May I extend my warmest welcome to you from this, the 40th International Carnahan Conference on Security Technology. It is truly wonderful to see so many of you supporting this Conference and to know that so many countries from around the globe are represented. Many of you have supported the conference for years but I want to express a special welcome to those young scientists and engineers attending for the first time.

Yes, this is the 40th – the Ruby Anniversary – of our Conference, which has been held all around the world every year, starting in 1967. I think I am one of the few who have been associated with the Conference since its inception. Because we have reached this milestone, I hope that you will excuse me if I indulge my thoughts about some of the major developments in security technology that this Conference has witnessed over the past forty years and to some issues, as I see them, about the future, and in particular, about the future of this Conference.

The aim of security technology is to address a specified threat. As much as technology has evolved over this period, so has the nature of the threat. In prior days, the World seemed a simpler place; the threat was mainly criminal attack against property, isolated cases of terrorist attack, and the ever-present possibility of escape from custody – not to say the threat of enemy attack in a theatre of war. This was just a few years after the Cuban Missile crisis and at the time of the “Iron Curtain” and the Cold War. From the beginning of the 1970s, we saw the evolution of organised terrorism as a growing threat, in Northern Ireland and the UK mainland, in the form of the IRA; in Spain, as ETA; in Italy, in the shape of the Red Brigade; and in Germany with Palestinian terrorists at the 1972 Olympic Games. But, up until then, little in the US. The threat has drastically changed. Frequently backed by the Islamist group Al Qaida, terrorists are now active worldwide. We remember with pride and sadness their victims of the attacks of 9/11/2001 in the US, as well as those in Madrid, London, Bali, in many other places including the Middle East. As a result of the successful use of intelligence and security technology, numerous planned terrorist attacks have been thwarted.

The huge advances in technology generally have brought with them their own problems for security technology. The mobile phone, now an essential part of everyday life, is a target for thieves and data hackers, apart from being a potential trigger device for a bomb. By far, the biggest of these general advances have been made in computer technology. In the 1960s, you needed a computer the size of a bargain basement to do fairly simple calculations, and few individuals owned one. Today’s households in the developed world are without routine access to powerful desk – or lap-top computers, giving them access, via the Internet, to a host of information and services. It has been necessary to develop a battalion of computer and IT security techniques, not only to protect the individual user from computer fraud and identity theft, but also to secure data so that it cannot be intercepted and read in transmission across the Internet. About half of the papers presented at this conference in the past 7 to 10 years have been on the subject of IT security. They have ranged from advanced
encryption techniques, including those for protection of voice over Internet, to methods of detecting and preventing Trojan horse attacks against systems. As the attackers become more sophisticated so, too, do the means of defeating them.

Biometrics has become a driving force in security technology. It is of great importance and is evolving in many areas, as covered by the four sessions dedicated to it at this Conference. Fingerprint identification became an established tool in the fight against crime in the 19th century. Right up to the mid-1970s all the fingerprint comparison work was conducted manually by fingerprint experts laboriously conducting one-by-one comparisons, often checking one suspect print against thousands of prints on record. The advent of high-speed computers with large memory capacity changed all that. Papers presented in the 1970s and 1980s showed how advanced comparison algorithms, based on the minutiae of individual fingerprints and implemented by computer, could produce a short list of potential matching fingerprints in a matter of seconds, leaving the fingerprint officer to simply check this list manually against the record prints. Truly a revolution in security technology!

Biometrics has advanced on many other fronts. In the early years, we saw the acceptance in Wiesbaden of voice print acoustics in criminal investigation, all work conducted on a PDP11 computer. Biometrics has advanced on many other fronts from iris scanning through facial recognition to palm geometry and even identification by ear profiles! A number of these techniques are part of our everyday life, in access control and some passport applications. Needless to say, these advances, all of which have been reported at this conference, could not have been made but for the existence of powerful computers which can deal with the complexity of the algorithms.

Many consider physical security as the “Cinderella” of security technology. Apart from anything else, it is vital to the protection of key national infrastructure. Physical security protects us not only from the bad guys getting in (that is the terrorists or other criminals) but also from the bad guys getting out (that is prisoners or others who are in detention for whatever reason). The developments that we have witnessed over the past 40 years have been no less than staggering. We have seen the most basic trip alarms develop to incredibly sensitive perimeter detectors, which use image analysis and zone analysis to identify true alarms and to reject those which are false. Once again, digital computer technology has been the platform on which these systems were based. Infrared, microwave, leaky feeder, vibration sensor, capacitative loop and various other sensors have been developed to be at the front end of these systems. And now, we are seeing wireless systems powered by battery cells, which can transmit alarm data via the Internet!

No presentation of this nature would be complete without at least passing mention of CCTV. In its early conception, close circuit television as a security application consisted of a single indoor camera, usually trained on a door or some other access point, and a guard whose job was to continuously monitor the TV pictures, which were black and white and pretty unstable, at a remote point to check for illegitimate activity. Because the vidicon cameras and the monitors, which 40 years ago were based on cathode ray tubes, were so expensive, the applications were few, mainly at embassies, high security prisons, and for protecting very high value assets.

Since the mid-1970s, we have witnessed many developments in CCTV. Camera systems now rely on charge coupled devices, which are produced by the thousands and are really inexpensive. Video tape recording is being replaced by digital recording, again because of the massive developments in computer memory technology. And, of course, flat screens have replaced those bulky monitors. All these advances mean that CCTV has become omnipresent, not only in cities where police use them to patrol streets, but also in public buildings, hospitals, and schools. The cheapness of the cameras means that CCTV is now one of the main components in domestic security systems, something we could not even contemplate 30 years ago. One key achievement of the advances in CCTV technology has been the use by police of recorded CCTV images of criminals not only to identify them but also to bring about their conviction in the courts.

I wish to conclude by referring to security at airports. In recent times, terrorists have used air passenger transport as a major vehicle for acts of terror. This has imposed a huge security burden on airlines and airport authorities. It means that virtually every passenger and item of baggage passing through any airport in the World has to be searched. Many excellent groundbreaking papers have been presented at this Conference in response to this need. Starting from early x-ray scanners, which were cumbersome and slow and pretty insensitive, we have seen the introduction of a range of sophisticated devices. The latest baggage x-ray scanners produce high-resolution 3D pictures, enabling the identification of firearms and other weapons as well as concealed explosives. Some of the most advanced use CT techniques were first used as diagnostic tools in hospitals. Hand-held and archway devices have also improved, mainly in reliability and sensitivity of detection and speed of throughput. A minute trace of an explosive can be easily detected. A few years ago we saw the introduction of millimetre wave technology as a passenger search
technique; quadruple resonance techniques are now being brought into this arena.

These are areas of security technology that we have seen presented at the Carnahan Conference since its inception and I apologise to those of you whose areas of work I have not mentioned.

I want to conclude by talking about the importance of this Conference and how it may develop in the future. This conference is unique for several reasons: first, no other conference on security technology has stood the test of time – forty years. Second, no other attracts such worldwide support and interest. And third, no other brings together the three elements of academia, Government, and industry in the way we do. That is why this Conference is of such importance and, in my opinion, will continue to grow in importance and prestige in years to come.

Where do we go from here? No one can predict the future, but some things are clear. There will be a continuing need to respond to threat, even if that changes. There is current evidence that threats are decreasing; quite the opposite. There is a continuing need to “stay ahead of the game;” a need to continue to outwit the intruder and to confound the terrorist, and be at least one step ahead of them. There is a need for greater sensitivity and greater automation in the use of systems. There will always be the need for human intervention when a decision has to be made on whether to respond to an alarm or to search someone. All this means that there will continue to be developments in the technology for many years, if not indefinitely. There will, therefore, continue to be the need to exchange ideas on systems, how they work, when they don’t work, and when it is better to use one in preference to another. In exchanging these ideas we can avoid unnecessary work in areas in which others have been working. On the other hand, we may want to check what others have done once we know what they have done.

There will continue to be a need for this Conference. There may even be a greater need for it than we have today.

I may not be your Chairman at the 50th Anniversary – the Golden Anniversary – of this conference in ten years. Many of you here today may well be attending then. I especially welcome the young engineers and scientists attending for the first time. I hope that the quality of what you see presented here and the discussions you have with others between sessions and with exhibitors, will encourage you to come back. We need the continuing support of regular attendees of this Conference – and I take this opportunity to thank them sincerely for their loyalty – but it is the younger folk that will provide the future lifeblood of this Conference.

Do come back; do continue to support this Conference, as only you, as delegates, presenters, and exhibitors can ensure its future.

Thank you.

– Larry Sanson,
Conference Chair
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Students!!! Why You Should Join This Society

My name is Jose Bolaños and I am a graduate of California State Polytechnic University (CAL Poly), Pomona, California. I have been a member of IEEE since I was a student (1980). I heard how important it was to belong to a professional society, therefore I joined. Currently I am a Senior Member of the IEEE and the Students’ Activities Chairman for AESS. I have been a member of the AESS Board of Governors since 1989.

I wanted to belong to a professional society in order to have it on my résumé. I was not as active at that time. Upon graduation I decided to become active. Once hired by my company, I immediately contacted the local AESS Chapter Chair and volunteered my services. Next I became the local Chapter Vice-Chair and performed multiple duties with the Section until I progressed to Section Chair. By the way, the former local Chapter Chair became the AESS Society President; we continue our personal and professional friendship to this date. The same is true with the AESS Conferences Chair.

As you can see, the mentoring opportunities in IEEE/AESS are abundant. Paul Kostek and Henry Oman have mentored me during IEEE/AESS activities. I learned from many of my IEEE/AESS associates about how to increase my technical and interpersonal skills. By holding various positions within AESS I have expanded the visibility of my organization networking with other professionals.

As student member of our society, you can contact your local AESS Chapter Chair or a member of the Board of Governors and ask for advice on activities for your chapter, or volunteer opportunities. One of the activities I enjoyed the most was plant tours. It is here that you have the opportunity to network with engineers working in the field. One of these plants may be your future employer.

Another benefit of volunteering is that by becoming active at the local, regional, or national level, you let your Student Advisor or your employer know that you are willing to “go the extra mile” and give back to your profession. This has been of extreme benefit to me.

While I was the AESS Chapter Chair, I met Henry Oman. He later recommended me for the AESS Board of Governors. I could not believe I was elected! My first assignment was National and International Chapter Coordinator and I was invited to participate at this critical level in the AESS organization.

At this time we have student chapters at Portland State University, at University of Missouri at La Rolla, and in Barcelona, Spain.

The benefits as a member of an AESS student chapter are:

- Receive $25.00 per technical meeting, up to four meetings per year (Chapter).
- AESS may finance specific student projects (for your Chapter).
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- You can attend local professional chapter meetings.
- You can attend AESS-sponsored conferences at a discount.

This is your opportunity to start a student chapter at your branch, if one does not exist.

Jose Bolaños,
(jbolasos@ieee.org)
AESS Student Chapter Activities Chair
March 2007  
**Distinguished Lecturers Program**  
**James R. Huddle, Chair**

All AESS Chapters and IEEE Sections are encouraged to take advantage of the AESS Distinguished Lecturers Program for their regular or special meetings. We have selected an outstanding list of speakers who are experts in their fields. The AES Society will cover up to $500 of the speaker's expenses for travel in North America, with any remaining amount normally covered by the AES Chapter or Section or by the speaker's organization. For travel outside North America, the AES Society will cover half of the speaker's expenses per trip, up to a maximum of $1500. The procedure for obtaining a speaker is as follows: If a Chapter or Section has an interest in inviting one of the speakers, it should first contact the speaker directly in order to obtain his agreement to give the lecture on a particular date. After this is accomplished, and if the Chapter or Section wishes to request financial support from the AESS, it should contact James R. Huddle on (818) 715-3264, F (818) 715-3976, j.huddle@ieee.org at least 30 days before the planned meeting, in order to obtain approval for the financial support. The list of distinguished speakers who have expressed their willingness to speak to Chapters or Sections, along with their organization, topics, and telephone numbers, is given below.

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<td>Target Tracking and Data Fusion: How to Get the Most Out of Your Sensors</td>
<td>Dr. Yaakov Bar-Shalom, Univ. of Connecticut</td>
<td>(860) 486-4823</td>
</tr>
<tr>
<td></td>
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<td>(860) 486-2285 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:ybs@engr.uconn.edu">ybs@engr.uconn.edu</a></td>
</tr>
</tbody>
</table>

All data on this page is under the purview of James Howard, VP-Member Affairs. Please send all corrections and omissions to him at the address on the inside back cover.
FROM THE EDITOR-IN-CHIEF

Call for Reviewers

The IEEE Aerospace and Electronic Systems Magazine is accepting requests from individuals wishing to be considered to be a reviewer of articles and papers submitted to Systems. All reviews are done on the eJournal Press’ web-based review systems at: http://sysaes. msubmit.net.

Typically, new Editors are selected from those who have been reviewers. If you are interested in being considered as a reviewer for Systems, please indicate your areas of interest/expertise and send your résumé to the Systems Editor-in-Chief: e.hirt@ieee.org.

– Evelyn Hirt

Your Society Governance — Fall 2006
Exceptional Service Award

Eli Brookner

For Unparalleled Sharing of Technical Expertise and Insight with the Radar and Phased Array Communities throughout the World and for Unparalleled Service to the IEEE Aerospace and Electronic Systems Society and the IEEE Boston Section.

A recognized global authority on radar and phased array systems, Eli Brookner has made a significant impact on the radar and phased array community through his extensive publications, teaching, and lecturing. He has set an unparalleled standard for sharing of technical expertise and insight with his professional community of radar and phased array engineers and scientists. A highly-acclaimed and much-sought-after teacher and lecturer around the world, he is known for his clear and dynamic courses and lectures on radars, phased arrays, and tracking which are interspersed with humor, photos of his travels, and his own hand-drawn Snoopy-type cartoons.

Dr. Brookner received his BEE from The City College of the City of New York in 1953 and his MEE and DrSc in 1955 and 1962 from Columbia University, all in electrical engineering. He began his career in radar in 1952 while an undergraduate student as a summer employee at the Radar Division of the USAF Rome Air Development Center, Rome, New York, where he had the good fortune of evaluating Armstrong’s FM Radar and flying around in a Goony Bird (DC-3) for 8 hours testing the resolution of an RCA radar.

Upon graduation, he started his career working on the design of long-range radars at the Columbia University Electronics Research Laboratory (CUERL). At that time one of the exciting radar developments of high interest was Marcum’s now famous 1948 report on radar detection, A Statistical Theory of Target Detection by Pulsed Radar which had just been declassified; it was published by the IEEE in 1960. At the Federal Scientific Corp. (now Nicholet) he invented the time-multiplexed circulating memory filter during the period 1957-1960. He returned to CUERL in 1960.

At the Raytheon Co. he is now a Principal Fellow. At Raytheon, Eli has worked or consulted on, and made significant technical contributions to over 25 major radar and phased array programs and studies including: ASDE-X (Airport Surface Detection Equipment) radar, ASTOR SAR/AMTI air surveillance radar, RADARSAT II space-based radar, Affordable Ground-Based Radar (AGBR), major Space-Based Radar programs for the US Navy and US Air Force, NAVSPASUR S-Band space surveillance upgrade, Cobra Judy Replacement radars, COBRA DANE radar, PAVE PAWS (Phased Array Warning System) radar, Missile Site Radar, commercial maritime radars, THAAD (Theatre High-Altitude Area Defense) radar, Brazilian SIVAM system, AEGIS SPY-3 ship-based radar, BMEWS (Ballistic Missile Early Warning System) radar, UEWR (PAVE PAWS and BMEWS radar upgrades), Surveillance Radar Program, COBRA DANE radar upgrade, Wake Measurement Radar, Long Range Radar upgrade program, Perimeter Intrusion Detection System (PIDS) for FAA, and the next generation IRIDIUM® personal communication satellite system. On each of these he demonstrated exceptional technical expertise and leadership by devising better
Exceptional Service Award

Presented to Eli Brookner
(IEEES'52, A'53, M'58, SM'70, F'72)
by the IEEE AES Society
and the
IEEE Boston Section
at the
IEEE 2007 Radar Conference

performing and lower cost radar and phased array systems.

Dr. Brookner has written and/or presented over 110 technical papers, correspondences, and more than 80 talks, including 7 times as Banquet or Keynote speaker at various conferences. Radar Performance During Propagation Fades in the Mid-Atlantic Region was awarded the 1999 IEEE Antennas and Propagation Society Wheeler Prize for Best Applications Paper. For Effect of the Ionosphere on Radar Waveforms he received the 1966 Journal of the Franklin Institute Premium Award. He wrote the feature article Phased-Array Radars for Scientific American February 1985, with a circulation of 600,000, translated into seven languages.

Many of his papers were selected for appearance in reprint volumes in addition to his authorship of books entitled:

- Tracking and Kalman Filtering Made Easy,
  (Wiley, 1988);

- Practical Phased Array Antenna Systems,
  (Artech House, 1991);

- Aspects of Modern Radar,
  (Artech House, 1988); and

- Radar Technology,

On his own time, he has presented more than 150 courses on radar, phased arrays, and tracking to over 11,100 radar engineers in 22 countries: USA, Canada, England, The Netherlands, Norway, Sweden, Germany, Switzerland, France, Spain, Italy, Turkey, South Africa, India, China, Taiwan, South Korea, Japan, Australia, Singapore, Chile, and Brazil. He has, for many years been a Distinguished Lecturer for the IEEE Aerospace and Electronic Systems and Antennas and Propagation Societies. He has served on many US Government and American Institute of Aeronautics and Astronautics (AIAA) committees and study boards, holds 8 US Patents and has chaired several IEEE Conferences.

Dr. Brookner's Fellow Citation:

• For contributions to radar signal processing and wave propagation in random media.

IEEE Awards include:

• the Meritorious Achievement Award of the Educational Activities Board,

• the 2003 IEEE AESS Warren D. White Award for Excellence in Radar Engineering for Significant Advances in Development of, and Education for Phased Array Radars, and


His other honors and awards are too numerous to list herein; refer to his IEEE Fellow Summary for a complete listing.
About the Conference

The latest in the series of the UK’s premier radar event returns in October 2007. Radar 2007 will cover all aspects of radar systems for civil, security, and defence applications and will showcase the latest developments in radar technology techniques and signal processing. Radar 2007 provides a unique opportunity to update your knowledge on the latest developments for all involved in advanced radar systems, from the experienced engineer to new graduates seeking to build a career in this field.

Conference Highlights

- Three days of presentations showcasing the latest worldwide research and development
- A valuable opportunity for you to receive an update on the latest technologies and future challenges facing the radar industry
- A Tutorial day on 15 October – your chance to study a state-of-the-art topic area in greater detail
- An exhibition of the latest, most innovative products and services from key suppliers
- Valuable networking opportunities, including lunch breaks served on the exhibition show floor, a welcome drinks reception, and conference dinner at the prestigious Royal Museum of Scotland

Key Conference Themes

Topics to be covered at Radar 2007 include:

- Dual-Use/Civil Applications
- Radar Systems
- ECCM/ECM
- Advanced Sub-Systems
- Environment
- Processing Techniques
- Emerging Technologies
- Computer Modelling and Simulation

To Register Your Place At This Exciting Conference

Conference registration will be available in April 2007. To register your interest and receive advance information, please contact the organizers on: +44 (0) 1438 765 647 or e-mail: Eventsa3@theiet.org

Main Sponsors: Thales and Selex Sensors and Airborne Systems
Sponsors: BAE Insyte, Raytheon, and UCL

The IEEE Aerospace & Electronic Systems Society (AESS) is a technical sponsor of Radar 2007, one in an ongoing series of International Radar Conferences. The AESS Board of Governors has scheduled its Fall 2007 meeting to coincide with Radar 2007 in Edinburgh.
IEEE STUDENT MEMBERSHIP APPLICATION
2007 IEEE AEROSPACE AND ELECTRONIC SYSTEMS SOCIETY
CURRENT IEEE MEMBERS DO NOT USE THIS FORM TO RENEW YOUR MEMBERSHIP; YOU WILL RECEIVE A RENEWAL NOTICE.
Mail to: IEEE, Admissions & Advancement Dept., 445 Hoes Lane, P.O. Box 8804, Piscataway, New Jersey 08855-8804 USA
Or Fax to: (732) 981-0225 (credit card payments only)
For info call (732) 981-0060 or 1 (800) 678-IEEE
E-mail: newmembership@ieee.org or www.ieee.org/join

1. NAME AS IT SHOULD APPEAR ON IEEE MAILINGS: SEND MAIL TO: ☐ Address During Academic Year OR ☐ Family/Home Address
If not indicated, mail will be sent to academic address. NOTE: Enter your name as you wish it to appear on membership card and all correspondence. PLEASE PRINT. Do not exceed 40 characters or spaces per line. Abbreviate as needed. Please circle your last/first name as a key identifier for the IEEE database.

TITLE
FIRST OR GIVEN NAME
SURNAME/LAST NAME
MIDDLE NAME

ADDRESS DURING ACADEMIC YEAR
CITY
STATE/PROVINCE
COUNTRY
POSTAL CODE

2. Are you now or were you ever a member of IEEE? ☐ Yes ☑ No
If yes, please provide, I known:
MEMBERSHIP NUMBER
Grade
Year Membership Expired

3. HOME / FAMILY ADDRESS

Street Address
City
Postal Code
State/Province

4. EDUCATION This information is required to qualify for student membership.

University
Campus
School or College
Program / Course of Study
Address
City
State/Province
Country
Postal Code

Degree Program (check one)
Undergraduate: ☐ 2 or 3 years ☐ 4 or 5 years Graduate: ☐ Master's ☐ Ph.D.
Course of Study: ☐ Computer Science ☐ Electronics Eng. ☐ Other

If Other (Please describe)
Do you hold other degrees? ☐ Yes (complete below) ☑ No

Highest Technical Degree Held
Degree Program / Course of Study

Degree / Year received Full College/School name and previous name, if applicable
City / State / Province / Country

Other Degrees Held
Degree Program / Course of Study

Degree / Year received Full College/School name and previous name, if applicable
City / State / Province / Country

5. SIGNATURE OF APPLICANT
I hereby make application for IEEE membership and agree to be governed by IEEE's Constitution, Bylaws, Statements of Policies and Procedures and Code of Ethics.

Full signature of applicant
Date

6. DEMOGRAPHIC INFORMATION — ALL APPLICANTS —
Date of Birth
Day
Month
Year
Male ☐ Female ☑

7. CONTACT INFORMATION
School Phone
Home Phone
School Fax
Home Fax
School E-mail
Home E-mail

8. 2007 IEEE MEMBER RATES

Check (☑) a box 16 Aug 2006 1 Mar. 2007
Residence Pay Full Year Pay Half Year
United States $30.00 ☐ $15.00 ☑
Canada (includes GST)* $31.80 ☐ $15.90 ☑
Canada (includes HST)* $34.20 ☐ $17.10 ☑
Other Countries $25.00 ☐ $12.50 ☑

Options for IEEE Members
Potentials Magazine (Outside U.S. and Canada) $5.00 ☐ $3.00 ☑
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of the IEEE Online $30.00 ☐ N/A
Print & Online $39.00 ☐ N/A

IEEE Women in Engineering (WIE) $37.00 ☐ Full Year Only
IEEE Standards Association (IEEE-SA) $37.00 ☐ Full Year Only
IEEE Canadian Business No. 12543/188

*If application is to be received by IEEE after 16 August pay full year.
Subscription to Spectrum ($16.02/year) and The Institute are included in dues.

2006 AESS MEMBER RATES

AES Systems Membership Fee* $13.00 ☑
Includes AES Magazine and online access to
IEEE/OSA Journal of Lightwave Technology
(print & electronic included in membership)
Publications available only with AESS membership:
Transactions on:
Aerospace and Electronic Systems Print $13.00 ☐
Electronic $13.00 ☐
Pattern Analysis and Machine
Intelligence Print & Electronic $18.00 ☐
Journal of Lightwave Technology,
IEEE/OSA Print $25.00 ☐

*IEEE membership required if joining the AESS Society
Amount Paid

METHODS OF PAYMENT: Prices stated are in US dollars
☐ Credit Card — American Express, VISA, MasterCard, Diners Club
☐ Check — Bank Drafts — Money Orders Payable on a US bank

9. IEEE Membership Dues

Aerospace and Electronic Systems Society Fees Total
Canadian residents pay 7% GST or 15% HST
Society fees only, Reg. No. 12543/1498

TAX $ 

AMOUNT PAID WITH APPLICATION TOTAL $ 

Prices stated are in US dollars; subject to change without notice.
☑ Check or money order enclosed (Payable to IEEE)
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M/C/Y
USA Only
Billing Statement Address

Full signature of applicant using credit card
Date

IEEE A&E SYSTEMS MAGAZINE, MARCH 2007 45
THE BENEFITS OF MEMBERSHIP

Core Benefits - IEEE is the world’s largest technical society, bringing Members access to the industry’s most essential technical information, networking opportunities, career development tools, and many other exclusive benefits.

Knowledge - Staying current with the fast-changing world of technology...

IEEE Spectrum Magazine - 12 monthly issues (print) and online
The Institute Newsletter - 12 monthly issues (4 print, 8 online)
IEEE Potentials Magazine - 6 issues (online)
IEEE Xplore - table-of-content and abstract access to 1.2-million documents
What's New @ IEEE - produced monthly, electronic newsletters on technical topics (10 topics to choose from)

Community - Belong to the network and buying power of 365,000 members in 150 countries...

IEEE Sections - network with others in the local member community, and participate in local educational events
Technical Chapters - engage with others through informative technical meetings
IEEE e-mail alias - with virus protection and spam filtering
ShopIEEE discounts - membership paying for itself, with as much as 50% off IEEE products
IEEE Conference registration discounts
Volunteering - opportunities that build leadership skills and networking opportunities
myIEEE - members-only personalized gateway into IEEE membership

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Career Alert - a weekly email newsletter containing career advice plus the job of the week from the IEEE Job Site
Continuing Education Partners Program - up to a 10% discount on online degree programs
Awards - recognize the accomplishments of technologists and engineers worldwide
Scholarships - enhance your resume with an IEEE scholarship
Consultants Database - a service available for matching technical consultants with clients
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Add-On Benefits

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Additional Memberships

IEEE Society Membership - expands the scope and depth of your technical knowledge, expanded networks
IEEE Standards Membership - influence the direction and application of standards development
IEEE Women in Engineering Membership - promotes the entry into and retention of women in engineering programs
RESPONDING TO OBJECTIONS

My company will not pay for my dues.

We’re grateful that some employers reimburse for IEEE membership dues, but IEEE membership is about individuals who desire to take ownership of their career, regardless of an employer’s willingness to reimburse dues. Individuals who belong to IEEE take personal responsibility for their careers.

IEEE membership is too expensive.

The cost of IEEE membership compared to most professional associations is significantly lower, as much as 30%, compared to organizations such as the National Society of Professional Engineers, American Medical Association, and the American Bar Association. When you really think about it, IEEE membership dues are quite reasonable when you consider the quantity and quality of benefits offered to members. Also, IEEE membership often pays for itself. The discounts members receive on IEEE products or attending a conference makes membership a good return-on-investment.

The value of IEEE membership does not justify the cost.

IEEE membership offers an array of benefits that may be of interest to you. Perhaps you are unaware of the some of these benefits. They include Access to technical publications; Professional and educational development; Unique networking venues; Discounts on conference attendance, insurance programs, IEEE products. And every member has their own, personalized gateway into IEEE membership via myIEEE.

I have no time to read the publications.

It’s a constant challenge between finding the time to be informed, and one day discovering that you’re not technically current. Our members tell us that reading IEEE publications saves them time, as they do not need to “reinvent-the-wheel” at work. IEEE publications are the world’s best collection of technical information. Taking the time to read this information keeps you technically current. Investing 30 minutes with one publication could save you 40 hours of research at work.

I can find all this information on Google—what’s the value of membership?

There’s a lot of information to be found on Google, but IEEE publications are not available for free on Google. Moreover, the quality of technical information found via Google is random, and doesn’t adhere to any consistent standards of technical excellence. Did you know that 80,000 patents cite IEEE information? – These patents cite IEEE, not Google. IEEE membership is much more than access to information. It’s about networking, professional development, and you taking personal responsibility for your career. Membership is about meeting new colleagues, and coming into contact with really great people—individuals who join IEEE form friendships that last a lifetime. You wouldn’t meet these people on Google.

I can get all of the information through my employer, so why should I belong?

Yes, organizations worldwide rely upon IEEE information to be technically current and competitive—it speaks to IEEE’s quality. IEEE membership is more than access to information. IEEE membership is about you being competitive and taking personal responsibility for your career. IEEE’s benefits include venues and tools for members to network, build valuable professional connections, and hone leadership skills. These are essential for managing your career. Membership is about meeting new colleagues, and coming into contact with really great people—individuals who join IEEE form friendships that last a lifetime. IEEE membership is more than what you receive—it’s also about what you’re giving back. When you belong to IEEE, you are supporting a much larger mission—your membership enables initiatives such as public information and policy efforts, affordable student membership, and the introduction of technology careers to young people worldwide.

I’ve recently been unemployed, and can no longer afford the dues.

IEEE will help you during these times. IEEE has a reduced-dues program for unemployed members, which allows you to keep your benefits, which are very helpful for finding a new job—for example, networking at local Section and Chapter meetings, uploading your resume to the IEEE Job Site, engaging the career navigator.
# IEEE 2007 AESS Member Application Form

## 1. Name As It Should Appear On IEEE Mailings

If the name is to appear as绂 the name should appear on membership card and all correspondence.

<table>
<thead>
<tr>
<th>Title</th>
<th>First Or Given Name</th>
<th>Surname/Last Name</th>
<th>Middle Name</th>
<th>Home Address</th>
</tr>
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<table>
<thead>
<tr>
<th>City</th>
<th>State/Province</th>
<th>Country</th>
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</table>

## 2. Are You Now Or Were You Ever A Member Of IEEE?

- [ ] Yes
- [ ] No

If yes, please provide, if known:

<table>
<thead>
<tr>
<th>Membership Number</th>
<th>Year Membership Expired</th>
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</table>

## 3. Business/Professional Information

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Company Address</th>
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<tr>
<th>Department/Division</th>
<th>Title/Position</th>
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<tr>
<th>Years in the Profession Since Graduation</th>
<th>PE</th>
<th>State/Province</th>
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<tr>
<th>Street Address</th>
<th>City</th>
<th>State/Province</th>
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<td>Postal Code</td>
<td>Country</td>
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## 4. Education

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<th>College/University</th>
<th>Baccalaureate Degree Received</th>
<th>Program/Course Of Study</th>
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<table>
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<th>State/Province</th>
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<th>Mo./Yr. Degree Received</th>
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<th>College/University</th>
<th>Highest Technical Degree Received</th>
<th>Program/Course Of Study</th>
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<table>
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<tr>
<th>State/Province</th>
<th>Country</th>
<th>Mo./Yr. Degree Received</th>
</tr>
</thead>
</table>

## 5. Signature of Applicant

I hereby make application for IEEE membership and agree to be governed by IEEE’s Constitution, Bylaws, Statements of Policies and Procedures and Code of Ethics.

Signature of Applicant: __________________ Date: __________

## 6. Contact Information

<table>
<thead>
<tr>
<th>Office Phone</th>
<th>Home Phone</th>
</tr>
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</table>

<table>
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<tr>
<th>Office Fax</th>
<th>Home Fax</th>
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<table>
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<tr>
<th>Office E-mail</th>
<th>Home E-mail</th>
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## 7. 2007 IEEE Member Rates

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<tr>
<th>Check (✓) a box</th>
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<th>1 Mar 2007</th>
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### IEEE Dues

<table>
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<tr>
<th>Year</th>
<th>Amount</th>
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<tr>
<td>2007</td>
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### Residence

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<th>Pay Half Year</th>
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<tr>
<td>United States</td>
<td>$227.00</td>
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<tr>
<td>Canada (includes HST)*</td>
<td>$227.00</td>
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<tr>
<td>Africa, Europe, Middle East</td>
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<tr>
<td>Latin America</td>
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<tr>
<td>Asia, Pacific</td>
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### 2007 AESS Member Rates

**Aerospace and Electronic Systems Society**

**Membership Fee**: $25.00

Includes AESS Magazine

<table>
<thead>
<tr>
<th>Print</th>
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<tbody>
<tr>
<td>Electronic</td>
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<tr>
<td>Print &amp; Electronic</td>
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**Online access to IEEE/OSA Journal of Lightwave Technology**

**Publications available only with AESS membership**

<table>
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<tr>
<td>Aerospace and Electronic Systems</td>
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<td>Print &amp; Electronic</td>
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<td>Print &amp; Electronic</td>
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<tr>
<td>Pattern Analysis and Machine Intelligence</td>
<td>$40.00</td>
</tr>
<tr>
<td>Print &amp; Electronic</td>
<td>$40.00</td>
</tr>
<tr>
<td>Journal of Lightwave Technology</td>
<td>$45.00</td>
</tr>
<tr>
<td>IEEE/OSA</td>
<td>$45.00</td>
</tr>
</tbody>
</table>

### Methods of Payment

- Credit Card – American Express, VISA, MasterCard, Discover
- Check
- Bank Draft
- Money Orders

## 8. IEEE Membership Dues

<table>
<thead>
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<th>Systems Sociology Fees Total</th>
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**AMOUNT PAID WITH APPLICATION**

<table>
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<tr>
<th>Total</th>
<th>$11.00</th>
</tr>
</thead>
</table>

Prices stated are in US dollars; subject to change without notice.

- [ ] Check or money order enclosed (Payable to IEEE)
- [ ] American Express
- [ ] VISA
- [ ] MasterCard
- [ ] Diners Club

Charge Card Number: __________________ Exp. Date: __________ Mo./Yr. 5 Digit Zip Code: __________________

Full signature of applicant using credit card: __________________ Date: __________