## AESS MEETINGS & CONFERENCES

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<tr>
<td>7-9 September 2005</td>
<td>2005 Military and Aerospace Applications of Programmable Devices and Technologies International Conference (MAPLD 2005)</td>
<td>Orlando, FL</td>
<td>R. Kell (301) 996-7632 (<a href="mailto:rskell@eck.com">rskell@eck.com</a>)</td>
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<tr>
<td>26-29 September 2005</td>
<td>AIAA 2005 Conference</td>
<td>Washington, DC</td>
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<tr>
<td>3-4 October 2005</td>
<td>2005 IEEE Symposium on Product Safety Engineering (PSE3)</td>
<td>Schaumburg, IL</td>
<td>S. Radovic (408) 306-2551 (<a href="mailto:sradovic@eck.com">sradovic@eck.com</a>)</td>
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<tr>
<td>23-27 January 2006</td>
<td>2006 Waveform Diversity and Design Conference</td>
<td>Kauai, HI</td>
<td>P. Woodard, (516) 330-3614 (<a href="mailto:pwoodard@mit.edu">pwoodard@mit.edu</a>)</td>
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<tr>
<td>4-11 March 2006</td>
<td>2006 IEEE Aerospace Conference</td>
<td>Big Sky, MT</td>
<td>R. Pente, (516) 330-3614 (<a href="mailto:pwoodard@mit.edu">pwoodard@mit.edu</a>)</td>
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<tr>
<td>24-27 April 2006</td>
<td>2006 IEEE Radar Conference</td>
<td>Valence, France</td>
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<tr>
<td>29-31 May 2006</td>
<td>2006 1st Int'l. Petersburg International Conference on Integrated Navigation Systems</td>
<td>St. Petersburg, Russia</td>
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## OTHER SOCIETY MEETINGS OF AESS INTEREST

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<td>6-8 September 2005</td>
<td>International Radar Symposium 2005</td>
<td>Berlin, Germany</td>
<td>German Institute of Navigation</td>
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<tr>
<td>13-16 September 2005</td>
<td>IEEE Conference on Intelligent Transportation Systems (ITSC 05)</td>
<td>Vienna, Austria</td>
<td>(49) 30/3993993993999 (30/3993993993999)</td>
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<td>19-22 December 2005</td>
<td>International Radar Symposium India - 2005 (IRSI-05)</td>
<td>Bangalore, India</td>
<td>D. Popov, (0) 91-524-1666 (0) 91-524-1666)</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.ieee.ieee.org/conferences.html](http://www.ieee.ieee.org/conferences.html)
This Month’s Cover . . .

Sheet 1 of 3 of the Weight Brother’s US Patent that described and illustrated their method of controlling a flying machine by using warping devices. Their Patent Application was filed March 23, 2001, as an uncounted number of experiments using their [Dayton] wind tunnel, months before they demonstrated that their idea worked on December 17, 1903, at Kitty Hawk, North Carolina, before witnesses. US Patent 821933 was issued May 22, 1906.

Correspondence

Editor:

The authors of the paper "Ultrasound/ Wireshed Radar Special Features & Terminology in the May 2005 issue of IEEE-AES Systems Magazine ask for comments on their proposed definition of Ultrasound Radar. I suggest that they define such radar by reference to the time domain. The ultrasonic bandwidth used – and the resulting range resolution obtained by the radar – are secondary parameters for this radar type. Using the range resolution much smaller than the target length along the direction of the motion has no exception for use as a definition. Some of these exceptions are weather radars, marine radars, and clutter measurement radars.

[Signature]
William C. Morchin
Past Chair, Standard Radar Definitions Panel

[Note: See also the report on the WWR Panel elsewhere in this issue.]

IEEE AESOP & ELECTRONIC SYSTEMS MAGAZINE

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In This Issue - Technically

Use of Modeling and Simulation to Support Airport Security

One approach to gaining a better understanding of this issue, as well as any new technologies and their impact in an airport's operational environment, is by using modeling and simulation tools. Modeling and simulation has become an effective way to target new technology advancements and operational concepts and to evaluate the behavior of complex systems, offering the opportunity to examine the complexities of the airport environment in a non-intrusive and cost-effective way, while also offering the means to evaluate, assess, and fine-tune equipment selections, configurations, and other operational factors without actually deploying or installing expensive security equipment or reconfiguring secure areas of the airport environment, unnecessarily interrupting passenger and baggage flow through an airport. In the long run, this will result in the implementation of more effective and efficient airport security solutions.

Distributed Collaborative Environments for Systems Engineering

Collaborative environments provide the framework and integrate models, simulations, domain specific tools, and virtual test beds to facilitate collaboration between the multiple disciplines needed in the enterprise. The Air Force Research Laboratory (AFRL) is conducting a leading edge program in developing distributed collaborative technologies targeted to the Air Force's implementation of systems engineering for simulation-aided acquisition and test process and capability-based planning. The research is focusing on the open systems agent-based framework, product and process modeling, structural architecture, and the integration technologies - the glue to integrate the software components. In past four years, two live assessment events have been conducted to demonstrate the technology in support of Air Force Agile Acquisition that included capabilities for system engineering. The AFRL Collaborative Environment concept will foster a major cultural change in how the acquisition, training, and operational communities conduct business.

Integrated System Able to Measure Errors of Satellite Navigation System Receivers

The report discusses the methodology of physical integration and characteristics of an integrated inertial satellite navigation system (ISNS). The report shows benefits of the physical integration method as compared with the traditional method of mathematical integration based on Kalman filter. Mathematical modelling, laboratory and flight tests allowed to state that ISNS is able to measure and remove the effect of systematic errors of GPS/GLONASS receivers on the accuracy of the integrated channel of navigation. The report presents results of the flight experiment for the measurement of errors of four types of GPS/GLONASS receivers.

An Alternative Solution to TPS Re-Host

The aging and obsolescence of Automatic Test Systems (ATS) is causing many programs to look at re-hosting their Test Program Sets (TPSs) to modern test systems. The major problem is that this undertaking is both time-consuming and expensive. With budgets decreasing, program managers have to find innovative ways to do more with less. To find those innovative ways, we must look at non-traditional methods of TPS development. We must be willing to consider that there are alternate solutions, and we must take them into consideration when making a decision on which ATS to re-host our TPSs.

This paper will discuss one of the alternative solutions to re-hosting TPSs that will realize significant savings in both time and money over the use of traditional ATS. Specifically, we will talk about using an in circuit test system (PinPoint II from DiagnoSYS Systems, Inc.) to re-host digital circuit boards from a legacy ATS and the techniques used to accomplish this task. This approach is not intended to fit all situations, but in the right situation, it can be very effective. To get the most out of this approach, it is important to identify exactly which TPSs are good candidates, and which are not.

Doppler-Surface Mapping Technique for Characterisation of Spinning Cylinders Illuminated by Radar

The objective of this paper is to present a new Doppler-surface mapping (D-map) technique for understanding the backscattering characteristics of broadside illuminated electrically large spinning cylindrical radar targets. The D-map technique utilises new results that indicate that for nominally axi-symmetric rotations, an asymmetric and discrete line Doppler spectrum will always be present. In essence these frequency spectra are mapped to the target surface and represented in the form of a scattering half angle. Two classes of target (metallic and dielectric) are studied at rotation rates between 1Hz and 8Hz. The technique has practical relevance since from knowing the scattering angle and target dimensions, it is possible to determine the area of the target surface contributing to the backscattered response. It is found that the target scattering angle is invariant with rotation speed. However, the scattering angle for the dielectric cylinder is 50% greater than for the metallic cylinder suggesting that the technique could be used to discriminate between targets with differing electrical (material) properties or surface roughness characteristics.

Biometric Recognition: Why Not Massively Adopted Yet?

Although there has been a dramatic reduction on the prices of capturing devices and an increase on computing power in the last decade, it seems that biometric systems are still far from massive adoption for civilian applications. This paper deals with the causes of this phenomenon, as well as some misconceptions regarding biometric identification.
Use of Modeling and Simulation to Support Airport Security

D.L. Wilson  
Department of Homeland Security

ABSTRACT

Currently, as well as in the past, an aggressive program to enhance security at airports throughout the United States has been pursued resulting in numerous advancements in the civil aviation security landscape. For government and industry planners concerned with future security improvements, being able to predict the overall impact of new technologies and/or procedures is an important issue, especially in the deployment of advanced airport security equipment. Recognized as part of the issue is that new security systems must be installed in and function as part of operating airports, which, throughout the entire process, must continue to handle ongoing operational requirements in a competitive and cost-efficient manner to the satisfaction and safety of their customers – the airlines and traveling public.

One approach to gaining a better understanding of this issue, as well as any new technologies and their impact in an airport’s operational environment, is by using modeling and simulation tools. Modeling and simulation has become an effective way to target new technology advancements and operational concepts and to evaluate the behavior of complex systems, offering the opportunity to examine the complexities of the airport environment in a non-intrusive and cost-effective way, while also offering the means to evaluate, assess, and fine-tune equipment selections, configurations, and other operational factors without actually deploying or installing expensive security equipment or reconfiguring secure areas of the airport environment, unnecessarily interrupting passenger and baggage flow through an airport. In the long run, this will result in the implementation of more effective and efficient airport security solutions.

INTRODUCTION

Previously, under the Federal Aviation Administration (FAA), and now, under the Department of Homeland Security/Transportation Security Administration, an aggressive program to enhance security at airports throughout the United States is being pursued, resulting in numerous advancements in the civil aviation security landscape. For government and industry planners concerned with future security improvements, being able to predict the overall impact of new technologies and/or procedures is an important issue, especially in the deployment of advanced security equipment at airports. At issue is the fact that new security systems must be installed in and function as part of operating airports, which must, throughout the entire process, continue to handle ongoing operational requirements in a competitive and cost-efficient manner to the safety and satisfaction of the customers – the airlines and traveling public.
IMPORTANT ISSUES

System integrators need to carefully address the issue of operational suitability and one approach to gaining a better understanding of these issues, as well as any new technologies and their impact in an airport's operational environment, is by using modeling and simulation tools. Modeling and simulation has been shown to be an effective way to evaluate the behavior of complex systems, offering the opportunity to examine the complexities of the airport security environment in a non-intrusive and extremely cost-effective way, while still being able to estimate the impact of new equipment, policies, and/or procedures within operational parameters, making a significant difference when ready to deploy. Since new equipment must not only reduce risk, but also maintain acceptable levels of passenger and baggage flow rates, simulations also offer the means to evaluate, assess, and fine-tune equipment selections, configurations, and other operational factors without actually deploying or installing expensive security equipment or reconfiguring secure areas of
Modeling and simulation has become an effective way to target new technology advancements and operational concepts, resulting in the identification of more airport security requirements. The simulation models have also assisted in developing and assessing various system alternatives for achieving security system design goals and determine which proposed configurations of systems are actually worthy of field tests. After field test data are available, the model can be used to evaluate other configurations that might prove too costly or have too great an operational impact to allow for field testing.

Fig. 6. Security Checkpoint Analysis

Fig. 7. Checked Baggage Handling System

the airport environment, unnecessarily interrupting that flow through the airport.

BENEFITS

Simulation modeling allows the analysis or prediction of operational effectiveness, efficiency, and detection rates (performance) of existing or proposed security systems under different configurations or operating policies before the existing systems are actually changed or a new system is built, eliminating the risk of unforeseen bottlenecks, under- or over-utilization of resources, or failure to meet specified security system requirements.

Fig. 8.

CHALLENGES

There are many challenges in modeling any part of the airport environment, especially the secure areas. The largest of these challenges is due to the extremely fluid nature of daily airport activity, the uniqueness of individual airports, and even the unique nature of different areas located within individual airports. On a different scale, additional challenges are due to the unpredictable nature of human activities. As with any model that is simply a representation of an actual system, it is necessary to incorporate a number of assumptions in order to simplify the required modeling effort. For example, while an airport security checkpoint may seem to be a fairly simple application for discrete event simulation, no less than thirteen separate input parameters may be required to accurately represent the checkpoint to the level of detail required for analysis.

To help meet these challenges, the modeling tools selected for use must include the features and flexibility in the modeling logic to overcome the challenges with little additional effort on the part of the modeler, combining capability with ease of use. The tools must produce models within a reasonable time-frame and allow development of models with an appropriate level of detail.
MODELING IN AIRPORT SECURITY ENVIRONMENT

While the primary use of modeling tools is to simulate the flow of passengers and/or baggage through security checkpoints, models are also used for checked baggage security screening systems and to examine various system combinations in an operational environment, providing a low-cost method for assessing proposed techniques or equipment combinations without placing those systems in the field.

Security Checkpoint Analysis

An enhanced model could allow the design of a test bed configuration that would allow the change of specific pieces of equipment, allowing more than one configuration to be tested with minimal change or interruption of service to the overall site, and without incurring the expense of an actual system purchase. Sophisticated simulations are used to assist in determining operational parameters and validating test results, which, along with the financial implications, carries a significant impact in terms of safety for millions of travelers.

CONCLUSION

As simulations are run, more benefits surface. Areas are identified where additional research is needed, allowing us to focus on research and development efforts and to apply limited R & D funds more efficiently.

Modeling and simulation offers the opportunity to examine security problems in a total operational context resulting in more effective and efficient airport security solutions. Simulations can also provide decision-makers with a better understanding of the impact of their decisions and help them to make more sound and rational choices in the ever-changing airport security environment.
Distributed Collaborative Environments for Systems Engineering

William K. McQuay
Air Force Research Laboratory

ABSTRACT

Distributed collaboration is an emerging technology for the 21st century that will significantly change how business is conducted in the defense and commercial sectors. Collaboration involves two or more geographically dispersed individuals working together to create a "product" by sharing and exchanging data, information, and knowledge. A product is defined broadly to include, for example, writing a report, creating software, designing hardware, or implementing robust systems engineering processes in an organization. Collaborative environments provide the framework and integrate models, simulations, domain specific tools, and virtual test beds to facilitate collaboration between the multiple disciplines needed in the enterprise. The Air Force Research Laboratory (AFRL) is conducting a leading edge program in developing distributed collaborative technologies targeted to the Air Force's implementation of systems engineering for simulation-aided acquisition and test process and capability-based planning. The research is focusing on the open systems agent-based framework, product and process modeling, structural architecture, and the integration technologies - the glue to integrate the software components. In past four years, two live assessment events have been conducted to demonstrate the technology in support of Air Force Agile Acquisition that included capabilities for system engineering. The AFRL Collaborative Environment concept will foster a major cultural change in how the acquisition, training, and operational communities conduct business.

INTRODUCTION

Since the 1940s, government and industry engineers in the defense sector have dealt with the design and development of large, complex defense systems. They have analyzed the need for a particular system, determined operational concepts, developed functional requirements, produced system architectures, allocated requirements among subsystems, managed the design of subsystems, assured design integration, assessed design trade-offs, and performed test and evaluation. These methodologies and processes became the discipline of systems engineering and the complementary area of systems analysis. Systems engineering and systems analysis are crucial for modern day defense research, development, test and evaluation, especially as we move from platform-centric views to system of systems and now net-centric views. Systems are integral to modern engineering as noted in a quote from the late Rear Admiral Grace Hopper (US Navy, Retired), who spoke at the Ohio State University in 1987 as part the twentieth anniversary of the formation of the Department of Computer and Information Science: "Life was simple before World War II. After that, we had systems."

Although there is no single definition of systems engineering, there is agreement on the general coverage of the term. The International Council on Systems Engineering defines systems engineering as "an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem [1]." The Naval Postgraduate School defines it as "the application of scientific and engineering efforts to (a) transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation; (b) integrate related technical parameters and ensure compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design; and (c) integrate reliability, maintainability, safety, survivability, human engineering, and other such factors into the total engineering effort to meet cost, schedule, supportability, and technical performance objectives [2]." Fundamentally, systems engineering focuses on the methodology to solve problems using quantitative approaches, represents the real world as models and simulations, and employs those models for analysis and synthesis.
Data, information, and knowledge are key ingredients for the systems engineering process. We define data as raw facts; information as data in a context relevant to an individual, team or organization; and knowledge as an individual’s utilization of information and data complemented by his or her unarticulated expertise, skills, competencies, ideas, intuitions, experience, and motivations. A key implication in the above definition is that knowledge is created only by individuals and is specific to the individual who created it. An organization cannot create knowledge by itself but can support creative individuals or provide the environments for them to create and share knowledge. Knowledge is often divided into two categories: explicit and tacit [3]. Explicit knowledge can be expressed in words or numbers, and shared in forms such as data, technical drawings, equations, specifications, documents, and reports. Explicit knowledge can be readily transmitted among individuals and formally recorded. Tacit knowledge, on the other hand, is highly personal, hard to formalize, and difficult to communicate or share with others. Tacit knowledge has two dimensions: technical (skills or crafts such as that represented in the know-how of the master craftsman), and cognitive (know-why, perceptions, values, beliefs, and mental models) [3].

Of all the knowledge that people possess, the knowledge that the organization should care about is the knowledge that people need to do their work. Most knowledge remains in people’s heads and never gets formalized, documented, and shared. The organization can enable knowledge sharing in general and, in particular, for systems engineering and systems analysis through an infrastructure which we will call a distributed collaborative environment (DCE). Information technology tools for document management and enterprise portals can archive explicit knowledge, which is classical information often in the form of documents. But the tacit knowledge is much more difficult to address. Collaborative communications (chat, instant messaging, desktop conferencing, forums, threaded discussion groups) can provide a partial impetus for cultural changes to enable the flow of tacit knowledge among an organization’s personnel, and it is critical for management to encourage such interchange as part of the workforce culture at all levels.

DISTRIBUTED COLLABORATIVE ENVIRONMENTS

A distributed collaborative environment for systems engineering and systems analysis includes the tools needed to accomplish analyses and permits distributed teams within the Air Force enterprise (product centers, laboratories, agencies, defense contractors, academia, and warfighters) to work together as a virtual organization. A DCE enables geographically, temporally, and disciplinarily distinct resources and users to seamlessly interoperate, archive and recall work products throughout the enterprise. A DCE supports both single individuals and collaborating groups by managing and distributing “virtual workspaces.” These virtual workspaces contain the necessary visualization and resource management tools each user needs to contribute to decisions throughout the systems engineering and analytical life cycle. The DCE supports and promotes an integrated approach to rapidly identifying, developing, and coordinating common capability requirements within the enterprise, and evaluating and implementing system of systems architectures and cross-cutting solutions.

Collaboration means different things to different people. Our working definition of collaboration is two or more geographically dispersed entities working together to share and exchange data, information, knowledge, and actions. The product of the collaboration is defined broadly, for example, to include writing a report, creating software, designing hardware, or developing an alternative course of action for the commander. Collaborative environments provide the framework and integrate models, simulations, domain specific tools, and virtual test beds to facilitate collaboration between the multiple disciplines needed in the enterprise. A collaboration framework is a standards-based infrastructure of communications, data processing, decision support, knowledge processing, and resource management services which can be configured to support a collaboration. A collaborative environment is a collaboration framework instantiated with domain specific resources to support a context-specific collaboration. The participants in the collaboration are called the collaborators.

A DCE implements functions such as the following permitting collaboration members to [4,5]:

- Access electronic versions of all documents including engineering documents, plans, intelligence reports, resource and asset schedules, meeting minutes, action items, databases, technical reports, and briefings
- Maintain documentation and software under configuration control with traceability and archiving of changes and automatic notification of updates and newly created action items
- View, discuss, and generate documents with each other using desktop video and audio conferencing
- View, discuss, and generate documents with each other using desktop video and audio conferencing
- Present data and information to various users in mission-specific and content-specific formats applicable to each user’s current needs
- Identify, release, and check out documents, software, or information
- Translate and mediate data between heterogeneous processing systems and diverse functional areas
- Remotely control and share the use of applicable analysis tools and resources.

- Monitor the progress of tasking and alert managers and support personnel to assess the impacts of variances in tasking and changes in plans, schedules, and configurations, and

- Remotely activate applications, such as simulations, analytical models or data extraction, and fusion utilities.

The DCE functions can be implemented with technologies such as collaborative communications tools, document managers, electronic forms, and workflow managers as shown in Figure 1. The DCE collaborative communications tools enable both local and geographically separated users to participate in synchronous and asynchronous sessions and to archive any resulting data and information. These tools include chat, shared whiteboards, shared application viewing, threaded discussions, instant messaging, and audio/video conferencing.

The instant messaging enables team members to communicate with other users who are logged into the same DCE server. The Instant Messenger enables the user to quickly send another person in the enterprise a message that will pop-up on their screen when it arrives. The Instant Messenger also lets the user invite another person to join them in a private chat. The invitation will appear on their screen as a request, which they can accept or decline. If they accept the invitation, a private chat frame will appear that other people cannot see or join, unless the user, the creator of the chat session, invites them. Chat is a messaging system that enables participants to communicate via text messages. All participants in a chat session receive the other participants’ text comments and can share their thoughts by typing into their local chat window then sending them to the group. Chat sessions are recorded for playback by users who join a session in progress, and chat transcripts can be archived in the document manager.

The whiteboard feature enables multiple users to share ideas graphically in a shared drawing area using assorted figures and text. Each participant in a whiteboard session receives the same virtual view and has the ability to “mark up” the board to illustrate a point. The user can construct pictures with basic geometric shapes and add text to the picture using the text tool or the pencil tool. The DCE collaborative communications tools support multiple simultaneous whiteboard sessions that individuals can join at will. Whiteboard sessions maintain a history, so latecomers can catch up in a current session. The final results of a whiteboard session can be archived in the document manager. The shared application viewer feature enables users to view the windows and displays of a remotely hosted application. One participant shares the application from the local computer, maintaining control over the operation of the application, while others in the session make contributions or discuss what they see.

Audio/video conferencing turns a properly equipped computer into a videophone. It allows enterprise users to communicate verbally while viewing not only the other participants, but also any artifacts that contribute to the discussion. The document manager provides enterprise wide web-based documentation management and allows users and software components to create, search for, access, and store documents from anywhere in the enterprise. Participants see only information they are authorized to see and can only use utilities, like copy or lock, based on those authorizations. The AFRL DCE combines the audio/video conferencing, application sharing, chat, and awareness functions into a Virtual Meeting Application.

The document/object manager retains past versions of documents and keeps track of document updates by maintaining an audit trail of changes. It also provides the ability to search enterprise documents and workflows by title, author, and keyword. A form processing feature enables users to fill out and store custom-created electronic forms. Forms can be easily integrated into workflows that can automate common processes such as routine reports and notifications.

Resource workflow provides the ability to develop, execute, and manage systems engineering or systems analysis processes, such as planning; support the execution and control of enterprise resources identified in a workflow, such as simulations or analytical tools; and provide runtime management capabilities and status information. A resource workflow consists of a collection of work tasks, which include workflow and work activities. A work process is a group of subtasks executed in a specified order. Workflow constructs support serial and parallel processing, looping, conditional branching, event-based activities, user interactions, and resource (software, hardware, and database) tasking and execution. A work activity is a single or self-contained activity, which tasks some resource to execute. Once defined, the workflow can be stored as a template for later use. For example, a complex, multiple source data and knowledge fusion process can be defined, executed, and monitored using these capabilities. The user does not have to stay on-line while the process executes because the system can send a notification to the user when a decision needs to be made or information needs to be reviewed. In addition, the process can be archived and reused, or it can be optimized when new information is obtained, when requirements change, or when new technology is developed.

A crucial element of a DCE is intelligent agent technology. The intelligent agent is the primary software component for performing tasks. The tasks may be performed autonomously using artificial intelligence concepts or in conjunction with a user who interacts with the agent. As examples, agents are used to manage applications, perform object transformation between two disparate databases, and manage the execution of conditional actions based on the occurrence of specified events.

In a systems engineering enterprise, important data and status information can be displayed on a portal — the single
access point for each participant. Each participant can have a tailored portal for the information that user determines to be critical to his job performance.

A CAPABILITY-BASED PLANNING EXAMPLE

One example of the application of systems analysis methodologies to Air Force applications is capability-based planning. Traditional Development planning was platform-centric and transformed warfighting needs into recommended program strategies for systems and products. The process included:

- supporting the warfighters in defining their needs
- generating alternative system (or system of systems) concepts
- conducting analyses to describe military utility, enabling technologies, operations and support factors, technical, cost, schedule, and operational risks, life cycle cost of ownership, and other aspects of potential solutions
- selecting preferred solutions based upon analysis results, and
- developing executable acquisition strategies for systems and products.

The military is now emphasizing capability planning, which at a high level follows a similar process to traditional development planning, but is oriented to warfighter capability needs and system of systems oriented. Critical to the process is robust analytical support and assessment of technology alternatives based on readily available information and knowledge. Design, performance, cost modeling, and analysis tools are needed in the planning process.

The AFRL DCE has been employed as a Capability Planning Resource Center to guide a geographically distributed team through the Capability Planning Study process. Users are able to search for and access various on-going or archived studies. As shown in Figure 2, the overall study process is captured as a resource workflow which coordinates all activities of all participants. The workflow will kick off sub-processes tailored to the analysis at hand, notify participants of their tasks, and maintain a milestone chart showing the progress and relationship of all tasks.

For each personal task, the user is alerted to the duties assigned and has access to a Knowledge Content Sheet (KCS) which describes the details of the task activities. This is important for junior personnel who lack experience and need tutorial support. The KCSs can be updated with a built-in process to facilitate further knowledge capture for future reuse.

One of the major areas within a capability planning process is the analysis of alternatives. We have demonstrated how this can be accomplished with a DCE using resource workflow and a set of traditional analysis tools. As an example we used a hypothetical analysis of alternative concepts based on an
AFRL experiment for Time Critical Targets (TCT) capabilities.

Four concept alternatives were examined:

- Use of generic manned and High Altitude Uninhabited Aeronautical Vehicle (UAV) versions of current baseline ISR assets

- Combined use of Advanced High Altitude Endurance UAV (AUAV) and Spaced Based Radar (SBR)

- Sole use of SBR, and

- Single use of AUAV.

A distributed analysis team employed the collaborative communications tools to plan and execute tasks leading to analysis of alternative concepts. The document manager served as the library to archive all data and documents. The experimental workflow was tailored after that of a typical analysis of alternatives.

Experimental results were geared toward providing detailed data for a comparison of different technology/system alternatives. In the experiment, alternatives involved substitution of various Intelligence, Surveillance, and Reconnaissance (ISR) system concept assets into a TCT prosecution scenario, with a primary goal of identifying a configuration that best reduced the costs associated with the conflict.

For the mission level simulation, a four-hour simulation period was used with randomly spread start times for target movement. A number of the missions were executed for each of the four ISR configurations, with results accumulated to provide input data to the campaign level simulation. Product and process models were defined for the experiment, and the process model was instantiated as a resource workflow. The process model identified what key resources (engineering and cost tools, engineering level models, simulations, data reduction tools, and analysts), methods, and rules that were needed for all necessary tasks. The results of each case were stored in the shared information for the collaboration (Smart Enterprise Common Object Model), with full configuration management and control including versioning. The different result files for each run were extracted from the DCE database and made available to each resource when required.

The analysis was executed in three stages: engineering level data preparation, mission level trade space reductions, and campaign level and cost concept comparisons. Using the workflow tool in the DCE, the process model was captured as a reusable workflow.

During the engineering level data preparation stage, a core set of models was used to perform detailed engagement analysis for each potential threat-blue asset pairing, generate PK tables for threat systems to be used in mission level modeling, and generate threat system detection ranges and other input data for mission level modeling.
CONCLUSIONS

Revolutionary and evolutionary advances in computer and software technology now provide significant opportunities to implement a vision for a distributed collaborative environment in support of systems engineering and systems analysis. Applications such as Virtual Capability Planning can provide decision-quality knowledge for Air Force investment planning including examining proposed capabilities and cost of alternative approaches, the impact of technologies, identification of primary risk drivers, and creation of executable acquisition strategies.

REFERENCES

Integrated System Able to Measure Errors of Satellite Navigation System Receivers

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ABSTRACT

The report discusses the methodology of physical integration and characteristics of an integrated inertial satellite navigation system (ISNS). The report shows benefits of the physical integration method as compared with the traditional method of mathematical integration based on Kalman filter. Mathematical modelling, laboratory and flight tests allowed to state that ISNS is able to measure and remove the effect of systematic errors of GPS/GLONASS receivers on the accuracy of the integrated channel of navigation. The report presents results of the flight experiment for the measurement of errors of four types of GPS/GLONASS receivers.

INTRODUCTION

The studied ISNS system was developed in GosNIAS on the basis of physical integration method (PIM) of 1-21 system (developed in MIEA, Russia), SNS receiver and a special calculator with physical integration filters (PIF), algorithms of the integrated channel navigation, and other algorithms.

PIF has a set of significant benefits as compared with the mathematical Kalman filter. One of them is the ability to use the a priori information about the statistics of errors and mathematical model of INS. So PIF can be applied for various types of INS (either based on platforms or not) and SNS receivers. PIF has a dynamic structure which can contain several structural cascades depending on the task [1, 2, 3].

Main PIF cascade receives linear velocities of INS and SNS receiver that preliminarily have passed through a special filter, at PIF output we acquire the control signal and the integrated linear velocity. The control signal realises the physical control of the angular velocity at the input of Schuler contour of INS (closed PIF [4]), or controls the linear velocity at the output of Schuler contour of INS (open PIF). Here, we study ISNS with open PIF [5, 6].

Integrated velocity, where almost all INS errors, noises, and systematic errors of SNS receiver are removed, enters the algorithm of navigation of the integrated channel.

ISNS has three navigation channels: inertial, satellite, and integrated inertial satellite channel whose accuracy is higher than the previous two. Methodical error of the integrated channel in the determination of coordinates is defined on the sinusoidal law with Schuler frequency whose amplitude does not exceed 1 m in 4 hours, and velocity error in level flight makes 0.02 m/s (residual noise); here INS velocity errors may reach 3.5 m/s, and systematic velocity errors of SNS receiver are up to 1 m/s [6].

When there is no information from SNS receiver the integrated channel continues its stable operation, during first 5 minutes the error incrimination on coordinates makes 40 m.

ISNS based on PIM has not only high accuracy, but the ability of real-time measurement of systematic velocity errors of SNS receivers. These measurements are taken in the level flight in the absence of dynamic errors of INS and SNS receivers. The degree of these errors can be much higher than the degree of systematic errors [5].

When ISNS-3 was operated at IL-20 aircraft there was a systematic error in the north component of the velocity of GG-24 receiver of SNS (Figure 1), though there were no mistakes in the east component. (No records in AT range.)

Figure 1 shows that at the level flight (LF) segment the error has changed from 0.28 m/s to 0/15 m/s while the latitude has changed to 12°. It was stated that such an error arrives only if the latitude is changed, and is considered as a methodical error, so it is inherent to all SNS receivers; its max value is 0.4 m/s at the equator latitudes.

This statement was proved by a flight experiment with simultaneously working four airborne receivers of GG-24 SNS (Ashtech), K-161 (FGUP “RIRV”), SNP (“COMPASS”)
Systematic velocity error for each SNS receiver was measured as a difference of two simultaneously working PIF channels with different structure of filters, to which were input velocities of INS and SNS receivers.

The first PIF channel removed velocity errors of INS channel and noises of SNS receiver velocity, while its systematic velocity errors were skipped. In the second channel other structures also removed systematic velocity errors of SNS receiver. So integrated velocities at the output of the first

design bureau), SN-3700 ("Navis" design bureau) types integrated with 1-21 INS. Their work was organised by parallel operation of four calculators with the same PIF algorithms as well as other algorithms of the integrated channel.
channel contained systematic errors, while at the output of the second channel there was only residual noise.

The difference of integrated velocities of the two channels is equal to the systematic velocity error of SNS receiver. The value of measurements (residual noise) in a level flight does not exceed ± 0.02 m/s.

Figures 2-5 show the velocity errors of these receivers measured by ISNS during the flight experiment, Figures 6 and 7 show the altitude (H), the flight path angle (α), and the pitch (u). At the level flight (LF) all receivers show the same methodical error in the north component of velocity ($\delta V_n$). In the east component ($\delta V_e$) there was no methodical error.

The residual noise of SNS receiver is superimposed on ($\delta V_n$) and ($\delta V_e$) errors, mean value of ($\delta V_n$) systematic error is 0.270 m/s for GG-24 receiver; 0.273 m/s for K-161 receiver; 0.281 m/s for SNP receiver; and 0.253 m/s for SN-3700 receiver.

Comparing methodical errors ($\delta V_n$) of GG-24 receiver of SNS at the same latitude measured in two flights (Figures 1, 2) we can see that they are similar.

So, results of the flight experiment proved high accuracy of ISNS and its ability to measure systematic velocity errors of SNS receivers; the results show also that SNS receivers have methodical errors on the north component of velocity that depends on the change of the latitude of the flight and may reach 0.4 m/s at the equator latitudes.

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An Alternative Solution to TPS Re-Host

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ABSTRACT
The aging and obsolescence of Automatic Test Systems (ATS) is causing many programs to look at re-hosting their Test Program Sets (TPSs) to modern test systems. The major problem is that this undertaking is both time-consuming and expensive. With budgets decreasing, program managers have to find innovative ways to do more with less. To find those innovative ways, we must look at non-traditional methods of TPS development. We must be willing to consider that there are alternate solutions, and we must take them into consideration when making a decision on which ATS to re-host our TPSs.

This paper will discuss one of the alternative solutions to re-hosting TPSs that will realize significant savings in both time and money over the use of traditional ATS. Specifically we will talk about using an in circuit test system (PinPoint II from DiagnoSYS Systems, Inc.) to re-host digital circuit boards from a legacy ATS and the techniques used to accomplish this task. This approach is not intended to fit all situations, but in the right situation, it can be very effective. To get the most out of this approach, it is important to identify exactly which TPSs are good candidates, and which are not.

To illustrate how this can be done, the process used by the AWACS program to find a cost-effective way of re-hosting TPSs from their obsolete depot tester (AN/GSM-285) will be outlined. The outline will describe the criteria used to determine which circuit cards are good candidates, and the differences in techniques used with this approach compared to traditional TPS development. It will also describe the limitations as well as the benefits obtained by using this approach. Examples will be given that illustrate the cost savings that can be realized over the use of traditional ATS.

INTRODUCTION
With weapon systems life spans’ being extended, the aging and obsolescence of ATS is becoming a major problem. ATSs are being used far beyond their original projected life span, and therefore are starting to become non-supportable. The TPSs worked on these systems are still needed to support the weapons systems commodities. This has made system managers look into re-hosting of TPSs on a large scale. The cost for re-hosting is significant, and managers are looking for a way to do more with less. This paper outlines one method of satisfying this requirement.

Methods of Re-Host
The traditional method of re-hosting is a very costly proposition, and can take a great deal of time. Typically re-hosting is done when an ATS is no longer supportable, and/or is getting too costly to maintain. Traditional re-host involves taking all of the current workload on an ATS and either finding an existing ATS that meets all of the requirements, modifying an existing ATS to meet the requirements, or building a new ATS to meet the requirements. Then all of the active TPSs are re-hosted to the new ATS. Re-hosting is done by moving programs from one ATS to another, which usually requires new Interface Test Adapters (ITAs), and at least partially rewriting software. Efforts are expended to reuse as much of the original TPS as possible to minimize cost and schedule. However, because of differences in technology, code reuse has not been very effective when moving TPSs from legacy ATS. The differences in technology also make it difficult to reuse ITAs which are a major cost factor of most TPSs. Although there are some translators that can help simplify the software re-hosting, the differences in ATE will almost always require some tweaking of the software to make it run.

This paper talks about an alternate method for re-hosting when the Unit Under Test (UUT) to be re-hosted is a digital Circuit Card Assembly (CCA). Advances in technology have made testers available that can test this type of UUT with a high degree of confidence. The method proposed herein is in-circuit testing of each component to verify that the UUT is functional. I will be using the DiagnoSYS Pinpoint II (PPII) tester as my example.
To illustrate how this method can be used successfully to re-host digital CCAs, I will be using the experience of the E-3 AWACS program office. They have recently used this method to re-host digital CCAs from their aging AN/GSM 285 depot tester. The E-3 AWACS program office has estimated that they will have a cost avoidance of approximately $22 million [1].

IN-CIRCUIT TEST METHOD

The in-circuit test method involves using clips and probes to functionally test each of the components on the UUT. The paths on the UUT can also be checked to verify continuity between components and the edge connector. The premise of in-circuit testing is that most failures will be hard failures, and therefore will be caught by this type of test. Since each individual component is tested to its operating parameters, the probability of the complete circuit being functional is very high.

This method is very useful when no test program is currently available, as each component can be tested for functionality without knowing the overall board functionality, and it will catch the majority of the failures normally encountered on digital CCAs. The PPII further has the capabilities of learning the paths between the components which can be very useful when no schematics exist for a UUT. This method of testing has been used very successfully in the repair of CCAs that have been identified as bad by the next higher assembly self test. It has been used by several private companies to reduce cost associated with getting circuit cards repaired. Instead of having to send back a circuit card to be repaired for several hundred dollars, they can determine which component is defective and replace it at a fraction of the cost.

Candidates

The success of using this method is to ensure that the UUT to be tested is a good candidate. This type of test method is limited, and trying to push it beyond its limit will invite problems. As will be illustrated later in the case study, the best candidate for this method is a digital CCA. The reason for this is that the in-circuit test method will test all of the integrated circuits for proper operation ensuring a complete test. The PPII has a vast number of chips in its library making it very easy for the TPS developer to quickly get a test written. The PPII also has the capability to do signature analysis, as well as ohms measurements which make it possible to also test any analog components that may be on a digital CCA.

Advantages

One of the major advantages of using this method is cost and timesavings. Because the libraries have functional test programs for most of the integrated circuits (IC), all that is needed is to tweak the test to work with the IC as it is in circuit. This results in a very short development time for a TPS. The cost of the equipment is also significantly less than traditional ATS.

An advantage of the PPII is that it does a very good job of learning how the chips are wired by checking for shorts and opens, and then modifying the program to work with the configuration. The PPII also has the ability to learn the paths between ICs, which is very useful, when a schematic is not readily available.

DisAdvantages

The major disadvantage of using in-circuit testing is that the UUT is not tested in a functional mode as a whole. What this does is lessen the level of confidence that the UUT is serviceable. However, with digital CCAs, the number of possible faults that would still be outstanding is minimal.

CASE STUDY: E-3 AWACS

The E-3 AWACS program office was faced with a major problem in that their depot tester was suffering support problems. They needed a cost-effective way of re-hosting several hundred TPSs. They found a cost-effective solution for re-hosting 158 digital UUTs by using the PPII. The method they used to come up with this solution is documented below.

Faced with the possibility of having aircraft grounded because of unsupportable ATS, the E-3 AWACS program office started looking for possible solutions for re-hosting their UUTs. Faced with budget restrictions, they had to find a method that would let them get the most bang for their buck. They ran across the PPII, and decided to do a study to see if it would meet their needs. They hired our company (Engineering Spectrum, Inc.) to do an independent evaluation of the capabilities of the PPII along with determining supportability of the tester and determining approximate TPS development hours.

The evaluation looked at the capabilities of the PPII, and then verified if it could live up to its specifications. One area that was found to be lacking was ECL testing. Although the PPII did have the capability of doing ECL testing, it did not have all of the power supplies required to do ECL testing. To overcome this shortcoming an ECL power supply was developed that connected to the PPII, and could be controlled without any additional software or programming. With the addition of the ECL power supply, it was found that the PPII did live up to its specifications, and would be supportable for at least 10 years.

During the evaluation, several test programs were written to determine the approximate time required to develop test programs. Several different categories of difficulty were devised to break down approximate development times. The development times were between one and four weeks on the average.

Another part of the evaluation was to determine which type of UUT would be best suited to re-host on the PPII. The evaluation looked at the different type of UUTs that the E-3 AWACS had to re-host, and determined that the best candidates are the UUTs that were all digital. The evaluation also determined that some of the hybrid UUTs could also be tested.

Based on the information obtained from this evaluation, the E-3 AWACS program office commissioned a study to
determine which of the UUTs currently being tested on the AN/GSM 285 would be candidates for re-host to the PPI. The study looked at all of the CCAs on the AN/GSM 285 and categorized them by type and complexity. Data packages were then put together for all of the digital CCAs that contained information such as schematics and board layout. This study determined that 158 of the UUTs to be re-hosted were digital and could be re-hosted on the PPI.

The list of candidates was then given to the commodity managers to prioritize. With the prioritized list, the E-3 AWACS program office contracted with organic and contractor developers to do the first batch of TPSs. As of this date, those TPSs are still under development.

The E-3 AWACS program office did a cost benefit analysis of using this method. They found that using this method, they could realize a cost avoidance of over $22 million in total life cycle cost. They also found that this method was better suited to meet future E-3 Commercial-Off-The-Shelf (COTS) diagnostic requirements. Using this method, they will also be able to shorten the re-host schedule considerably. All of these benefits add up to make this a very good solution for the E-3 AWACS program office [1].

SUMMARY

When faced with the daunting task of re-hosting from legacy ATS, all methods of re-hosting should be considered. Budget and time constraints are critical factors in getting UUTs re-hosted. If the legacy ATS fails, weapons systems can be grounded, causing detrimental effects on the war fighter. When the UUTs to be re-hosted include digital CCAs, in-circuit testing can be a very cost-effective solution. More UUTs can be re-hosted faster, limiting the impact of any legacy ATS failure. For the E-3 AWACS program office, this method has proven to be so beneficial that other agencies are looking into doing the same thing with their systems. This should show that there are alternatives to using traditional ATS, and that those methods are effective.

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Doppler-Surface Mapping Technique for Characterisation of Spinning Cylinders Illuminated by Radar

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ABSTRACT

The objective of this paper is to present a new Doppler-surface mapping (D-map) technique for understanding the backscattering characteristics of broadside illuminated electrically large spinning cylindrical radar targets. The D-map technique utilises new results that indicate that for nominally axi-symmetric rotations, an asymmetric and discrete line Doppler spectrum will always be present. In essence these frequency spectra are mapped to the target surface and represented in the form of a scattering half angle. Two classes of target (metallic and dielectric) are studied at rotation rates between 1Hz and 8Hz. The technique has practical relevance since from knowing the scattering angle and target dimensions, it is possible to determine the area of the target surface contributing to the backscattered response. It is found that the target scattering angle is invariant with rotation speed. However, the scattering angle for the dielectric cylinder is 50% greater than for the metallic cylinder suggesting that the technique could be used to discriminate between targets with differing electrical (material) properties or surface roughness characteristics.

INTRODUCTION

Recently published results investigating the dynamic radar signatures of broadside illuminated electrically large cylinder targets indicate that for nominally axi-symmetric rotations, an asymmetric and discrete line Doppler spectrum will always be present [1]. In this paper a new technique is described that maps these frequency spectra to the target surface via the estimation of the target scattering half angle. It is suggested that the Doppler-surface mapping (D-map) technique is of practical relevance and importance since from knowing the scattering angle and target dimensions, it is possible to determine the area of the target surface contributing to the backscattered response.

The results and D-map application are a novel contribution to open source literature in a topic area generally poorly reported. In the few areas where discrete line spectra from rotating cylinders have been addressed, the papers have been theoretical in nature; practical results and/or suggested applications have not been given. Numerical approaches have been adopted for some classes of target. In particular quasi-stationary methods used in conjunction with the geometrical theory of diffraction have been used to estimate the backscattered power density spectrum of a large rotating conducting orthogonal polygon cylinder of arbitrary cross section [2]. No other similar references could be found. Other recent and relevant work addressing broadside illuminated cylinders, includes the study of resonant attenuation of perfectly conducting elongated objects [3], and the study of complex pole patterns of finite length cylinders [4]. However, both references only discuss the target under static conditions.

The main body of this paper entitled Part 2: Cylinder Target Details and Physical Measurement Results, is structured into four parts. In the first part the D-map technique is described. In the second part the physical characteristics of the two classes of cylinder target to be studied (dielectric and metallic) are presented. Details of the metrology techniques used to determine the target surface profiles are also described. In the third part the radar experimental details and measurement results are presented. In part four the measurement results are mapped to the target surface using the D-map technique and summarised in terms of scattering half angle.
PART 1: DOPPLER-SURFACE MAPPING (D-MAP) METHODOLOGY AND THEORETICAL BASIS

The formulation of the D-map technique is best described and understood with reference to Figure 1. It is assumed that the cylinder is plane wave illuminated by radar and that some energy is backscattered in the direction of the radar source. This energy will contain discrete Doppler components that will fall within a bandwidth not greater than twice the maximum Doppler frequency. It will be shown later that the bandwidth is narrower than expected and will fall within an angular region about the central axis of the cylinder orthogonal to the plane of illumination. Figure 1 shows the respective positive and negative half angle segments.

The velocity of a point on the cylinder surface can be calculated using standard formula. Hence, the maximum radial velocity and the maximum Doppler at the cylinder edges can be calculated for rotation frequencies of interest, as shown in Table 1.

Table 1. Maximum Doppler frequency (f_d)

<table>
<thead>
<tr>
<th>Rotation Frequency</th>
<th>Maximum Doppler Deviation</th>
<th>Doppler at Edges</th>
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<tbody>
<tr>
<td>1 Hz</td>
<td>161.38 Hz</td>
<td>± 80.69 Hz</td>
</tr>
<tr>
<td>2 Hz</td>
<td>322.76 Hz</td>
<td>± 161.38 Hz</td>
</tr>
<tr>
<td>3 Hz</td>
<td>484.14 Hz</td>
<td>± 242.07 Hz</td>
</tr>
<tr>
<td>4 Hz</td>
<td>645.52 Hz</td>
<td>± 322.76 Hz</td>
</tr>
<tr>
<td>5 Hz</td>
<td>806.90 Hz</td>
<td>± 403.45 Hz</td>
</tr>
<tr>
<td>6 Hz</td>
<td>968.28 Hz</td>
<td>± 484.14 Hz</td>
</tr>
<tr>
<td>7 Hz</td>
<td>1129.66 Hz</td>
<td>± 564.83 Hz</td>
</tr>
<tr>
<td>8 Hz</td>
<td>1291.04 Hz</td>
<td>± 645.52 Hz</td>
</tr>
</tbody>
</table>

The angular velocity relative to the radar will have a \( \sin \theta \) dependency, where \( \theta = \text{azimuth scattering angle about the central longitudinal axis of the cylinder} \). The Doppler component will therefore also possess a \( \sin \theta \) dependency, i.e., at the point closest to the radar (\( \sin \theta = 0 \)) the relative velocity and Doppler component will be zero.

The velocity (and hence, Doppler) to the edge of cylinder with respect to radar observer can therefore be plotted and used as a means to relate the empirically derived Doppler line frequency spectra to a position on the target surface via an estimate of scattering half angle. A simple motion trajectory-Doppler template look-up table relating scatterer position to relative velocity (and Doppler frequency) has therefore been constructed using an Excel spreadsheet.

Fig. 2. Surface height profile test: metallic cylinder

In summary, the frequency sideband defines the scatterer position and hence defines angular velocity relative to the observer radar. By relating frequency to position it is possible to estimate the width of the surface that corresponds to a particular frequency window/scattering angle. However, it is noted that the method will be inaccurate in the central portion where the velocity is zero.

PART 2: CYLINDER TARGET DETAILS AND PHYSICAL MEASUREMENT RESULTS

The radar backscattering characteristics of two 100mm diameter, 540mm length, cylinder targets are studied later. However, an appreciation of the physical characteristics of each target is required before it will be possible to fully understand the implications of the radar results. The two targets, metallic and carbon fibre reinforced plastic (CFRP) cylinders, are respectively shown in Figures 2 and 3.

It may be seen from Figures 2 and 3 that a dial test indicator is used to measure the target surface height profile. This parameter is key to understanding the target phenomenology at
high frequencies where surface roughness becomes a critical parameter. For these measurements the targets were mounted in the actual experimental apparatus used for the spinning measurement tests; the apparatus (rotation rig) is shown in Figure 4.

In the test setup shown, the targets are mounted in the lathe chuck that is rotated by a drive shaft and pulley system. N.B.: Contact bearings are attached to the drive shaft to provide stable virtually vibration free rotation. For the purposes of the height profiling measurements each target was manually rotated and statically measured at points around the circumference. Figure 5 shows typical height profile results for the metallic and CFRP cylinders.

The circumference of the cylinder is 314mm and equates to one 360 degree rotation. The measurement results indicate that the surface roughness over one wavelength (3.89mm) are better than ±0.06mm for the metallic cylinder and ±0.12mm for the CFRP cylinder.

It may also be seen that the concentricities of the cylinders vary by 1mm and 1.2mm for the metallic and CFRP targets, respectively. The results therefore suggest that both cylinders are electrically smooth, i.e., the heights of the surface scatterers are below the Rayleigh criterion [5].

N.B.: The CFRP cylinder was dropped and damaged subsequent to the radar measurements and prior to metrological testing. The resultant surface damage is therefore the likely cause of the peak in the response at around 200º.

**PART 3: EXPERIMENTAL DESIGN AND RADAR MEASUREMENT RESULTS**

Radar measurements of the cylinder and dielectric cylinders were respectively performed at rotation rates between 1Hz to 8Hz in 1Hz increments and in a clockwise direction. The experimental design is shown in Figure 6. The results were gathered under quasi-beam-fill conditions at a range of 2 metres. The illumination footprint at the target has a diameter...
of 210mm and was aligned to the target centre. Radar absorbing material was used to screen the target stand/moving parts.

The radar shown in the foreground of Figure 6 operates at 77GHz, is quasi-monostatic, provides fully polarimetric operation, is coherent, and uses phase coded pulse Doppler modulation.

The radar measurement results are available as in-phase (I) and quadrature (Q) channel data. The format allows complex Fast Fourier Transform (FFT) techniques to be used to study the positive and negative spectral components.

PART 4: APPLICATION OF D-MAP TECHNIQUE AND ANALYSIS OF RESULTS

A sensitivity analysis was performed to determine the optimum threshold with which to study the sideband components. The optimum was found to be -10dBc. Figures 7 and 8 show the relationship between rotation rate and measured bandwidth for respective VV and HH polarisation results.

Analysis of the results summarised in Figures 7 and 8 show that for both sets of co-polar responses the bandwidth is linearly proportional to the rotation rate. Other results not presented show that the ratio of metallic bandwidth to CFRP bandwidth is invariant with rotation rate and is typically 50%, i.e., half the bandwidth.

Having determined the respective VV and HH bandwidths, from 0 to 8Hz, the D-map technique (Excel spreadsheet look up table) is used to generate the scattering half angle results shown in Figures 9 and 10.

Analysis of the D-map results summarised in Figures 9 and 10 shows that the scattering angle is invariant with respect to rotation rate for both the metallic and CFRP cylinder targets in both VV and HH polarisation. Additionally it can be seen that the scattering angle for the CFRP cylinder is double that for the metallic cylinder target.

The results shown in Figures 9 and 10 show the average scattering angle. The bandwidth and hence scattering angle may not always be perfectly symmetrical about the zero Doppler component. Other analyses not presented compare the maximum positive and negative line spectra to identify asymmetries in the BW about the zero Doppler component. For VV polarisation it was found that the metallic BW is more asymmetric than the CFRP BW, and for HH polarisation it was found that the CFRP BW is more asymmetric than the metallic BW. However, these asymmetries are generally small when assessed as a percentage of the total bandwidth.

A further supplementary analysis is presented that investigates sideband conversion. The results are shown in Figures 11 and 12.

It may be seen from Figures 12 and 13 that the carrier to Doppler sideband conversion is significant. For VV polarisation there is 50% conversion for both target types. For HH polarisation there is 40% conversion for the metallic cylinder and a 75% conversion for the CFRP cylinder.

**Figure 7. Bandwidth vs. rotation rate: -10dBc threshold: VV polarisation**

For both targets and polarisation types the spin rate appears to be relatively invariant with respect to the percentage of sideband conversion. However, a few anomalies are noted. For

**Figure 8. Bandwidth vs. rotation rate: -10dBc threshold: HH polarisation**

VV polarisation the sideband conversion drops to below 10% at 1Hz rotation rate and remains at this level until 5Hz. At 5Hz there is a step in the metallic cylinder response up to the 20% level. For HH polarisation there is a 10% variation between the metallic cylinder initial level at 1Hz and that at 5Hz. At 8Hz all four HH polarisation responses have coalesced to a nominal value less than 10% of the initial zero Doppler energy.

**Figure 9. Scattering angle vs. rotation rate: -10dB threshold: VV polarisation**
Fig. 10. Scattering angle vs. rotation rate: -10dB threshold: HH polarisation

It may be noted that the energy is distributed evenly between the positive and negative sidebands for both targets and for both sets of co-polar results.

Fig. 11. Ratio of carrier to sideband for positive and negative components: VV polarisation

DISCUSSION

For both targets the Doppler bandwidth (BW) was smaller than theory would suggest. The results can perhaps be explained if one considers the cylinder surface as a number of short tangential strips rather than point sources. The effect of Snells cosine law, e.g., specular returns at oblique angles, will then create the following dichotomy:

Maximum amplitude backscatter and zero Doppler will be seen head on but minimum amplitude backscatter and maximum Doppler will be seen at the edges. The implications of the phenomena may explain why Doppler components are only evident out to approximately 15% and 30% of the expected maximum Doppler for the respective metallic and CFRP cylinders. It would be an interesting exercise to perform multi-static radar measurements to interrogate the Doppler components at the edges from different observation positions. A possible configuration is shown in Figure 13.

From a metrological perspective the metallic and CFRP cylinders are shown to be smooth to within 1.5% and 3% of a wavelength. However, in practice the CFRP cylinder may be less electrically smooth than the mechanical dial gauge tests would indicate. This may be a function of the way in which the CFRP cylinder was manufactured. The cylinder is constructed from axial and longitudinal filament windings that are impregnated with resin. Inhomogeneous areas may therefore exist beneath the resin surface that may account for the difference in results between the CFRP and metallic cylinder targets, i.e., the doubling of the Doppler half scattering angle.

The implications of the above results are important and suggest that the D-map technique could be used to discriminate between targets with differing electrical (material) properties or surface roughness characteristics.

SUMMARY OF FINDINGS

Key findings are summarised and listed below.

- Significant co-polar sideband conversion occurs, for both the metallic and CFRP cylinders, under dynamic conditions.

- Co-polar sideband conversion is invariant with respect to rotation frequency.

- Doppler bandwidth is linearly proportional to rotation frequency.

- The ratio “metallic to CFRP” bandwidth is invariant with respect to rotation frequency.
• The Doppler bandwidths for the CFRP cylinder are 50% greater than those for the metallic cylinder.

• The measured Doppler bandwidths for the metallic and CFRP cylinders are respectively 15% and 30% of the theoretical maximum.

• The scattering half angles for both metallic and CFRP cylinders are invariant with rotation frequency.

• The scattering half angles for the CFRP cylinder are 50% greater than those for the metallic cylinder.

CONCLUSIONS AND RECOMMENDATIONS

The D-map methodology is simple to apply and exploits the unique spectral features associated with the Doppler frequency spectra from rotating electrically large cylindrical targets. The technique has been shown to be useful for studying dynamic target signatures and is therefore a valuable contribution to the state-of-the-art in this area.

The use of the half scattering angle to map the Doppler spectra to the target surface is novel and has been shown to be a robust technique. The D-map methodology provides a mechanism to discriminate between targets with differing electrical (material) properties or surface roughness characteristics and hence has utility for a variety of scientific and industrial applications.

The D-map methodology is commended to the reader for the study of dielectric and metallic spinning canonical targets such as cylinders, spheres, and cones.

ACKNOWLEDGEMENTS

The following are thanked; DSTL for sanctioning the release of this paper, for professional support and permission to use the experimental radar; Thales Missile Electronics (TME) for technical support (radar hardware); and QnetIQ for the loan of the cylinder rotation rig assembly and control hardware.

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Decades of Improvements in
Re-entry Ballistic Vehicle Tracking

Pierre Minvielle
This magazine has not traditionally accepted contributions that occupy more than a few finished pages, or that contains material that—at first glance—appears better suited for our other publications.

The accompanying article falls into that gap between our usual articles for *Systems* and those for *Transactions* or one of our *Tutorials*.

Based on the extremely favorable reviews received, however, we elected to bring this article to your attention as an “extra.”

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Suggestions for topics and the authors are always welcome.

_Evelyn Hirt_
_Editor-in-Chief_
Decades of Improvements in
Re-entry Ballistic Vehicle Tracking

Pierre Minvielle
CED DAM

Abstract— This paper deals with a missile defense challenge, which has been studied extensively for decades and still remains a topic of active research, the tracking of a ballistic vehicle in its re-entry phase. With Anti-Ballistic Missile or Anti-Tactical-Ballistic Missile goals, most of missile defenses need to track re-entry vehicles with a view to locating them precisely and allowing low altitude interception. The re-entry vehicle leaves a quiet exoatmospheric phase and a quasi-Keplerian motion to an endoatmospheric phase with large aerodynamic loads and a sudden deceleration. The motion is then obviously non-linear and furthermore both the extent and the evolution of the drag are difficult to predict. Since the sixties, while more and more efficient sensors, such as sophisticated phased-array radars, were developed, the associated data processing techniques have been improved, taking advantage of computer performance increases. Although re-entry vehicle tracking is undoubtedly a non-linear filtering problem, it was firstly solved by rustic linear filters with fixed weight and an assumed drag table. Then, Kalman filters were exploited. Uncoupled and polynomial for a while, they are now fully coupled and really non-linear. They are called Extended Kalman filters, are based on the linearization about the estimated state and are the current efficient and classic solution to non-linear filtering. Moreover, they perform drag estimation which may be useful to the identification capabilities of the missile defense. In the future, even more sophisticated techniques, such as the promising and fashionable particle filtering, are likely to be developed in re-entry vehicle tracking.

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1. Introduction

Anti-Ballistic Missile (ABM) or Anti-Tactical-Ballistic Missile (ATBM) defenses may be confronted with numerous challenging tracking problems, that depend on the threat and on the defense layer architecture: the boost-phase missile tracking for early warning or interception with laser weapons, the multiple target tracking against MIRVs (multiple independently targeted reentry vehicles) and decoys, the multi-sensor tracking and fusion of infrared sensors, the latest crucial seconds of tracking by a hit-to-kill interceptor, etc. Amongst these problems, the tracking of ballistic vehicles in their re-entry phase has been studied since 1960, following the work of Kalman and Bucy on recursive linear filtering [1]. It still remains now a topic of active research (as those few references [8,9,10,15,16,17,20] of the last five years testify it).

At the time of the sixties and the seventies, there was a widespread interest in re-entry vehicle (RV) tracking [2], as the Cold War urged the United States and the Soviet Union to develop each their own ABM defense in order to protect themselves against the others. In 1975, the US Safeguard system [3], which was descended from a succession of previous projects such as the Sentinel program and was reduced following the 1972 ABM Treaty, became operational and protected the Grand Forks site and the Minuteman ICBM (Inter Continental Ballistic Missile) fields from limited Russian or Chinese attacks. Nevertheless, it was quickly said that the Safeguard system could be easily overwhelmed by the then new Russian MIRVs. Also the system was completely closed in 1978 and only its supporting radar remains now. At the same time, the Russian elected to defend Moscow [3]; their ABM defense, notably armed with their nuclear interceptor Galosh, has been upgraded for the past decades and still exists today. Meanwhile, ATBM defenses has spread with many efforts on terminal interception and on RV tracking. For example, Israel has developed the ATBM "Arrow" system that is able to intercept Scud missiles; Arrow is based on an L-band phased array radar and a missile that uses a fragmentation warhead [4]. Furthermore, the current U.S. National Missile Defense (NMD) project, firstly without any terminal layer which can defend only a limited area, is to be merged with ATBM projects and is likely to integrate terminal layers which could specifically defend strategic areas.

The paper focuses on techniques and algorithms which have been used for RV tracking and, more precisely, for targets which are not maneuvering. We will only bring up the radar aspect even if both are closely linked. Since the beginning of ABM defenses, phased array radars have been employed and improved [4]. Their key advantages are their ability to allow the beam from a large antenna to be rapidly steered without mechanically moving the antenna, to maintain many targets in track, and to be easily hardened against nuclear
blast. Moreover, various radar techniques strengthened by
the use of digital processing, such as pulse compression,
MTI (moving-target indicator), and multimode, have
contributed to the advance of phased-array radars. Fig 1-3
illustrate different applications of phased-array radars. Fig 1
represents “Cobra Judy”, an U.S. shipboard radar built by
Raytheon and designed for collection of data on foreign
ballistic missile tests and also for satellite tracking. Fig 2
represents the Russian “Pill Box” radar, part of the Moscow
ABM system, with its four phased array providing a 360°
coverage. Fig 3 shows the transportable grounded-based
“Green Pine” radar, built by IAI/ELTA and used within the
ATBM Israeli “Arrow” system.

The paper deals with the evolution of the RV tracking
software techniques since the sixties, from the first rustic
linear filters to the current sophisticated forming methods.
The work is a summary and piecing together of previous
work; all information comes strictly from the open literature
and the mentioned papers.

The organization of the paper is as follows. Section 2 briefly
describes the problem of RV tracking. Section 3 introduces
the optimal filtering applied to RV tracking. Then Section 4
describes the evolution of the techniques over the past
decades. Section 5 gives the concluding remarks.

2. PROBLEM FORMULATION

2.1 Ballistic Re-entry Vehicle Motion

The motion of the ballistic RV forms a complex dynamic
phenomenon [5,6]. The determining factors are:
- the vehicle characteristics which can deteriorate:
geometry, inertia (asymmetry, unbalance), materials,
spin, etc.
- the environment characteristics: local gravitational
field, atmospheric properties (pressure, density,
temperature and derived quantities), hydrometry, etc.

![Figure 4 - Re-entry dynamics & atmospheric density]

The atmospheric re-entry, which follows an exo-
atmospheric phase (a) (gravity-dominated with quasi-
Keplerian motion), is usually made up of two phases (Fig 4):
an accelerated phase (b) between 120 and 60 km altitude
(gravitational forces still dominate atmospheric contact
forces) where the aerodynamic moment and velocity vector
become in a line and where incidence fluctuations damp
down, a decelerated phase (c) under 60 km altitude
(aerodynamic drag is comparable, then largely dominates
gravitational forces) where incidence normally converges.
During that last phase with its considerable heat flux,
ablation might lead to inertial and aerodynamic asymmetries
which are harmful to re-entry.

2.2 Radar Measurements

The phased array radar scans the target with a varying rate
(Fig 5). The radar is quite free in the number of pulses
(monopulse or pulse train) and in the design of each pulse
(e.g., modulation in phase, frequency). However the
transmitted energy must be enough to provide a correct
signal-to-noise ratio and detection.
When the radar manages to detect the target, a measurement is generated (Fig 6). The extracted information consists of the target angular direction (azimuth $\Delta z_m$, elevation $E_m$), the target range from radar $d_m$, and possibly, the Doppler velocity (range rate). This measurement is imprecise with possible bias and noises.

![Radar scanning of the re-entry vehicle](image)

**Figure 5 – Radar scanning of the re-entry vehicle**

Measurement noise is usually assumed to be white and Gaussian [5], with the following standard deviation:

$$
\sigma = \frac{\delta}{\sqrt{2 \cdot S/N}}
$$

($\delta$ the radar resolution in the given dimension, $S/N$ the signal-to-noise ratio).

![Radar measurement imprecision](image)

**Figure 6 – Radar measurement imprecision**

### 2.3 Re-entry Vehicle Tracking and Motion Characteristics

Generally speaking, the aims of RV tracking are:

- to follow the target and to create a persistent perception of the target which is required by the situation assessment process and by any action or action planning that are going to lie within the duration,
- to allow the engaging and guiding of interceptors or any weapons in charge of the destruction or neutralization of the target,
- to determine the target impact point and the launching point, enabling real-time ‘counter-attack’ (must be done early during the trajectory),
- to contribute to the classification and identification of the target (e.g., lethal target/decoy, type of the debris) by exploiting cinematic features,
- continue pointing at the target, producing measurements, and maintaining tracking.

Thus, in spite of the dynamic non-linearity, tracking must lead to a precise localization of the target and to a correct prediction of this localization in the future. Therefore, the target position and the first two derivatives, i.e., velocity and acceleration, need to be estimated. In the deceleration phase (3), aerodynamic drag is predominant and the acceleration vector and the velocity vector are collinear. One parameter may be enough to characterize the deceleration: the ballistic coefficient $\beta$, which is introduced in the classic Allen approximation [5,6], a re-entry model (1) with null incidence and no lift, where it remains constant.

$$
\dot{V} = \frac{1}{2} \rho \cdot V^2 \cdot \beta
$$

($V$ is the target velocity magnitude, $\dot{V}$ the acceleration magnitude and $\rho$ the local atmospheric density)

In the real situation, the incidence is not null and $\beta$ changes while the incidence varies and the aerodynamic characteristics, principally the drag component, move. The observation of $\beta$ is evidently not direct and its estimation precision relies on the estimation of both the velocity and the acceleration. In the exo-atmospheric phase, (1) suggests the indetermination of $\beta$ since the atmospheric density is insignificant and the acceleration negligible. The ballistic coefficient finds a meaning when the target penetrates the dense layers of the atmosphere and when a variation in $\beta$ involves a variation in the deceleration. Then, the determination of $\beta$ is essential to quantify the deceleration. Its estimation depends on the quality and the rate of the radar measurements. It also depends on the performance of tracking methods, i.e., the ability to put up with dynamic non-linearity, to exploit and control measurements, to use the knowledge about environment, and to be content with a priori information produced by upper sensors. Indeed, tracking techniques need to integrate various information with a suited modeling (Fig 7). That integration has evolved while the techniques improved and the computer performances increased (cf. section 4).

![RV tracking, information and modeling](image)

**Figure 7 – RV tracking, information and modeling**

### 3. RV TRACKING AND OPTIMAL FILTERING

RV tracking deals with the state determination of a dynamic system using noised measurements. Non-linearity may be present both in the dynamics and the measurements. Applied
to RV tracking, non-linear filtering is described by the
dynamic model, the measurement model, and the a priori
knowledge (or initial distribution). The choice of each of
them determines the filter design, its estimation accuracy,
its numeric stability, and the required computation workload.
This chapter is a quick presentation of optimal filtering and
recursive Bayesian estimation for RV tracking with the
intention to be able to show in Section 4 how the successive
techniques position themselves in the general framework of
these non-linear non-Gaussian state-space models and how
they differ.

**Dynamic State Model**— The dynamic (system) model of
the target is represented by a probabilistic description, i.e. a
non-linear, Markovian discrete-time stochastic process:

\[ X_{k+1} = f_k(X_k, v_k) \]  

(2)

At time k, \( X_k \) is the (hidden) state vector, \( f_k \) is the non-
linear (possibly time-varying) system transition function, \( v_k \)
is the model noise which is not necessary white, nor
Gaussian. We suppose herein that the target is not
manoeuvring (no input interfering with dynamics).

The state vector describes the target state at time k. The
choice of the state space (and its dimension) is crucial. In
RV tracking, one naturally introduces the position and the
velocity of the target. Derivatives of higher order may be
introduced and are supposed to improve the precision when
the target position is extrapolated in the future. However it
may be useless and even harmful to add certain parameters to
the state space when they can not be estimated. This
observability question is indeed very general in estimation
techniques [7] and of course depends on the measurements
and on the produced information. Concerning RV tracking,
it seems difficult to introduce more than the deceleration,
quantified by the ballistic coefficient, since the drag
component strongly fluctuates.

The choice of the dynamic model arises from the knowledge of
the dynamic motion of the target, on its representativeness about the motion characteristics and
on practical considerations, such as computation time.
Likewise, the model noise includes the imprecision about the
motion coming from the approximate chosen model, including for example uncertainties on the atmosphere state and
on the local gravitational field.

According to the Newton’s Law expressed in the non-
Galilean coordinate system of a ground observer, the
dynamic model can be generally described by the motion of
the center of gravity (G) [6]:

\[ \ddot{V}_R = \ddot{\bar{r}}_R = \ddot{\bar{R}}_R + \ddot{\bar{g}} - \left[ \sum E + 2\dot{\Omega}_E \times \dot{V}_R + \dot{\Omega}_E \times (\dot{\Omega}_E \times \dot{V}_R) \right] \]  

(3)

- \( \ddot{V}_R \) and \( \ddot{\bar{r}}_R \) are respectively the velocity and the
acceleration of G,
- \( \ddot{\bar{R}}_R \) is the resultant on G of the aerodynamic forces,
- \( \ddot{\bar{g}} \) is the gravitational acceleration which varies
according to the target position,
- the expression in square brackets combines the
centripetal acceleration and the Coriolis term.

\[ \ddot{R}_g \] depends on the local atmospheric density \( (\rho) \) and its
predominant drag component is more precisely in proportion to the
dynamic pressure \( (q) \):

\[ q = \frac{1}{2} \rho \cdot V^2 \]  

(4)

\( (V) \) is the velocity magnitude.

The description of the gravitational force comes within the
knowledge of the local gravitational field. The model
complexity (spherical model, ellipsoidal model, local
model) is determined by the precision level which is
accessible to RV tracking. The imperfect knowledge of the
atmosphere (difference between the real atmosphere profile
and the supposed one) also involves incertitude, and
possibly, bias or errors on different components of the state
estimator.

**Measurement Model**— The measurement model is defined
by the following stochastic equation:

\[ Z_k = h_k(X_k, w_k) \]  

(5)

At time k, \( Z_k \) is the measurement vector (dimension p),
\( h_k \) is the (possibly time-varying) measurement function,
\( w_k \) is the measurement noise (not necessary Gaussian but
conditionally independent given the process \( X_k \)).

The radar measurement provides information about the
target range, the target angular direction, and possibly the
Doppler velocity. For example, \( Z_k \) may be in dimension 3
(without Doppler velocity): \( Z_k = [\beta_m \ \gamma_m \ \hat{d}_m] \) where
\( \beta_m \) and \( \gamma_m \) are the directional cosines which determine the
angular direction, \( \hat{d}_m \) is the target range measurement. The
choice of the state coordinate system determines the relation
between state and measurement, i.e. the degree of non-
linearity of \( h_k \). Notice that the system state is partially
observed (\( h_k \) is not injective).

**Prior Knowledge**— The prior knowledge (initial
distribution) is, at the first time 0, the information on \( X_0 \) that
the radar gets before the first measurement. While
information about position and velocity can come from
upper sensors, the information on the expected deceleration
can be provided by technical considerations. The
information may be both an estimator \( X_0 \) of the state vector
and a quantification of the associated incertitude. In general,
this knowledge is given by the prior probability density
function \( f_{X_0} \).

**Optimal Filtering**

The radar scans the target and produces measurements at
different times (with a varying rate). The estimation problem
is a discrete time filtering problem which consists in
determining the information state [7], meaning a function of the
available information (the sequence of noised
measurements) that completely summarizes the past of the system and that estimates in the best way the system state in the present and in the future.

The sequence $X_k$ can also be viewed as a Markov process described by a transition probability $Q_k$:

$$P(X_k \in dx | X_{k-1}) = P(X_k \in dx | X_{k-1}) = Q_k(X_{k-1}, dx)$$  \hspace{1cm} (6)

The measurements $Z_k$, conditionally independent given the process $X_{k-1}$, are totally (in a probabilistic way) described by the conditional densities $f_{z_k | x_k}$. Calling $Z_k = [Z_1 Z_2 ... Z_k]$ the random sequence of measurements and $X_k = [x_1 x_2 ... x_k]$ the associated realization, and assuming the whiteness of both the two noise sequences, the best information [7] that can be produced with $X_k$ is the conditional density of $X_k$ given $Z_k$:

$$f_k = f_{X_k | z_k}$$

The determination of $(f_k)_{k \geq 0}$ is called optimal filtering. The probability density function (PDF) $f_k$ is any distribution, not reducible to the first moments; the dimension of the problem is generally infinite.

**Recursive Bayesian Estimation**— The optimal filter estimation may be computed in a Bayesian recursive way, and can be divided into two stages: a prediction stage and a correction stage (cf. Fig. 8).

![Figure 8 - Optimal filtering recursion](image)

The prediction state is obtained by a convolution product (⊗) of the model transition probability by the probability density of the estimated state (a priori density) at the last time:

$$f_{x_k | x_{k-1}, z_{k-1}} = Q_k \otimes f_{x_k | z_{k-1}}$$

The above equation is known as the Chapman-Kolmogorov equation. The transition probability $Q_k$ can be expressed by the following stochastic integral:

$$Q_k = \int f_{x_k | z_{k-1}}(x_k, x_{k-1}) f_{z_{k-1} | x_{k-1}}(z_{k-1}, x_{k-1}) \, dx_{k-1} \hspace{1cm} (9)$$

The correction stage is produced by Bayes rule with the following relations between a priori and a posteriori densities:

$$f_k = f_{x_k | z_k} = \frac{f_{z_k | x_k} \cdot f_{x_k | z_{k-1}, x_{k-1}}}{\int f_{z_k | x_k} \cdot f_{x_k | z_{k-1}, x_{k-1}} \, dx_k}$$

The normalizing denominator, which generates non-linearity, can be developed as:

$$f_{z_k | x_k} = \int f_{z_k | x_k} \cdot f_{x_k | z_{k-1}, x_{k-1}} \, dx_k$$

Analytical solutions to these relations are only realizable in a few simple situations. Thus, in the Linear Gaussian Hypotheses', the two stages come to the Kalman filter. In the non-linear general situation, numerical suboptimal algorithms need to be used.

In the RV tracking problem, that obviously does not fulfil the Gaussian Hypotheses, only approximate methods may be used. Those methods have evolved since their beginnings as it is described in the next chapter.

**Estimators**—With the knowledge of the posterior density $f_k$, it is possible to compute estimates with respect to any criterion. For example, the minimum mean-square error (MMSE) estimate is the conditional mean of $X_k$:

$$\hat{x}_k = E(X_k | Z_k) = \int x_k \cdot f_k(x_k) \, dx_k$$

while the maximum a posteriori (MAP) estimate is the maximum of $f_k$ (it may be more suited when the posterior density $f_k$ is multi-modal). Furthermore, a measure of accuracy of a state estimate (e.g., covariance) may also be obtained from $f_k$ and confidence regions may be determined.

### 4. EVOLUTION OF THE TECHNIQUES

An attempt of chronology about the main successive RV tracking techniques is represented in Fig 9, with first their development, then their practical use and finally their decline. The lists of numbers in square brackets make up references connected to the implementation of each technique of RV tracking. After the fixed-gain filters, which were the first rustic filters of the 1950s and the beginning of the 1960s, Kalman filters were exploited. They were quite quickly replaced by derived forms called Extended Kalman filters (EKF) which, since the seventies, have been the classic solution to non-linear filtering. Iterated Extended Kalman filters (IEKF), close to EKF, were also

---

1 Linear Gaussian Hypotheses: Gauss-Markovian process + white Gaussian noises (mutually independent) + Gaussian a priori pdf [8]
used. Among the current emerging methods, the Unscented Kalman filters (UKF) and, above all, particle filters (PF) may replace EKF in the medium or long term.

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<tr>
<td>Kalman Filters</td>
<td>[5,8,9,10,11]</td>
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<tr>
<td>EKF, IEKF, etc.</td>
<td>[2,5,9,10,11,15,16,20]</td>
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<td>UKF, PF, etc.</td>
<td>[15,16,17,18]</td>
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**Figure 9 – RV tracking chronology**

In this chapter, the principles of the successive techniques are firstly presented. Then, an analysis of the evolution is developed, including a comparison of the performance and of the complexity.

### 4.1 Fixed-Gain filters

Various applications have been given to the fixed-gain filters, among which fixed-weight filters, steady-state filters and Wiener filters in their frequency form. The most famous implementations of fixed-gain filters, suitable for noisy kinematic models, are the α–β filters and the α–β–γ filters. Only the principles will be presented next; refer to [7] for a complete description of fixed-gain filters.

**Optimal filter approximations**— Those fixed-gain filters require the strong assumption that the system is linear and time-invariant, meaning both the state and the measurement equations (2) et (5) are linear and time-constant (stationarity). Under suitable conditions, the state estimation covariance (the estimation of the uncertainty on the estimated state) will converge to a steady-state value. The correction stage may then be computed using a fixed multiplying factor that weights the importance attributed to the current measurement. In RV tracking, these required assumptions are not valid at all. Roughly speaking, it could be grasped as if this wrong assumption was compensated, concerning the state model, by a high model noise. Choosing a piecewise constant Wiener acceleration model [7,10], the state model (2) is represented by the third order equation:

$$X_{k+1} = \Phi \cdot X_k + \nu_k$$

with

$$\Phi = \begin{bmatrix} 1 & T & \frac{T^2}{2} \\ 0 & 1 & T \\ 0 & 0 & 1 \end{bmatrix}$$

In RV tracking, the main alternatives for choosing the state coordinate system are a Cartesian coordinate system, such as an Earth-centered fixed\(^3\) (ECF) coordinate system, and a "sensor" coordinate system, such as a range, azimuth and elevation (RAE) coordinate system or a range, directional cosines coordinate system. Whatever the coordinate system, the state vector ought to integrate components on position (P) (RAE for example), on velocity (V) and on acceleration (A) required by the third order model (12).

Decoupling the state, each state vector component in each coordinate is propagated using the polynomial expansion (12). Then, the prediction stage (8) consists in (for the range component R of a RAE coordinate system):

$$\begin{bmatrix} \hat{r}_{k+1|k} \\ \hat{r}_{k+1|k} \\ \hat{r}_{k+1|k} \end{bmatrix} = \Phi \cdot \begin{bmatrix} \hat{r}_{k|k} \\ \hat{r}_{k|k} \\ \hat{r}_{k|k} \end{bmatrix}$$

\[(13)\]

where \(\hat{r}_{k|k}\) and \(\hat{r}_{k+1|k}\) are respectively the estimated range at time \(k\) and the predicted range at time \(k+1\). Working in the RAE state coordinate system, the measurement model (5) is straight and the correction stage (10) may be computed by the following equations (for the range component R):

$$\begin{bmatrix} \hat{r}_{k+1|k} \\ \hat{\hat{r}}_{k+1|k} \\ \hat{r}_{k+1|k} \end{bmatrix} = \hat{r}_{k+1|k} + K_R \cdot (r - \hat{r}_{k+1|k})$$

\[(14)\]

where \(r - \hat{r}_{k+1|k}\) is the measurement error and where \(K_R\), \(K_R^\prime\) and \(K_R^\prime\) are precomputed filter weights [10].

**Implementation principles**— Fig 10 sums up the above description of a fixed-gain filtering recursion applied to RV tracking. The state vector dimension is 9, with 3 position components (P), 3 velocity components (V) and 3 acceleration components (A). The initialization consists in the state vector \(\hat{x}_0\) (given by a hand-over).

As it was mentioned before, the prediction or propagation of the state estimator \(\hat{x}_{k|k}\) is uncoupled and polynomial. More, this prediction stage must use an a priori drag table in order to take a drag deceleration into account. This drag table, where the ballistic coefficient \(\beta\) is a function of the altitude, is precomputed and estimated for an a priori trajectory [10] which must correspond more or less to the expected trajectory.

The radar process, including actions such as pointing and signal processing (detection, S/N evaluation, etc.), uses the information of the predicted state \(\hat{x}_{k+1|k}\) and will finally produce a measurement. The correction stage consults a data base containing the fixed weights that are a function of the altitude. The weights are precomputed by a supervised training, based on the a priori trajectory [10]. At the end of the correction stage (14), the update estimated state \(\hat{x}_{k+1|k+1}\) is provided.

\(^3\) ECF coordinate system: (O \(x_1\), \(y_1\), \(z_1\)) cartesian and non-Galilean coordinate system. \(x_1\): Earth center, \(y_1\) along Earth axis of rotation, \(z_1\) and \(y_1\) rotate with the Earth.
Remarks— The computational and memory requirements of the fixed-gain filters are known to be very modest. Moreover, they were implementable as early as the 1950s with the then amplifiers and time-invariant network elements, such as resistors and capacitors [19].

However, their efficiency and their accuracy are mediocre, still worse when the measurement conditions are difficult (low rates, misdetections) or when the trajectory and its drag evolution is quite different from the a priori trajectory [10]. In that case, they can encounter instabilities and divergences. Implicitly based on a high model noise which compensates a poor model process, fixed-gain filters for RV tracking are not able to reach a precise level of estimation. Furthermore, they are not adapted to the initial transient period when they should give more weight to the measurements than to the weak previous information. Fixed-gain filters are probably more suitable for the exo-atmospheric phase where their assumptions are pretty well ascertained.

Finally, fixed-gain filters applied to RV tracking are completely incapable of estimating the deceleration and the ballistic coefficient evolution of the target, as they need to use this evolution as an a priori hypothesis, both for the state prediction and the achieving of the correction weight K. Thus, they can not provide this discrimination information.

Variants— Several variants and improvements may be added to RV tracking fixed-gain filters. Among them, the propagation equations can be coupled or the precomputed weights can be refined with a growing memory mechanism [8]. This system avoids the maladjustment of the initial transient period by the temporary use of a zero-process noise filter [7].

4.2 Kalman filters
Kalman filters, known as Kalman-Bucy filters when they are used in continuous time problems, first appeared at the beginning of the sixties [1] and were a major breakthrough for the linear estimation in dynamic systems. Refer to [7] for a complete description of Kalman filters.

Optimal filter approximations— The Linear Gaussian Hypotheses, described in chapter 3, is required for this filter. The PDF $f_k$, that we try to determine, is Gaussian and is completely described by the mean $\hat{x}_k = E(X_k|Z^k = z^k)$ and the covariance matrix $P_k = \text{Cov}(X_k|Z^k = z^k)$. $P_k$ represents the (estimated) incertitude on the estimated state. In RV tracking, the state process is not linear. As for the above fixed-gain filters, a straight process model, such as a piecewise constant Wiener acceleration model, may be used with an adapted model noise. About the measurement model, the description of the state vector in a “sensor” coordinate system involves that (5) is linear:

$$Z_k = H \cdot X_k + w_k$$

(15)

with $H = \begin{bmatrix} 1 & 0 & 0 & \ldots \\ 0 & 1 & 0 & \ldots \\ 0 & 0 & 1 & \ldots \end{bmatrix}$ and $w_k$ is the model noise (additive, zero mean and white) and $R_k$ its covariance.

The Kalman filter recursion is close to the fixed-gain one, with the propagation of the covariance matrix $P_k$ (16-18) and a dynamically calculated weight $K$ (17).

$$P_{k+1|k} = \Phi_k \cdot P_{k|k} \cdot \Phi_k' + Q_k$$

(16)

$$K_{k+1} = P_{k+1|k} \cdot H_{k+1} \cdot S_{k+1}^{-1}$$

(17)

$$P_{k+1|k+1} = P_{k+1|k} - K_{k+1} \cdot S_{k+1} \cdot K_{k+1}'$$

(18)

where $S_{k+1} = H_{k+1} \cdot P_{k+1|k} \cdot H_{k+1}' + R_{k+1}$

Implementation principles— Fig 11 sums up the above description of a Kalman filtering recursion applied to RV tracking.

The state vector dimension is 9, with 3 position components (P), 3 velocity components (V), and 3 acceleration components (A). The initialization step consists in both an estimated state $\hat{x}_0$ and the associated incertitude $P_0$ (given by a hand-over).

The prediction stage and the correction stage propagate at once the estimated state and the covariance matrix. The ballistic coefficient may be computed [9], from the estimation of the velocity and the acceleration, and using the relation (1) (adding if the need arises a gravitational term).

Remarks— The computational and memory requirements of Kalman filters are slightly more important than the fixed-gain filters. As a matter of fact, Kalman filters with all their matrix calculations needed the integrated digital circuit modules which were developed from the beginning of the sixties [19].
Although the ballistic coefficient $\beta$ can be estimated, its estimation is rather noisy [9] because these Kalman filters are not able to integrate in their state model process knowledge about the ballistic re-entry motion. Thus, their estimation of the deceleration component is fully affected by the measurement noise, without any smoothing.

**Figure 11 – Kalman filtering recursion**

Variants—Different possible variants [10], like coupled/decoupled or second order/third order model process, are possible and influence notably the computational load.

4.3 Extended-Kalman filters

Extended-Kalman filters (EKF), derived from Kalman filters, is a suboptimal algorithm adapted to nonlinear systems where the implementation of the optimal filter is mostly (and in RV tracking truly) unfeasible. Refer to [7] for a complete description of Extended-Kalman filters.

**Optimal filter approximations**—EKF directly takes place in the RV tracking reality, meaning the nonlinearity of the dynamics and the measurement equations. As earlier, both the model process noise and the measurement noise are additive, zero mean and white. The main assumption is then that the PDF $f_{x}$ will remain more or less Gaussian and will be approximatively described by the mean $\hat{x}_k \approx E(X_k | Z^k = z^k)$ and the associated covariance matrix $P_k$. Basically, EKF resorts to a series expansion of the first (or second order) of the nonlinear equations of the dynamics and the measurement with the intention of obtaining the state and measurement predictions. For a first order EKF, that involves the computation of the Jacobian $\left(\frac{\partial \hat{x}}{\partial x}\right)_{\hat{x}_k}$ at the latest estimate of the state and the computation of the Jacobian $\left(\frac{\partial h}{\partial x}\right)_{\hat{x}_k}$ at the predicted state.

**Implementation principles**—Fig 12 sums up the above description of a EKF filtering recursion applied to RV tracking. Introducing a level knowledge of the RV vehicle motion, one can use a state vector of dimension $7$ [2,10,15]:

$$X_k = [x \ y \ z \ v_x \ v_y \ v_z \ \beta]$$

where $(x, y, z)$ are target position coordinates in ECF, $(v_x, v_y, v_z)$ are target velocity coordinates in ECF and $\beta$ is the ballistic coefficient. The initialization of the state vector specially is given by an a priori Gaussian incertitude on the ballistic coefficient $\beta$.

**Figure 12 – EKF filtering recursion**

According to the Newton’s Law (3) expressed in the non-Galilean ECF with only a drag term,

$$\begin{align*}
\dot{x} &= v_x \\
\dot{y} &= v_y \\
\dot{z} &= v_z \\
\dot{v}_x &= G_x + \Omega^2 x + 2\Omega v_y - q\beta \frac{v_y}{v} \\
\dot{v}_y &= G_y + \Omega^2 y - 2\Omega v_x - q\beta \frac{v_x}{v} \\
\dot{v}_z &= G_z - q\beta \frac{v_z}{v}
\end{align*}$$

(19)

where $G_x, G_y, G_z$ are the gravitational force components, $v$ is the velocity magnitude, $q$ is the dynamic pressure and $\Omega$ is the Earth rotation rate. The prediction stage consists of numerically integrating, by an ODE solver such as the Range-Kutta method, the above
fully coupled ballistic equations (19). It also consists in propagating the covariance matrix \( P_k \) by (16) with \( \Phi = \left( \frac{\partial f}{\partial x} \right)_{x_{k-1}} \). About the ballistic coefficient \( \beta \), its dynamics are considered as almost constant [2,10,15] in the dynamic model (\( \beta \) evolution is generally slow for a non-maneuvering vehicle). That does not keep the estimator \( \hat{\beta} \) from varying during the tracking, due to the added \( \beta \) process noise (\( \beta \) process is actually an independent-increment Wiener process).

The correction stage is quite similar to the Kalman one, apart the use of the Jacobian \( \left( \frac{\partial h}{\partial x} \right)_{x_{k-1}} \).

Remarks—EKF are much more greedy in calculations and memory than the former ones. However, that can strongly differ according to the choice of the coupled/uncoupled equations, on the integration method, and on many optimizations which can be introduced in all the steps.

RV tracking EKF, that uses knowledge on the local gravitational field and on the atmospheric density, leads to a more accurate estimation of the state vector. The ballistic coefficient \( \beta \) is estimated [2,10,15] without the noisy behavior of the Kalman method. Moreover, it offers an estimation of the incertitude around the estimated \( \beta \). Nevertheless, unstability and divergence may occur when the initialization is too imprecise, when the measurement conditions are degraded and when, more generally, the local approximations are not checked.

Many methods, more or less sophisticated, have been studied to improve RV tracking EKF [11], mostly on the propagation of the covariance matrix. Among them, the choice of the coordinate system seems to be the more sensitive. According to [2,11], a “sensor” coordinate system (yet not very practical to express the dynamics (3)), like the RAE, would be the best option. Measurement equations remain linear and the process model holds all the nonlinearity. Moreover, it allows a decoupling of the error covariance matrix and reduces its ill-conditioning. Thus, an EKF in a “sensor” coordinate system would be as efficient as an IEEF [2], a more complex derived form described straight after.

4.4 Iterated Extended-Kalman filters

The effects of linearization errors in the EKF can be reduced by relinearizing the measurement equation (5) around the updated state rather than relying only on the predicted state. Thus, Iterated Extended-Kalman filters (IEKF) consist of a few added iterations (the number is decided either a priori or based on a convergence criterion) of the EKF correction stage, computing each time the Jacobian \( \left( \frac{\partial h}{\partial x} \right) \) at the new updated state. This technique may improve RV tracking when obviously the measurement equation is nonlinear, i.e. when the state coordinate system is Cartesian [2]. Refer to [7] for a complete description of Iterated Extended-Kalman filters.

Variants—Several other techniques, close to EKF and IEKF, have been suggested for RV tracking. For example, [2] describes a single-stage iteration filter which is more or less an one iteration IEKF with, what is more, a relinearization of the dynamics around a smoothed (meaning backward predicted) estimate. In the other hand, Interacting Multiple Model (IMM) techniques can be useful as they are able to switch between a bank of filters, each of them adapted to a different phase (boost, exo-atmospheric, endo-atmospheric) of the ballistic missile [20].

4.5 Unscented Kalman filters

Unscented Kalman filters (UKF) are an emerging method, closely related to EKF. In order to capture the nonlinearity, their basic idea is to propagate the matrix covariance, not only by using a local approximation at the estimated state and a few terms of a Taylor series expansion, but by propagating a judicious number of deterministically chosen points (coherent with the state uncertainty) through the nonlinear dynamics model and by using those predicted points as an approximation of the predicted covariance matrix. Refer to [17] for a complete description of UKF. [16,17] illustrate the application of UKF to simplified versions of RV tracking.

4.6 Particle filters

Particle filters (PF), also called Sequential Monte Carlo methods, emerged towards the end of the 1980s. They are simulation based methods and include several closely related algorithms known under the names of Bootstrap filters, Condensation, Monte Carlo filters, interacting particle approximations, etc. These stochastic algorithms can also be looked upon as genetic algorithms, with alternate phases of crossover, selection and mutation [14]. Refer to [13,14] for a complete description of particle filters.

Optimal filter approximations—The main idea of PF is the approximation of the PDF \( f_k \) by a set or a population of random samples (or particles) \( \{x_k(i)\} : i = 1, \ldots, N_F \), where \( N_F \) is the number of samples. The associated empirical distribution is \( S_k^{N_F}(x) = \frac{1}{N_F} \sum_{i=1}^{N_F} \delta_{x_k(i)}(x) \) (\( \delta \) is the Dirac delta function); it is supposed to tend to \( f_k \) as \( N_F \) tends to infinity. Then, the integral calculation of the prediction and the Bayesian correction stage are computed in a Monte Carlo way, propagating the particles by the stochastic model process, strengthening their weight according to their likelihood towards the current measurement, sampling, and resampling if necessary, etc.

In the prediction stage, each sample of \( \{x_k(i)\} : i = 1, \ldots, N_F \) (representing \( \int_{X_{k-1}} \left| Z_{k-1} = z_{k-1} \right| \) at time k-1) is propagated independently (independent realizations of noise \( v_{k-1} \)) with the dynamic model:

\[
x_k(i) = f_k(x_{k-1}(i), v_{k-1}(i))
\]

\( \{x_k(i) : i = 1, \ldots, N_F \} \) is then representative of the PDF
\[ f_{X_k|z^{k-1}} = f_{z_k|X_k^{*}(i)} \] of the optimal filter equation (8).

In the correction stage, the likelihood of each sample \( X_k^{*}(i) \) is evaluated, relating to the new measurement \( z_k \). The normalized (importance) weight of each sample becomes:

\[ q_i = \frac{f_{z_k|X_k^{*}(i)}(z_k)}{\sum_{j=1}^{N_E} f_{z_k|X_k^{*}(j)}(z_k)} \]  

(21)

The Bayesian correction (10) is then realized, with the Bootstrap filter, by resampling \( N_E \) samples from \( \{ x_k^{*}(i) \} i = 1, \ldots, N_E \}, \) according to the importance weights \( q_i \). The most probable samples are selected preferentially and it can be demonstrated that the set of random samples \( \{ x_k^{*}(i) \} i = 1, \ldots, N_E \} \) is representative of the a posteriori PDF \( f_{X_k|z^{k-1}} \) (14).

In this framework, both the process model and the measurement do not need to be linear and the approximation is not simply local as it used to be for EKF. Any process and measurement noises (for example multi-modal distributions) can be taken into account.

**Implementation principles**—Fig 13 sums up the above description of a particle filtering recursion applied to RV tracking. Using a state vector of dimension 7 described in the Cartesian coordinate system ECF [15], the sample components (position, velocity, and ballistic coefficient) are \([x, y, z, v_x, v_y, v_z, \beta]\).

The initialization consists of a set of random samples (a few thousands for example) that represents the uncertainty on the state (given by a hand-over). The prediction stage (20) propagates each sample, applying the process noise (mutation effect) and integrating the fully coupled ballistic equations (19) with an ODE solver. The correction stage (21) selects the most probable samples by resampling techniques, Multinomial resampling being the simplest but not the most efficient method [13].

Various state estimators can be computed, such as the MMSE estimator (approximated by \( \frac{1}{N_E} \sum_{i=1}^{N_E} x_k^{*}(i) \)) or the MAP estimator, more suited when \( f_k \) is multi-modal.

**Remarks**—The computational and memory requirements of particle filters are undoubtedly much higher than EKF ones. However, as for EKF, that can strongly depend on various choices and many optimizations can be introduced. Among them, some techniques are now emerging that manage to reduce the number of propagated particles while maintaining the estimation accuracy of \( f_k \) [13]. An other way to accelerate PF methods could be to use parallel processing.

Particle filters could be specially useful when the tracking conditions are unusual, i.e. for example when the initialization is very imprecise (EKF may diverge as the local EKF approximation is too wrong) or when the measurements stop being quasi-Gaussian and when several modes appear [15]. More generally, SMC methods can improve RV tracking for they give a larger framework to integrate imprecise information about dynamics, measurement, and knowledge.

**Figure 13 – Particle filtering recursion**

However, degeneracy problems (meaning the number of selected samples rapidly collapsing to a few values, and even a single value) may occur if one does not take care.

**Variants**—Many techniques are being developed to improve PF and to solve degeneracy problems. Among them, the addition of a sampling Markov Chain Monte Carlo (MCMC) step [13] or the massive resort of EKF or UKF for each particle in order to guide its propagation with the latest measurement.

Other new methods are currently tested for non-linear filtering. For example, grid-based numerical approaches are developed to solve the stochastic differential equations of the optimal filtering recursion [18].

**4.6 Analysis of the evolution**

The improvements of the RV tracking data processing techniques have been continuous since the 1960s. More and more accurate, they have became more robust as [10] testified it for an EKF implementation at the millimeter wave (MMW) radar of Kwigalein (Marshall Islands). They are more and more able to get out of difficult tracking conditions, such as data loss periods [10] or unexpected RV dynamics [15]. After a few decades, they are now capable of modeling and integrating, inside their behavior, knowledge about the RV motion, and also capable of taking the uncertainties (dynamics, environment, measurement) into account in the closest way. By this very fact, they no longer require tuning or an a priori table, either before or during tracks [10]. Finally, they can potentially perform a precise
estimation of the ballistic coefficient and thus may contribute to the classification or identification of the target.

These improvements have been mainly accomplished thanks to the great advances made in the digital computer technology in the last four decades. The well-known checked Moore’s Law of Fig 14 illustrates it, with its exponential increase of the number of transistors on a chip and the processor speed in MIPS (million instructions per second). The successive Intel processors are located on the graph.

![Moore's Law Graph](image)

**Figure 14 – Moore’s Law**

![Processor speed versus year](image)

**Figure 15 – Processor global improvement and RV tracking requirements**

Fig 15 represents the relative exponential increase of both the processor and the memory capacity since 1960 (this rough evaluation is based on the civilian computer evolution but is likely to apply more or less to more confidential computers). Furthermore, domains of computational (and memory) requirements are shown for each RV tracking technique. This evaluation comes partly from references [8,15] and partly, we must admit it, from a rough guess. The incertitude is due to the requirement variation between various implementations of a RV tracking technique (e.g., coupled/decoupled, polynomial/ODE integration, number of propagated particles for a particle filter). Of course, and it could not have been different, all those techniques are consistent with the computer technology of their time. Fixed-gain filters were implementable with the then rustic analog and vacuum tubes technology, Kalman filter needed the digital technology of the 1960s [19] and, since the 1970s, Extended-Kalman filters have been riding on the wave of integrated circuit and microprocessor development. The particle filters have been in gestation for a long time [13] and are now emerging while the computer performances afford it. SMC methods are doubtless now more attainable than the fixed-gain filters were at the beginning of the sixties.

5. CONCLUSIONS

Some of the RV tracking techniques, that have followed one another since the sixties, have been presented. From the first simple rustic linear filters to the current Monte-Carlo simulation based methods, the performances, meaning the accuracy and the robustness, have naturally raised and the classification abilities have been developed. Those techniques have benefited from the considerable increase of computer capabilities.

More generally, the RV tracking techniques and the associated performances must be considered jointly with the radar system (or any other sensor), within a defense system and against an expected threat.

REFERENCES


Biometric Recognition:
Why Not Massively Adopted Yet?

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ABSTRACT

Although there has been a dramatic reduction on the prices of capturing devices and an increase on computing power in the last decade, it seems that biometric systems are still far from massive adoption for civilian applications. This paper deals with the causes of this phenomenon, as well as some misconceptions regarding biometric identification.

INTRODUCTION

Biometric systems offer some advantages over the classical handheld tokens (card, ID, passport, etc.) and knowledge-based (password, PIN, etc.) authentication methods. However, it seems that classical systems are not being replaced by biometric ones. According to [1], this is due to four fundamental problems:

1) Security:
How to guarantee that the sensed measurements are not fraudulent.

2) Privacy:
How to make sure that the application is indeed exclusively using pattern recognition for the expressed purpose.

3) Accuracy:
How to accurately and efficiently represent and recognize biometric patterns.

4) Scale:
How to acquire repeatable and distinctive patterns from a broad population.

This paper intends to discuss these four aspects providing new points of view. In addition, we will try to beat some misconceptions regarding biometric recognition, using the experience and knowledge of some other fields, such as anthropology and law.

The problem concerning security was described in detail in [2]. One of the main critical facts is that when biometric identifiers have been compromised, the legitimate user has no means to revoke the identifier in order to switch to another new one. This is a serious drawback when compared with a handheld token or a knowledge-based verification method, which can be replaced. Probably one solution should be a change on the philosophy: the biometric pattern can be considered as a “login” instead of a “password,” or a login plus biometric plus password based system. Thus, the recognition relies on both information: login and password, where the latest can be kept secret and changed, if necessary. This lets us improve the security, although loses the nice property of biometric authentication systems, where it is not necessary to remember anything, nor to hold any card. However, the engineers still try to use the biometric signal as password. Another solution is the combination of several biometric systems [3]. In this case it is more difficult for a hacker to fake several systems than a single one. If there is a human supervisor during the acquisition of the biometric signal, the possibility to introduce a fraudulent signal is almost negligible. An example of this situation would be border entrance control.

The problem concerning privacy was described in detail in [4]. Probably the best way to preserve privacy is through regulations and fines to those who break it. Thus, it is the work of legislators to deal with. This is not a problem specific to
biometrics, and strong efforts are dedicated to set up personal data protection laws.

The last two problems are mainly related to algorithmic issues and point out that biometric identification is not a solved problem yet. Thus, more research must be done in order to improve current systems. However, *Is biometric recognition as easy as we think?*

The remainder of this paper gives some arguments about why performing biometric recognition is not as easy as we think. For this purpose we will use some arguments taken from other fields, probably more mature than biometrics.

“...In the end I managed to lay my hands on some postcards depicting African fauna. I had at least a lion and a leopard and showed them to people to see if they could spot the difference. Alas, they could not. The reason lay not in their classification of animals but rather in the fact that they could not identify photographs. It is a fact that we tend to forget in the West that people have to learn to be able to see photographs. We are exposed to them from birth so that, for us, there is no difficulty in identifying faces or objects from all sorts of angles, in differing light and even with distorting lenses. Dowayos have no such tradition of visual art; theirs is limited to bands of geometric designs. Nowadays, of course, Dowayo children experience images through schoolbooks or 'identity cards;' by law, all Dowayos must carry an identity card with their photograph on it. This was always a mystery for me since many who have identity cards have never been to the city, and there is no photographer in Poli. Inspection of the cards shows that often pictures of one Dowayo served for several different people. Presumably the officials are not much better at recognizing photographs than Dowayos...

...The point was that men could not tell the difference between the male and the female outlines. I put this down simply to my bad drawing, until I tried using photographs of lions and leopards. Old men would stare at the cards, which were perfectly clear, turn them in all manner of directions, and then they say something like 'I don't know this man.' Children could identify the animals...."

Thus, the face recognition ability of human beings is not as trivial as we could think. It is the result of a long learning process, which is not really well understood, varies along our life, and even relies on different parameters [6]. Probably it is similar to learn to pronounce some phonemes. It is not a problem when we are children, but after several years, it is almost impossible (for instance, a French person cannot pronounce the /r/ phoneme of the Spanish word “perro,” which means dog). Taking into account the experience of this anthropologist, we can see that really the enrollment phase, where the computer tries to learn a model for each person using some (limited amount of) training data, is fundamental.

Even when we are used to seeing photos and recognizing faces, there are difficult situations. The first coming to mind is that related to changes in hairstyle, makeup, facial hair, addition or removal of eyeglasses, hats, scarves, etc. Figure 2 shows six different photographs of the actor Val Kilmer on the film *The Saint.* Although it is an extreme case, where the user is trying to avoid his identification, most faces databases contemplate changes on facial expression, illumination, etc. because it is an actual problem in real scenarios.

---

**Fig. 1. Dowayos looking at drawings**

**BIOMETRIC RECOGNITION: AN EASY TASK?**

Before having an automatic system able to solve our identification problems with the accuracy and scale we desire, we can examine the situation when the operator is a human being. Probably if a person can perform this task, and we can summarize the procedure done by him/her, the answer is yes. *But does that really mean that “a human can do the task easily?”* In this section we describe some facts that can help us understand the complexity of biometric recognition.

**Face Recognition: An Easy Task For Human Beings?**

Although common sense points out that face recognition is an easy-task for human beings, it is more complex than we think. It is not an innate ability, at least when using two-dimensional representation of faces (photos, drawings, etc.), and it must be acquired when we are young. A British anthropologist, Nigel Barley, went to study the Dowayo people (see Figure 1), a strangely neglected group in North Cameroon, and he reports in his book [5]:

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Another difficult situation is when trying to recognize a human face different from the race that we are used to dealing with in our normal life. For instance, [7] reports that "The last half-century's empirical studies of cross racial IDs has shown that eyewitnesses have difficulty identifying members of another race..."

On the other hand, human beings are also subject to errors on our face identification decisions, even more than we think! This is well-known on justice courts. One of the most famous cases [8] of mistaken identity occurred in the 1896 English trial of Adolf Beck. Beck was convicted based on the identifications of ten women. He was convicted and spent 7 years in prison, all the while maintaining his innocence. He claimed he was mistaken for a man named John Smith. While Beck was still in prison, more of these offenses occurred. Smith was eventually arrested and Beck was released. Afterwards it was discovered that Beck had spent seven years in prison for a crime he did not commit, a committee was formed. The committee found that "evidence as to identity based on personal impressions, however bona fide, is perhaps of all classes of evidence the least to be relied upon, and therefore, unless supported by other facts, an unsafe basis for the verdict of a jury."

Thus, [8] concludes that "No person should be deprived of his liberty solely on the basis of eyewitness testimony unless the jury is fully aware of the ways in which such testimony may be flawed."

The conclusion of this section should be that things are not as easy as they seem, and for some recognition systems, we cannot expect 100% identification rates neither 0% false acceptance and rejection rates.

Are Human Beings Better Than Machines For Biometric Identification?

We should not be surprised if automatic face recognition systems exhibit some amount of errors. This is not exclusive of face recognition technology. In [9-10] we found that human beings outperform computers for the task of locating the characteristic points of a fingerprint. Thus, there is still room for improvement on this technology, and even better results can be expected. However, in fingerprints it is easy to define what we are looking for. Mainly it is terminations and bifurcations on the ridges of the fingerprint [11-12]. For other biometric patterns, a human being can experience troubles in identifying people, because they are not used as identifiers in our normal life. For instance, Figure 3 shows four snapshots of four hands. How many different people can we differentiate? If, instead of four hand scanned images, there were four photos of their face, the answer would be trivial.

For this quiz, plots number 1 and 4 really belong to the same female person, and 2 and 3 to another one. In this case, it is easier for a computer to work out some parameters like finger length, width, etc., and assign identities, than for a human being. Thus, there certainly are situations where a computer can outperform a person. In any case, the adoption of a biometric solution can dissuade criminals, and it is nowadays good enough for a huge set of civilian applications. Although it
is not a trivial problem, let us hope much better solutions in a near future.

REFERENCES


Planar Microwave Engineering

Thomas H. Lee
Cambridge University Press, Cambridge, UK
2004, 862 pages + CD, Hard cover
ISBN 0-521-83526-7

Scientists and engineers working in the fields of radio and microwaves have always been hard-working authors as well. Since the days of the Second World War—and even before—we have entire libraries of high quality books in many languages describing the various design methods, applications, physical backgrounds, and later, also computer simulations of RF circuits, devices, and equipment. However, as many of our readers are well aware, the vast majority of written material is inherently of narrow scope. An entire 1000-page giant can be full of electromagnetic theory, and its author possibly still calls it “An Introduction.” We have seen some attempts of broader approach, but typically such books have been crunched to unreasonably low page numbers and they have turned more to entry-level illustrative collections of practical engineering.

Cambridge University Press mailed to me some months ago an interesting set of their recent titles that they thought might be of interest to Systems readers. I picked Planar Microwave Engineering, authored by Professor Thomas Lee, for a closer look, because already its Preface suggested that this time we may have the opportunity to get a real multi-purpose RF engineering book—something that is typically of more use to system engineers and scientists in the laboratory. In its 23 separate chapters, the book covers some basic microwave circuit concepts and theory, the Smith chart with its applications, connectors and cables, passives, microstrip and stripline design, diodes, mixers, transistors, amplifiers (both high power and low noise), oscillators, synthesizers, antennas, filters and measurement methods, and devices such as spectrum analyzers, oscilloscopes, network analyzers, and noise figure instrumentation. The text in this book is told to be a considerable extension of lecture material used at Stanford University.

The author of Planar Microwave Engineering, Professor Thomas H. Lee got his degree from the Massachusetts Institute of Technology and currently has his office at Stanford University. He has been a Distinguished Lecturer of the IEEE Solid-State Circuits Society and the Microwave Theory and Techniques Society. More than one hundred scientific and technical papers have already come from his prestigious work, earning him four Best Paper Awards in key conferences plus the Packard Foundation Fellowship. Besides the current book under review, Professor Lee has authored The Design of CMOS Radio-Frequency Circuits. His engineering career is very impressive as well. According to our sources, Lee holds close to forty US patents and has been one of the founders in several commercial enterprises, most notably in Matrix Semiconductor. Taking into account such a long professional and educational career, we can imagine that Professor Lee certainly has one of the best possible starting points for authoring the above listed topical areas.

Besides its 23 main chapters, Planar Microwave Engineering has 21 appendices “embedded” in the chapters. The total number of pages is 862 and partly due to this there is a list of not less than 2000 index words. My normal counting indicates about 600 illustrations, 59 tables, and 1250 equations. There are no lists of reference literature but instead we have 620 footnotes, many of which actually serve as references. As if this were not enough, there is an attached CD as well. It comes with many design and analysis software packages suitable for university courses or own trials such as SonnetLite 9.51, Mstrip40, EZNEC 3.0, The Motorola Impedance Matching Program, Puff, LTSpice, Ladder, EZPLL, PLL_LpFilt, AppCAD, RFsimm99, Eagle 4.11, and PCB Elegance. Because we understand that these packages have not been developed solely for Planar Microwave Engineering, we don’t analyze their obviously valuable contents or features any deeper. The CD further has the US spectrum chart, two Smith charts, and Maxwell’s biography.

The book starts with a historical introduction that certainly gives new thoughts to students. Professor Lee has apparently an interest in technical history—so deep is the discussion here. Small anecdotes, author’s comments and evaluations, and real patent and design documents make the story come “alive.” Throughout the book, the author has tried to keep a balance between mathematical manipulations and descriptions of circuits. Maxwell’s equations and integrals appear in the fundamental chapters, e.g., when working with the Smith chart and impedance matching, but the majority of mathematics in this book is simplified calculus. The long practical experience has encouraged the author to use a style where he tells the readers “how to” and defines the ways in which a particular circuit is hoped to work. This has led to rather long
explanations and occasionally there is a risk of losing the point into a verbal jungle (an amusing one). However, the individual chapters are mostly of very suitable size, perhaps slightly shorter on the average than those in competing volumes. It is therefore easy for a novice to concentrate on one topic at a time, say, noise figure measurements, without fear of being trapped under a huge amount of new information before the end of the chapter is reached. By the way, Professor Lee continues his comments and historical notes throughout the book, so beware! His writing style is very informal at times, amusing and relaxed. Such freedom is not given to everyone authoring similar books. It may well be that a group of professional colleagues considers jokes and exaggerations to be less appropriate in technical books but students seem to benefit educationally of relaxed “easy reading” and “easy listening.”

Typical microwave circuit modules and individual components are discussed in Planar Microwave Engineering from various viewpoints. It is particularly fine that the practical test, tuning, and measurement procedures are included. The text is supported by high-quality drawings and illustrations. Photographs appear less often. However – as is usual with software screen dumps in almost all books and magazines – outputs of simulations suffer from vanishing font sizes, for example in Chapter 12 the amplifier plots are hardly readable. What is good in a full-size PC screen is not that after a 1:4 reduction. For strange reasons Figure 1.16 is fully identical to Fig. 2.1 only a couple of pages ahead. Many items are treated in Planar Microwave Engineering in a manner far better than usual. Radio frequency aspects of resistors, capacitors, and coils and lumped element couplers are good examples. Hobby-type projects are utilized in selected places to support the book’s main message. In Chapter 8, we read about a low-cost slotted line and a fast pulse generator, both suitable for home lab impedance measurements. Real component values and physical dimensions are given, too. Some might think the “penny” diode detector example of Chapter 9 approaches the limit, it is indeed fun and illustrative in engineering sense but could also be slightly too far away from the main path. Or perhaps it is fine as it is.

In Chapter 12 the author gives real design examples of transistor amplifiers. Typical textbooks seldom indicate realistic component values but here the reader is sure to get those. However, transistor parameters might have been included as a small table, e.g., on page 402. Otherwise a distant reader (such as this reviewer) should rush to the manufacturer’s www-pages, but my cottage no more has such luxury – the student youngsters of our family have their permanent residence in the university campus dormitory! The following chapters include numerous tips for practical circuit layouts, for example, for low-cost PCB low-noise amplifiers and measuring set-ups. Occasionally, the warnings and guidelines are so overwhelming that a first-time reader (the poor student) could get confused and we find him or her later sitting under the lab table, weakly weeping. He or she might not have the courage to touch any item on the test set-up after all those alarming messages. But, taking into account the desperately expensive microwave equipment it is still better to announce a loud warning than to lose a VNA.

Some chapters, e.g., number 14 on noise figure measurements, are pretty short indeed. Waveguides are covered in two pages only – maybe they are not needed here at all. In general, final circuit diagrams containing detailed component values, types, and physical dimensions are normally not shown. You must pick those from the text. Very few real measurement results have been included. Although the book’s name contains the word “Planar,” many places in which a microstrip circuit element would have been an alternative show just a lumped approximation. Additionally, small details, partly of editorial nature, popped up while I was going through Lee’s book. There is almost one footnote for every page. If it were just the references, that would not cause too much trouble but the point is that Professor Lee has also added some really interesting and even important details down there. This implies that a motivated reader can get tired because he or she has to continuously monitor two things – the main text and the footnotes. The publisher might well consider (for the next edition) changing the arrangement so as to have classical References after each main chapter and only very limited footnotes. Interestingly still, in many cases the author actually repeats the key idea of a preceding footnote in one of the coming subsections of his text!

Occasionally I could not fully agree with the author. In Appendix B of Chapter 3 the author describes the background that once gave us 50 ohms as standard RF line impedance but, unfortunately, omits one very important issue – the fact that we have to live with 50-ohm test instrumentation in most cases and therefore there seldom is any real freedom! Chapter 5 about connectors is fine and well motivated but should have had full-size cross-sectional drawings and proper photographs – now the reader can’t see the difference between SMA, SMB, and SMC types, for example. I don’t agree with the author about the upper practical frequency range of commercial BNC connectors – in most cases 500 MHz or so tends to be the real maximum instead of 3-4 GHz. Certain brands do better but if one is really forced to go the low-cost way, then it’s better to be conservative here. The author is very correct in asking the readers to discard mismatched connectors but does not mention that the most important reason is that such items will spread the destruction to the following counterparts. Two important omissions come up: the tendency of foam dielectrics to absorb moisture is not described nor is there any mention about the need for double-screened coaxial cable in very many RF applications.

RF transformers are not so well outlined in Chapter 6, where only some very basic transformer theory is given. Then in Chapter 7, the proper coax-to-microstrip transition is barely mentioned (and considered too expensive) and a lot of space is used to describe a nice but purely hobbyist-grade alternative. I can’t see the real problem with edge-mounted connectors although I have used the low-cost design suggested by the author as well. Typical microstrip designs will have impedance...
levels unsuitable for any intermittent measurement couplings (unless one wants to apply only the probing principle outlined by Professor Lee). Vector network analyzers are shown in Chapter 8 not as the first or the second way of impedance measurement but come as number three alternative and their calibration procedures—although discussed in a rather lengthy way—remain somehow unclear. Time domain reflectometry is interesting and sometimes the only way to go, but VNA is the tool for the majority of everyday impedance measurements.

Diodes, mixers, and transistors are basically covered well, but there is not that much true practical connection here. The text looks pretty similar to the dozen other RF books. Oscillators in Chapter 15 appear mainly on an introductory level. Very little actual dimensioning guidance for the student's first real RF oscillator is given. As the author tells it, making an oscillator work is not so easy. The PLL design example is in true numbers, but for a task-specific Motorola IC. Then, the 4046-chip story is sad in that the author wants to use its built-in very low frequency VCO. I would have liked the prescaler issues (and problems) covered somewhere around here. In Chapter 18, the spectrum analyzer measurement method is actually hidden from the subtitles although it is there properly, as the first phase noise evaluation process. This is just an editorial issue. Following this, Chapter 19 comes in a rather strange order—after phase noise measurements and before power amplifier design. I would have liked to see the various circuit blocks appear one after the other. Finally, real patch antenna dimensioning is not included in Chapter 21, although suitable experimental data, also for a home lab enthusiast, would be readily available. The necessary drawings are already there but the physical dimensions should be added!

As a conclusion to my review, Planar Microwave Engineering is a massive, well-written book. It contains—contrary to many other RF books—a reasonable mixture of analytical equations and practical circuits suitable for rapid laboratory experiments and classes. With some minor adjustments, additions (it is not that serious, if you already have 862 pages, you surely can afford 950) and editorial polishing, it could well become the book of microwave engineering. The scope is very wide and therefore one can't expect a unified level of treatment everywhere. In fact, we can possibly forget the first word of the title due to the comprehensive nature of this book. Professor Lee's very friendly style and the high publishing standards make reading and using this text pleasant. As such Planar Microwave Engineering is suitable for everyday engineering use and for advanced university classes.

Reviewed by Pekka Eskelinen
Digital Avionics Systems Conference

UPCOMING 2005 DIGITAL AVIONICS SYSTEMS CONFERENCE (DASC)

The 2005 DASC will be held in Washington, DC, October 30- November 3, 2005 with the theme “Avionics in a Changing Market Place - Safe and Secure?” Sponsored by the IEEE Aerospace and Electronic Systems Society (AESS) and the American Institute of Aeronautics and Astronautics (AIAA), this conference will bring together leading technical experts in the fields of Digital Avionics and Systems Engineering from around the globe. The 2005 DASC will focus on how to develop safe and secure next generation avionics, looking at improvements that apply to commercial, military, and space electronics. It is anticipated that this modernization will include air traffic architectures, communications infrastructure (NEXCOM), and GPS-based navigation (WAAS and LAAS). As is customary, the 2005 DASC will offer two full days of Professional Education sessions led by experts in the field.

The 2005 Conference Chair is George Andrew of Booz Allen and Hamilton with Technical Program Chairs Paul Kostek of Boeing and John Moore, Rockwell Collins. Glen Logan of American Systems will again be Exhibits Chair.

For more information, contact the DASC website at: www.dasconline.org.

HIGHLIGHTS OF THE 2004 DASC

Last year’s (23rd) DASC, with the theme “Avionics Systems: Transitioning to the Next Generation,” was held in Salt Lake City, Utah. 188 papers highlighting advances in digital electronics and systems engineering were presented in 44 sessions organized into 13 tracks. Subjects included air traffic management, UAV/UCAV avionics, systems/software engineering, human factors, and open systems—among others. The technical program was preceded by 24 tutorials.

INTRODUCTION

2004 Conference General Chair, James Rankin of the Avionics Engineering Center at Ohio University, welcomed participants and encouraged them to attend the various special programs. Technical program co-chairs were George Andres, Booz, Allen and Hamilton and John Gonda of MITRE CAASD. A special technical panel focused on Electronic Flight Bags (EFBs). The social program included an exhibitor’s luncheon and evening receptions plus a variety of tours for spouses and other guests.

PLENARY SESSION

A Plenary session kicked off the conference by highlighting changes that could hasten transition to the next generation of avionics. These new avionics are intended to integrate a variety of operational concepts that span commercial, military, and space environments. To achieve this end a number of integrated project teams (IPTs), with representatives from industry and government, have been formed to review and study system characteristics and identify needed improvements.

John Kern, FAA member of the interagency Joint Planning and Development Office (JPDO), began the plenary by
highlighting the challenges in transition of today’s ATM system to the next generation. R&D programs are being developed to provide advanced capabilities that will transform FAA operations. Because of 9-11 the US will probably keep primary radar as a backup far into the future.

MITRE CAASD director David Hamrich identified capacity, efficiency and safety as key concerns for any advanced avionics system. A performance-based National Airspace System (NAS) that reconfigures airspace and uses advanced avionics and procedures will be required. This new NAS roadmap can offer increased efficiency and lower cost by introducing new technologies and eliminating old or unneeded systems. New performance capabilities are expected to include CPDLC, Sat Com, GPS, ADS/multilateration, and integrated avionics. With traffic virtually back to 2000/2001 levels, and traffic congestion delays looming, action is required now. Impending controller retirements and decreasing budgets magnify this urgency.

Steve Bradford, FAA Air Traffic Chief Scientist, described their new FAA organization and its approach to increasing capacity and efficiency. Reducing altitude separation (RVSM) to 1000 feet is a recent example of how to increase airspace capacity. As budgets decrease over the next 5 years, the new FAA organization will focus on automation and infrastructure enhancements. Improvements 5-10 years out will include increased use of EFIs, digital communications, and digital cockpit displays. Longer term (years 11-15) Bradford expects to see radios replaced to meet spectrum requirements and transition of surveillance from secondary radar to ADS-B.

Daryl Israel, Director, Ogden Air Logistics Center (ALC), discussed challenges for today and tomorrow. As on-board systems become more integrated, increased bandwidth will be required so that the 1553 databus must be updated/replaced to provide necessary throughput. Other technical challenges include fiber optics, the glass cockpit, and improved HUDs. To ease loading and verifying test software the test and evaluation (T&E) equipment is becoming laptop computer based. Maintenance and Operations (M & O) in the future will be driven by transition to the net-centric battlefield.

Nan Mattai, Rockwell Collins VP of Engineering, described avionics transition from a contractor’s point of view. Open architectures between business, air transport and military aircraft has become more common. To be more cost-effective, open systems must be real-time and information-based.

Fig. 4. Plenary Speaker, Nan Mattai of Rockwell Collins

Fig. 5. Cleon Anderson (l) and Jim Rankin with Ervin Gangl, IEEE-AESS 2004 Pioneer Awardee

Industry is already leveraging commercial technology into the military marketplace. The first commercial-to-military application was the installation of Global ATM (GATM) systems in AF KC-135’s. To ensure performance and overcome today’s security threats, new avionics designs must begin with extensive modeling and simulation.

PRESENTATION OF AWARDS

IEEE AESS Pioneer Award

Incoming 2005 IEEE President Cleon Anderson presented the IEEE AESS Pioneer Award to Ervin Gangl, inventor of the MIL-STD-1553 data bus. After Mr. Anderson highlighted
Gangl's accomplishments, Erv described the rocky road he traveled to gain acceptance and approval of the data bus concept. His remarks can be found in the May 2005 issue of *Systems*, (20, 5).

**Best Papers**

Best paper awards were presented for each track. The Track 13 winner, *Next Generation Avionics*, by **Randy Black** will be published in *Systems* later this year.

The **Best of Conference award** went to **M.S. Ali, R. Bhagavathula** and **R. Pendse**, all from Wichita State, for *Airplane Data Networks and Security Issues*.

**IEEE 2005 President Clean Anderson with Jeanne & Erv Gangl following the presentation at DASC 2004**

Student Paper Award winners were **Cecilia Aragon, Cary Feldstein** and **Thomas Riviere**.

Additional information on the 2004 DASC, including an up-to-date program, viewgraphs from the Plenary, and a variety of photos, can be found at www.dasconline.org. A copy of the 2004 (23rd) *DASC Proceedings* is available by contacting IEEE publications, Piscataway, NJ at (800) 678-IEEE or via e-mail at: customerservices@ieee.org.
FROM THE EDITOR-IN-CHIEF

VOTE! – Centerfold – Tutorial II

VOTE! Your IEEE Ballot will arrive next month. Mark your calendar now so that your input will be recorded. Many IEEE elections have been decided by a very narrow margin, due to apathy about voting by our membership. Let's be sure AESS is heard, and VOTE! when your ballot arrives. Online voting is also available.

At the Centerfold of this issue we have included a contribution that was, after many reviews, deemed of such importance we had to give you the opportunity to read it in its entirety. As you will read in my introduction to the contribution, it is not material that fits neatly into one of our three publishing categories: Systems articles, Transactions contributions, and Tutorial subjects. We have opened this avenue for bringing the best in our field to you, with no need to force-fit it to appear in an existing publishing category. Please let us know your opinions.

Part Two of this issue is Tutorial II, the second in our new series. We hope you find it educational and useful. Tutorial III is already well on its way for early 2006. Again, please let us know your thoughts; your responses to Tutorial I were almost unanimous in praise, especially of the quality of content. Those comments will be used together with responses to Tutorial II to guide us as we proceed down this path of increased service and quality content to you, our readers.

— Evelyn Hirt

New Portal Personalizes Member Information

As an IEEE member, if you've ever tried to learn the names of the journals to which you subscribe, wanted to buy life insurance, or needed to submit a change of address, you've probably been frustrated by the number of IEEE sites you had to visit before you found what you wanted. No more! A new site – dubbed the Member Portal – now brings together in one location links to information about all the features and benefits of membership.

Find out more at: http://boldfish.ieee.org/u/360/06861272.

Job Site Takes Global View

The change is in its early stages, but thanks to volunteers and staff, the IEEE Job Site is becoming a more useful tool for members seeking jobs outside the United States. The site features help-wanted postings from Asia, Canada, Europe, and Latin America.

Find out more at: http://boldfish.ieee.org/u/361/06861272.
Visiting India as a Distinguished Lecturer

Sajjad H. Durrani

I had the pleasure and honor of visiting three Sections in India in January 2005, sponsored by the AES Society’s Distinguished Lecturers Program (DLP). It all started with a simple invitation from Dr. M.A. Joshi, a Professor at the Pune Institute of Engineering and Technology (PIET); she was the Convenor of an International Conference on Multidisciplinary Aspects of Engineering and wanted me to give a tutorial on Satellite Communications. Pune is part of the Bombay Section, and when Dr. J. Vasi, a Past Section Chair, learnt about it, he asked me to speak to me to speak there as well. I was happy to accept the invitation, because I would have to go through Bombay (or Mumbai, as it is called now) on the way to Pune in any case (Figure 1).

The First Stop: Bombay

Bombay is a State Capital and the second largest city in India, with a population of about 18 million spread over several ethnic and religious groups. It is a bustling port city and commercial center, and has many shrines, places of worship, parks, beaches, and monuments from the British era as well as preceding centuries. Since we arrived on a weekend, we had plenty of time for sightseeing, and we visited many of the attractions, including caves with Buddhist statues hewn into rocks about 1900 years ago.

Dr. Vasi teaches at the Indian Institute of Technology (IIT) in Bombay, which is one of eight such institutes in India. It has modern well-equipped labs and offers graduate and undergraduate programs to about 4000 students selected on the basis of a tough competitive examination. The campus is located on the shore of a lake several kilometers outside the city and offers a serene and beautiful environment conducive to study and introspection – in sharp contrast to the crowded stores and busy roads just outside the campus perimeter. Most of the students live on campus, in eleven “hostels” (dormitories) for men and two for women. There are two faculty guesthouses and several other facilities typical of a large university. Some alumni of the Institute have become highly successful businessmen and have made large donations, so that several buildings bear their names. Two very new and spectacular hostels, shaped like a ship and overlooking the lake, were also donated by an alumnus who made it well in industry.

The Section organized my talk at the IIT, which was attended by about 150 students and faculty members. The talk was a condensed version of a tutorial which I have presented at several Sections under the auspices of the AESS – DLP. It traced the growth of satellite communications over the last forty years, gave an overview of the technologies, services, and regulatory issues involved from its infancy in the 1960s through maturity in the 1980s, and concluded with a discussion of the technical and business-related challenges faced by the industry in the 21st century. A short Question and Answer period followed.

The Section also arranged a dinner of the IEEE Executive Committee in a local hotel, where several current and past
THE SECOND STOP: PUNE

PIET is a venerable institution, which celebrated its 150th year in 2004. Its Director, Dr. Ashok Ghatol, welcomed us and gave an overview of their activities and goals. The Institute has several fully accredited programs and a large student body. They are conducting a vigorous process to improve the curriculum, and a number of labs are being upgraded with help from the Federal Government and the World Bank. The campus is located on the bank of a river and has an active Boat Club, which competes against other similar clubs in an Annual Regatta and is a source of pride for the college.

Dr. Joshi is Head of Electronics and Telecommunications Department, and also Chairs the Women in Engineering (WIE) Affinity Group, which has 500 members and is the largest such group in the world. Among other activities, WIE has been conducting a Community Development Program in rural schools, in order to get girls interested in science and technology.

Fig. 2. Presentation to each speaker at IMAE

Fig. 3. Keynote Speaker Recognition

Fig. 4. The Audience

The Conference lasted two days and was extremely well-organized, mostly by women engineers and students. Several prominent women spoke at a keynote session. They included Mrs. Mehendale, a Joint Secretary in the Ministry of Petroleum and National Gas, and Mrs. Poonawala, head of a charitable organization. Many women engineers gave technical papers; a few men also participated but they were a distinct minority!

My tutorial on Satellite Communications was given to a full house of more than 250 attendees, and was well-received. Another tutorial, on Telemedicine, was given by Prof. D. Konditi of Kenya, who had received his doctorate from an Indian university several years ago. Two other tutorials were on Signal Processing by Dr. (Mrs.) P. Rao of PTET, and on Radar Level Gauges by Mr. D. Vyavahare from a local firm.

On the second day, there were several parallel technical sessions. I chaired one of them, and attended some others. As a whole, the Conference was highly successful and was a showcase for what women engineers can accomplish in a modern technology-based society with a little help from their male colleagues.

Three pictures from the Conference will give readers a glimpse of the proceedings:

- When each speaker came to the podium, two ladies formally presented a plaque and a bouquet to him (or her) (Figure 2);
- The Panel Members applauding the Keynote Speaker, Mrs. Mehendale, who is holding a presented plaque (Figure 3);
- A view of the colorful audience in a part of the auditorium (Figure 4), about half of the large hall.

We were invited to visit a neighboring institution, Cummins College of Engineering for Women, established in 1991; the first such college in India. It is run by a not-for-profit organization founded in 1896 and is named after a local...
company, Cummins Diesel Foundation, which made a large
donation to get the College started. We were impressed by the
facilities: 18 classrooms, 40 laboratories, and a workshop and a
hostel for 825 students. It offers fully accredited B.E. degrees
in four disciplines: Electronics & Telecommunications;
Computer Engineering; Instrumentation & Control; and
Information Technology.

Although we were in Pune for three days, I was busy with
the Conference most of the time and could not do any
sightseeing. However, some of the ladies very graciously took
my wife to see several historical sites, and she greatly enjoyed
their company and the trips.

THE FINAL STOP: DELHI

Delhi needs no introduction: it is well known as the Capital
of India with many historical buildings and monuments – some
of which have been designated parts of the World Cultural
Heritage. Our stop there was arranged by Dr. R.G. Gupta,
who is a senior civil servant in the Ministry of Information
Technology and has held many offices in the IEEE Delhi
Section. He proposed to arrange a meeting in his department or
under the auspices of the Delhi Section. However, the dates of
my stay were somewhat uncertain, which caused some
confusion in scheduling in spite of several last minute e-mails.
Thanks to the perseverance of the current Section Chair, Dr.
Subrata Mukhopadhyay, the lecture was finally organized at
the IIT in Delhi, but it had only a small audience, consisting of
the Section Officers and a few faculty members and students.

An interesting sideline to the visit: In 2001, the Washington
& Delhi Sections had become Sister Sections – the first such
pair in the IEEE. This came about primarily due to the efforts
of Dr. Shyam Bajpai, who was then the Washington Section
Chair, and the support of his counterpart in Delhi, Dr.
Balasubramanian. As a Past Chair of Washington Section, I
had intended to visit the Delhi Section in December 2001 and
convey our greetings to them but had to cancel the trip for
personal reasons. The current trip allowed us to make up for it.
Thus, the Delhi Section held a brief ceremony at the end of my
talk when we exchanged greetings from the Sister Sections. I
was especially pleased that Dr. Balasubramanian was able to
attend the function.

During the Delhi stop, we saw several historical sites and
took a side-trip to Agra. The Taj Mahal fully stood up to its
reputation as one of the Wonders of the World, and I was struck
by the restorations of the main monument and improvements
in and around the grounds since my last visit 20 years ago. We
also visited some forts and shrines, including a 72 m tall tower
built in the 12th century and the tombs of two poets from the
Mogul era, about whom I used to read in my college days.

THE REST OF THE STORY

Our total stay in India was rather short – just shy of two
weeks – but it covered a lot of ground. After that, we went to
Pakistan for a week to visit family and old friends in Lahore
and Islamabad. During another private visit in 2003, I had
spoken at meetings of the IEEE Section in both cities and had
given a short course on Satellite Communications at the
University of Engineering and Technology in Lahore. I could
not do something like it this time, but was pleased to learn that
the IEEE was in good hands, with a lot of interaction between
academia and industry. Several private entities and
non-governmental organizations (NGOs) were offering
Programs to promote literacy and IT skills in rural areas and
establishing Study Centers and other facilities with the support
of village elders and community leaders. Here also some
alumnae are providing support to their alma maters, but not on
the same scale as India – Pakistan doesn’t have as many
successful businessmen as India!

I learnt a lot from my visit, and found once again that the
AESS Distinguished Lecturers Program is a great vehicle for the
exchange of information as well as for creating goodwill
among IEEE members worldwide. In my new role as the AESS
VP-Education, I will strive to organize additional Tutorials and
Short Courses under our Continuing Education Program – but
will leave that topic for a future discussion. In the meantime, I
welcome your feedback and suggestions.
M. Barry Carlton Memorial Award for 2003


This award was established in 1937 by friends of the late M. Barry Carlton who dedicated his life, and finally gave it, promoting the reliability of communications equipment, particularly that carried in aircraft. It is ironic that he died, on June 30, 1956, in the greatest commercial air disaster in history to that date. In this disaster two airplanes crashed in the Grand Canyon in Northern Arizona, in a midair collision, killing all 128 persons aboard.

Excerpts From Nomination Letters

Excerpts from the letters received in support of the nomination of the 2003 MBC Award paper are presented to illustrate what the nominators thought of this contribution. Comments similar to those that follow are what keeps IEEE Transactions on Aerospace & Electronic Systems consistently among the top-rated journals in the field.

This work considers the practical implementation of modern adaptive signal processing for target detection in advanced radar systems—a very propitious technology that attracts a high level of interest among AES members and the general radar community. The meticulously benchmarking of various detection schemes using carefully collected experimental data from two state-of-the-art (sky-wave and surface-wave) over-the-horizon (OTH) radar systems makes this paper extraordinary. To the best of my knowledge, this is the first paper to convincingly demonstrate the promised advantages of the estimated adaptive subspace detector (ASD) with respect to the adaptive matched filter (AMF) and conventional tapered beamformer (OTB) on live data in a real-world radar application. The significance of the results to actual radar performance is striking and this work represents a key advance in the state-of-the-art for multi-channel adaptive radar detection.

Specifically, the paper introduces the use of alternative models for the signal of interest (i.e., a multi-rank subspace model) and the jamming disturbance (i.e., a compound-Gaussian model) that are experimentally shown to be more realistic than traditionally used antenna array processing models. The authors present a high quality and well-organized analysis to validate theoretical expectations for the AMF and ASD using measured OTH radar data. In addition, the paper proposes an original theoretical extension of ASD to address the problem of false alarms caused by coherent sidelobe signals, a practical issue that is often overlooked. Apart from the unique experimental analysis and novel theoretical contribution, this scholarly paper is also extremely well-written and self-contained with a clear description of the relationship links to previous work.

In my opinion, this is a remarkable paper containing a rare balance of experimental and theoretical treatments in the area of practical adaptive target detection at a time of intense interest to the radar community.

Jian Li, University of Florida

This work describes possible detection procedures in an OTH radar system. The target detection technique is very specific in the OTH application case due to the specific interference situation and the specific desired signal structure. The spatially structured interferences are superimposed by jamming pulses which will occur in practical applications. The desired target structure can even derive from the classical plane wave model. This new technical task and technical challenge has been carried out in an analytical way and with first experimental experiences which are described in the paper. This signal situation is described in mathematical model and in analytical form. System comparisons are carried out on a quantitative performance basis. In a sky-wave and surface-wave OTH radar measurement situation several detection schemes, e.g., spatial processing of conventional beamformer, adaptive matched filter and a scale-invariant adaptive subspace detector, have been analysed and compared on a quantitative performance level. It is important to note that all these analytical steps and model assumptions have been validated by experimental measurements with an OTH radar.

The paper is clearly written, well-structured, and organized. It is an important contribution to the radar community in this specific OTH system application and the related detection procedure.

Hermann Rohling, Technische Universität Hamburg-Harburg

This work concerns the problem of detection of a subspace target signal against spatially structured jamming and noise sources. The jamming is modelled as a compound-Gaussian process and it is assumed to belong to a subspace orthogonal to that of the target signal. The validity of this model for HF antenna arrays in the Over The Horizon (OTH) radar case has been demonstrated by experimental evidence. An adaptive detector is derived for this problem by applying the concept of adaptive subspace detector (ASD) and the orthogonal rejection testing theory to an OTH radar scenario. A distinguishing aspect of this paper is the secondary data. Detector performance is validated by processing real data collected in two separate experiments, where a sky-wave and a surface-wave OTH radar were used.

This is a landmark work. To the best of my knowledge, this is the first paper to present, in such a well-organized way, experimental results that compare the spatial processing performance of the CFAR-ASD with the conventional tapered matched filter and the Adaptive Matched Filter (AMF). It tackles an extremely hot problem in the Radar Community. It is also very well-written and presents the results of extensive experimental studies very clearly and in a well-organized way. This represents a timely and very important advance towards the realization of practical systems for adaptive radar detection.

Patrizio Gini, University of Pisa

This work is devoted to an extremely important problem of signal detection in the presence of structured jammers and noise. A new relevant signal model has been developed and based on this model, a highly efficient subspace-based adaptive detector has been derived to solve the problem. The performance of the proposed detector has been validated using real OTH radar data from two different experiments.

I do think that this is a landmark, truly outstanding paper in the field of adaptive radar detection, both in terms of presenting an elegant and powerful theoretical result and in provoking convincing and comprehensive experimental results for sky-wave and surface-wave OTH radars. This paper solved a longstanding open problem in the field.

Alex Gershman, University of Duisburg-Essen
Standards and the Ultrawideband Radar Committee (UWBRC) of the IEEE Aerospace and Electronic Systems Society (AESS)

Arnold Greenspan
Chairman, AESS Standards Committee & Secretary, UWBRC

The need for, and benefit of, standards is generally acknowledged across the engineering community. As one takes a closer look at the impact of standards and the activities of the Institute of Electronic and Electrical Engineers Standards Association (IEEE-SA), some interesting aspects of standards become manifest. For example, prior to my becoming involved with the IEEE-SA as a member of the New Standards Committee (NESCO) and the Standards Board (SB), I had no idea of the disparity that existed between the various IEEE societies and their active involvement with the SA. The Power Systems Society is by far the largest element of the standards association activities in respect to standards administered. Other societies participate to a lesser extent; if viewed from another perspective, however, the picture changes.

The large volume of standards work related to the Power Systems Society reflects regulatory needs within society to coherently administer a proven technology that society depends upon. This body of standards work reflects a stable technology that is well regulated within the United States.

The largest volume of standards work reflecting new technology currently comes from the Computer Society relating to communications. There is little question in the mind of the writer that the volume would be much greater if competitive elements within industry would decide that a de jure standard that acts as a firm base for all industry growth would serve as more productive stimulus for growth than de facto competitive standards that service the short term interests of various competing industry consortia.

The remaining IEEE societies lie between the older technology of Power Systems and the new and burgeoning technology of computers and communications in respect to their standard efforts.

In the case of the AESS, the activity with, and volume of, standards efforts have been relatively small. The AESS has many liaisons to committees jointly sponsored with other societies and thus endorses and supports the standards produced by those jointly sponsored groups. There has not been a significant volume of standards work forthcoming from AESS groups such as Systems Engineering, the Radar Systems Panel or others. The reasons for this might be that the engineering efforts within the purview of AESS are not subject to massive regulation (such as power) or are the focus of high public interest (such as computers and communications). Rather, the technologies of AESS are more narrowly focused upon Department of Defense or commercial aviation applications, not that commercial aviation does not have a need for regulation and concern for public safety. These concerns are largely attended to by quasi-regulatory agencies such as Aeronautical Radio (ARINC), the commercial standard arm of the airlines industry, in concert with the Federal Avionics Administration (FAA).

I think that the standards activity level of AESS may be about to change. Recently a new committee was formed under the auspices of AESS, the Ultrawideband Radar Committee (UWBRC). This came into being through the hard work and dedication of Stephen Johnston. Mr. Johnston recognized the growing interest in and applications for Ultrawideband Radar (UWBR). Through his efforts and with the assistance of David Dobson, they gained the attention of Paul Gartz, AESS President and Jim Leonard, AESS Executive Vice President. The end result of these efforts was MY appointment as the Chair of the AESS Standards Standing Committee reporting to Jim Huddleson, Vice President-Technical of the AESS.

Shortly after this, a number of parallel activities occurred. Engineers interested in the development of UWBR were identified and a Project Authorization Request (PAR), was developed and submitted to New Standards Committee (NESCO) for the development of a standard of terms and definitions for UWBR. An operations manual was developed and submitted to the Audit Committee (AUCOM) of the SA defining the organization, operation and processes of the UWBR. The PAR was approved by NESCO, the Operations Manual was accepted by the Procedures Committee (PROCOM), and the work of the UWBR was launched.

Currently the UWBRC has established a UWBR Working Group (WG) responsible for the development of P1672 Ultrawideband Radar Standard 1672, Terms and Definitions. This working group is international in composition, consisting of 25 members, with 10 from Europe Asia and the Middle East. They met in May '05 in Washington, D. C. in conjunction with the Radar '05 Conference to review the first draft of P1672. They expect to meet next in November in Atlanta, GA.
Since the establishment of the UWBR WG, and as a result of the technical exchanges that have taken place pursuant to the P1672 effort I have come to believe that this technology will require and result in the development of a variety of new standards under the auspices of the UWBR Council and AESS.

The applications of UWBR are very diverse, including medical, nautical, military, industrial, and security applications. The variety of interests in respect to the uses for which UWBR is applied creates differences in view regarding the manner in which Ultrawideband and Ultrawideband Radar are defined. Developing a clear, consistent and effective definition for these terms and others within P1672 is the task of the working group. It is interesting to note that the sponsors of differing definitions generally support a definition consistent with the application area in which they have a particular interest. For those applications in which they show little or no interest, the consequence of omitting these areas from the umbrella of the definitions tends to be of lesser or no concern. The diversity of views further emphasizes the importance of a need for P1672 and, further, for P1672 to be as broadly usable as possible to effectively support the growth of UWBR across all applications.

The encouraging aspect of the current discussions on UWB and UWBR definitions is the attendant need for differing consideration and design for UWBR applications. This can lead to the need for one or a family of UWBR system design standards dependant upon the application of interest. Beyond the possibility of UWBR systems design standards, the need for other application areas may present themselves. Application-specific software standards, test standards, safety standards, display standards and others come quickly to mind.

The foundation laid by P1672 will provide the firm basis for effective communications across the broad field of UWBR applications. This, in turn, could result in the development of a variety or family of application specific standards which can facilitate the growth, success and effective implementation of this ubiquitous technology.

(The report of P1672 appeared in this publication in our July 2005 issue on page 39 — Editors.)

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**AESS Continuing Education Program**

The AESS Board of Governors recently developed a new strategic direction including emphasis on Education and Training. Surveys have identified these as key needs of professionals and corporations in the 21st Century, and IEEE has several resources that can be useful to help meet these needs. I want to share some of our plans and invite your ideas and suggestions.

Continuing Education (CE) is an important service to our members; we offer it through three separate Programs:

- **Distinguished Lecturers Program (DLP):**
  This on-going program supports lectures in certain specialized areas. A Chapter can invite a DL, and if he/she is available, AESS pays travel costs within limits; the Lecturer does not charge a fee. For details, see the Distinguished Lectures in this or any issue of IEEE A&E Systems.

- **Conference Related Tutorials (CRTs):**
  Many conferences offer valuable tutorials, but only attendees benefit. This will enable us to bring CRTs to your Chapters in a traditional Face-to-Face (FTF) format. We will start with a few and expand after ascertaining demand. For this Program, AESS may subsidize a part of the cost. However, financial feasibility would depend on the number of fee-paying “students,” and the willingness of local employers to pay their fees or provide space and other facilities. You can greatly help in this by identifying your technical needs and obtaining corporate support.

- **XELL Program:**
  Under this program, the Educational Activities Board (EAB) is organizing a series of courses to be offered through the Internet. EAB has selected 20 topics and Instructors, including two from AESS, and a number of corporations, including Boeing, are already beta testing this product. For details of the XELL program, please visit: www.ieee.org/organizations/eab/xell/index.htm and click on “prototypes.” If some of these courses are of interest to you, please contact Marilyn Catis, EAB at: mcatis@ieee.org for follow-up.

I look forward to hearing from you regarding specific topics for the CRTs and the XELL Program; additional ideas are always welcome!

Sajjad (Saj) Durrani  
Vice President-Education
# August 2005

## Distinguished Lecturers Program

James R. Huddle, Chairman

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 AESS 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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<th>Name</th>
<th>Contact Number</th>
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Please send all corrections and additions to him at the address on the inside back cover.
Canadian Distinguished Lectures

"I have been getting some enquiries regarding the outcome of Dr. Bill Ward's trip to Ottawa. Here is a report — which perhaps covers elements in too much detail for many. But it was a very worthwhile exercise, and everyone seemed to benefit. Bill Ward and Al Richard took quite a chunk of time for the trip. My thanks to all those who provided assistance."

Hugh Reekie
IEEE - AESS Ottawa Chapter

Bill Ward had been approached by me over 2 years ago, but he declined for health reasons. I was delighted when, in early August 2004, he finally accepted my invitation to come to Ottawa and Kingston; he offered two presentations for each city. In order to meet the IEEE Ottawa Section AGM (early November) deadline with print material on-hand, I had to act quickly — I was to be on vacation for 6 weeks, September - mid-October. To meet the theme of Beat the Winter Blues — with a Social Element, a location with a light supper was selected, and a Thursday evening in February 2005 chosen by mutual agreement. The RA Centre room could take 120 persons maximum, theatre-style; the restaurant was one minute away.

Although primarily sponsored by AESS, approaches were made to various groups, September to December, to add to the publicity and share the financial load. IEEE Chapters of VTS and Robotics/Control Systems were added, and the IEEE-UK Ottawa Centre made the 10 February event their February meeting. Later they agreed to fully sponsor the before-supper punch. A December visit to the Ottawa Chapter, Royal Astronomical Society of Canada monthly meeting, with associated publicity, also increased the attendance. Publicity included many directed e-mails; one such group was to the IEEE Life Members in the Ottawa area.

In January, it became clear that the Kingston activity would not work out, and was dropped by mutual agreement. The Radar presentation was set up at the Communications Research Centre, with assistance from the Friends of CRC — a retired group that provided publicity and necessary volunteer stuff for admission control.

Bill, with his assistant Al Richard, were so determined to get to Ottawa on time; that travel arrangements provided a 4:00 pm Wednesday arrival — for a Thursday evening initial activity. As Bill had offered a second NASA presentation, sometime on Friday during the planning stages, (it was dropped). I had the audacity to ask him if he could add a Thursday morning presentation to a High School; he kindly agreed.

Lisgar Collegiate — 10 February, 10:00 am
Bill Ward was well-received for his 1-hour presentation to grades 11, 12, and a few grade 9 and 10. He gave a toned-down version of his evening NASA presentation. Admission to the auditorium was by ticket (150 students). The High School staff could not understand how a specialist lecturer from Boston could be made available at no charge. I mentioned the IEEE, with its many Societies, and AESS as part of my introduction. NASA awareness at the school is high — 6 years ago, 2 students went on a one-week Space activity trip to NASA Houston. I also mentioned the EIR Ontario Program, which was used to make contacts. They were interested in the result.

RA Centre, 8:00 pm — NASA Space Probes and Planet / Moon Images
The logistics of transport to the RA Centre on a cold snowy night were not the most congenial, but doorside drop-off for Bill was arranged by Al and me. The Cocktail Hour had everyone chatting, with Bill setting up his gear with attention to details — a remote control extension cord coming in useful. The light supper took longer than anticipated, but the transport of 2 wheelchair attendees via the custom elevator (required between the lecture room and restaurant) worked well. Fifteen people elected to skip the supper (some were unregistered), and the RA Staff provided an extra 10 chairs quickly. The 80 attendees enjoyed the presentation; there were about 6 spouses for dinner. Seven attendees indicated they were IEEE Life Members.

Communications Research Centre — CRC — 11 February, 9:30 am
Publicity for this CRC on-site event The DEW Line and the Texas Towers included a mass e-mail to CRC Staff. Both Bill and Al had dealings (many years before) with some CRC staff — so the presentation was a bit of an Old-Home-Week for some: 24 attended. A last-minute arrangement for Al and Bill to visit the adjacent David Florida Satellite Assembly and Test Centre was a big surprise; it worked out well.

Bill and Al returned home to Boston, via Montreal on Friday without incident. A Raytheon Canada staffer, who missed the DEW line presentation, is following up information.

Postscript by Bill Ward:
Al Richard, a long-time colleague of mine at MIT's Lincoln Laboratory, accompanied me on the trip. His primary purpose was to support my talk, given at the Communications Research Centre, on the Distant-Early-Warning (DEW) Line. That talk originated in the observance of the 50th Anniversary of the Laboratory's formal establishment (1951). His assistance was also most helpful for my delivery of two Distinguished Lecturers on the exploration of the outer planets by robotic spacecraft.
IEEE AEROSPACE AND ELECTRONIC SYSTEMS SOCIETY CHAPTERS

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Hugh D. Griffeth
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Tessaloniki, Greece
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REGION 10 — Asia and Pacific
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India Council, http://www.ieee.org/10/india/council
Japan Council
South, http://www.isee.org/10/south
Australia, http://www.ieee.org/10/australia
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IEEE A&E SYSTEMS MAGAZINE, AUGUST 2005
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*In March 2005, the IEEE and the ION® entered into an agreement whereby both organizations would equally sponsor and support the technical program and conference management of the PLANS 2006 conference. As part of the agreement, the PLANS 2006 conference will replace the ION’s annual summer meeting. The ION’s annual awards and fellow awards, which are typically awarded during the ION’s summer meeting, will be awarded during the course of PLANS 2006.
We invite you to participate in the joint IEEE/ION® meeting with exciting new opportunities for technical exchange and networking.
# IEEE AEROSPACE & ELECTRONIC SYSTEMS SOCIETY ORGANIZATION

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<tr>
<th>Position</th>
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<tr>
<td>President</td>
<td>Paul E. Gartz</td>
</tr>
<tr>
<td>Executive Vice President</td>
<td>James V. Leonard</td>
</tr>
<tr>
<td>Secretary</td>
<td>John R. Weyrauch</td>
</tr>
<tr>
<td>Treasurer</td>
<td>Charles H. Gager</td>
</tr>
<tr>
<td>Vice President – Administration</td>
<td>Robert N. Trebits</td>
</tr>
<tr>
<td>Vice President – Conferences</td>
<td>Barry C. Breen</td>
</tr>
<tr>
<td>Vice President – Education</td>
<td>Sajjad H. Durrani</td>
</tr>
<tr>
<td>Vice President – Member Affairs</td>
<td>James Howard</td>
</tr>
<tr>
<td>Vice President – Publications</td>
<td>Edward K. Reedy</td>
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<td>Vice President – Technical Operations</td>
<td>James R. Huddle</td>
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## Associate Officers

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<td>Jose R. Bolanos</td>
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<tr>
<td>Associate VP – Administration</td>
<td>Open</td>
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<td>Associate VP – Conferences</td>
<td>Irm J. Weinstein</td>
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<tr>
<td>Associate VP – Education</td>
<td>Open</td>
</tr>
<tr>
<td>Associate VP – Member Affairs</td>
<td>S. Zafar Taqvi</td>
</tr>
<tr>
<td>Associate VP – Publications</td>
<td>Joel F. Walker</td>
</tr>
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## Board of Governors

### Senior Past President — Paul J. Kostek

<table>
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<th>Name</th>
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<tbody>
<tr>
<td>Evelyn H. Hirt</td>
<td>Theodore S. Sanders</td>
</tr>
<tr>
<td>James M. Rankin</td>
<td>Marina Ruggieri</td>
</tr>
<tr>
<td>Ronald L. Ticker</td>
<td>Robert N. Trebits</td>
</tr>
<tr>
<td>Irm J. Weinstein</td>
<td>John R. Weyrauch</td>
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### Junior Past President — Russell J. Lefevre

<table>
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<tr>
<td>Walter D. Downing</td>
<td>Paul E. Gartz</td>
</tr>
<tr>
<td>J. Scott Goldstein</td>
<td>Hugh D. Griffiths</td>
</tr>
<tr>
<td>Philip Holmer</td>
<td>James V. Leonard</td>
</tr>
<tr>
<td>Toseyu Takahashi</td>
<td>Peter K. Willett</td>
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### Members-at-Large

<table>
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<tbody>
<tr>
<td>W. Dale Blair</td>
<td>Jose R. Bolanos</td>
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<tr>
<td>Barry C. Breen</td>
<td>Robert P. Lyons, Jr.</td>
</tr>
<tr>
<td>Robert C. Rassa</td>
<td>Cary R. Spitzer</td>
</tr>
<tr>
<td>S. Zafar Taqvi</td>
<td>Joel F. Walker</td>
</tr>
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- Accomplishments Search – W. Cooper
- Awards – Erwin C. Gangi
  - M. Barry Carlton Award – W. Dale Blair
  - Harry Rose Mimmno Award – Ron Schroer
  - Warren D. White Award – Mark Davis
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- Transactions – W. Dale Blair
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- Target Tracking & Sensor Fusion – W.D. Blair, Chair

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- Journal of Lightwave Technology – M. Cardinale
- Transactions on Pattern Analysis & Machine Intelligence – J.R. Harris

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  - (RPT and SSTS Standards) – A. Greenspan
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- IEEE-USA, Energy Technical Policy – H. Oman
- IEEE-USA, PACE – M. Cardinale
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**IEEE A&E SYSTEMS MAGAZINE. MARCH 2005**

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### 1. NAME AS IT SHOULD APPEAR ON IEEE MAILINGS: SEND MAIL TO:  
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<tr>
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<th>BUSINESS/SCHOOL ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>If not indicated, mail will be sent to home address.</td>
<td>NOTE: Enter your name as you wish it to appear on membership card and all correspondence.</td>
</tr>
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</table>

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<thead>
<tr>
<th>TITLE</th>
<th>FIRST OR GIVEN NAME</th>
<th>MIDDLE NAME</th>
<th>SURNAME/LAST NAME</th>
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**STATE/COUNTRY**

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### 2. Are you now or were you ever a member of IEEE?  
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- [ ] No  

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- **STATE/PROVINCE:**
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### 7. 2005 IEEE MEMBER RATES

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*IEEE Canadian Business NO. 125634188  
**IEEE application is to be received by IEEE after 16 August pay full year. Subscription to Spectrum ($16.00/year) and The Institute is included in dues.

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**FULL SIGNATURE OF APPLICANT USING CREDIT CARD**

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**IEEE A&E SYSTEMS MAGAZINE, JULY 2005**