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**AESS MEETINGS & CONFERENCES**

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| March 2-3, 2005 | Military & Aerospace Electronics 2005 Conference & Exhibition | Boston, MA | Kathleen Morris, (617) 891-9164  
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**OTHER SOCIETY MEETINGS OF AESS INTEREST**

<table>
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| September 6-8, 2005 | International Radar Symposium 2005 | Berlin, Germany | German Institute of Navigation  
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Send all corrections and omissions to Barry C. Breen at his address on the inside back cover.
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In This Issue - Technically

IEEE Aerospace Conference: Junior Engineering and Science Conference

The IEEE Aerospace Conference sponsors a unique Junior Engineering and Science Conference where children in grades K-12 present talks on scientific and engineering topics. This highly successful and growing conference is designed to encourage young students to learn more about a technical topic and sharpen their presentation skills. The Junior Conference runs in much the same format as a professional engineering conference. Participants report that the experience gives them confidence and many want to pursue careers in technical fields. They also testify that the experience is fun.

GPS III System Operations Concepts

Over the past three years, the Lockheed Martin GPS III team has analyzed potential operational concepts for the Air Force. The completed tests support the government’s objective of a “realizable and operationally feasible” US Strategic Command (USSTRATCOM) and Air Force Space Command (AFSPC) concept of operations. This paper provides an overview of the operational improvements for the command and control of satellites, the provision of safe, precise navigation and timing services to end-users.

The GPS III system changes existing operational paradigms. Improved operator capabilities are enabled by a new high-speed uplink/downlink and crosslink communication architecture. Continuous connectivity allows operators a “contact one satellite—contact all satellites” concept enabling near-real-time navigation updates and telemetry monitoring. This paper describes potential improvements for the following operations: Constellation Monitoring, Command and Control, Navigation Upload Monitoring, Global Service Monitoring, Global Service Prediction, Civilian Navigation (CNAV) Messaging, and Anomaly Detection and Resolution.

This paper also describes future operational improvements as GPS applications continue to proliferate and the need for an improved infrastructure to effectively manage all the systems that affect GPS services grows.

Radar: The Evolution Since World War II

Modern radar design has benefited from the evolution of specialized digital processing, allowing high resolution ground mapping, target identification, and target tracking under many conditions. Air-to-air interception makes use of complex decision processes to select from many modes that depend on the clutter backgrounds and flight profiles. Today’s multimode radars provide this information for each task while minimizing distractions. Fire control radars support a wide selection of weapons, including cannons and guided missiles. This is possible because of advanced digital processing.

In the interval since WW II, radar design evolved from vacuum tubes to semiconductors and then to massively integrated circuits. Computers specialized for Fast Fourier Transforms (FFTs) have revolutionized radar data processing. System reliability has improved from a few hours to hundreds of hours. Effective built-in test informs ground maintenance personnel of problems for easy maintenance and low failure rates reduce or eliminate field maintenance benches at forward locations.

Optimization of the Ship’s Navigation and Controlling System With Results of Sea Trials

This paper considers the state-of-the-art information technologies applied to solve the automatic track-keeping problem of the ship on a preset system of straight tracks and on a preset route to the area of hydrographic survey. A navigation-and-controlling system aboard a hydrographic vessel GS-439 was used to provide the fulfillment of the task. The results of the sea trials of control problems are given. They have shown rather good accuracy of the ship track-keeping on a preset system of straight tracks and on a preset route as well as the efficiency of automatic ship passing to the first task and passing over to the next tasks in surveying the seabed relief, using a multi-channel echo sounder.

Software Approach to Access UWB Interference on GPS Receivers

Ever since the FCC approved the use of UWB devices in commercial and federal bands, various agencies whose operations and/or products rely on the integrity of signals within certain “restricted” radio frequency bands have voiced concerns over the potential impact of the UWB interference. GPS signals are among these “restricted” bands. Several groups in the GPS community have conducted experimental studies concerning the impact of UWB interference on the performances of various grades of commercial and aviation GPS receivers.

In this paper, we present a software approach to simulate and evaluate UWB interface on GPS receivers. The software approach provides greater flexibility in the design of testing scenarios, such as the inclusion of a large number of aggregated UWB devices, the generation of new UWB signals and modulation schemes, and the possibility of extending the study to new GPS signals. The paper will discuss a general framework for developing algorithms to evaluate UWB and GPS interference under a wide variety of hardware and software conditions. This framework consists of three classes of components: Input, Processing, and Analysis. The input components are responsible for the generation of UWB signal waveforms and modulation schemes, and GPS signals. The processing components include a simulated model of GPS RF front end and software implementation of GPS processing blocks, such as acquisition, tracking, and post-processing. The Analysis components focus on the study of specific receiver processing component outputs. Both real and simulated UWB signals can be used in the study. The real UWB signals are primarily used to validate the simulation procedure, whereas the simulated UWB signals are used to allow the immediate incorporation of new UWB waveforms and modulations in the evaluations.

Data Fusion in Biometrics

Any biometric system has drawbacks and cannot warranty 100% identification rates, nor 0% False Acceptance and Rejection Ratios. One way to overcome the limitations is through a combination of different biometric systems. In addition, a multimodal biometric recognition is more difficult to fool than a single biometric system, because it is more unlikely to defeat two or three biometric systems than one. This paper summarizes the different data fusion levels, and how it must be performed in order to improve the results of each combined system on its own.
IEEE Aerospace Conference: 
Junior Engineering and Science Conference

Sue Ellen Haupt and Randy L. Haupt 
The Pennsylvania State University

ABSTRACT

The IEEE Aerospace Conference sponsors a unique Junior Engineering and Science Conference where children in grades K-12 present talks on scientific and engineering topics. This highly successful and growing conference is designed to encourage young students to learn more about a technical topic and sharpen their presentation skills. The Junior Conference runs in much the same format as a professional engineering conference. Participants report that the experience gives them confidence and many want to pursue careers in technical fields. They also testify that the experience is fun!

MOTIVATION

Engineers need to become involved in K-12 education in order to generate a technically qualified workforce for the future. School teachers and counselors are not familiar with engineering and typically do not encourage students to become engineers. Students do not take engineering courses in K-12 but do get courses in science, math, and other related subjects. Feeble attempts at technology courses in middle and high school often turn students off and are certainly not representative of college engineering courses. Until appropriate changes occur in K-12, we engineers must find innovative ways to teach children about our profession and encourage bright students into engineering, as pointed out in a recent guest editorial in the IEEE Transactions on Education [1]. Positive exposure to engineering and science must occur prior to college in order to recruit future engineers. Engineers primarily reach out to K-12 students through either the formal school system or activities outside of the normal school day. There are some excellent programs for children to learn about design, science, math, and technology, such as science fairs (perhaps these should be renamed science and engineering fairs), robotics education projects and contests, computer programming competitions (both in school or extracurricular), Science Olympiad, MATHCOUNTS (a math coaching and competition program for middle school students sponsored by the National Society of Professional Engineers), Odyssey of the Mind (a team competition that fosters creative thinking), CRAFTSMAN/NSTA Young Inventors Award Program, Future Scientists and Engineers of America, Naval High School Science Awards Program, and Girl Scout and Boy Scout Badge Projects and camps. There are beginning to be more university or externally sponsored events, such as the Engineering Day for Girl Scouts run at Utah State University where Girl Scouts earn a science or technology badge by circulating through hands-on engineering activities planned by professors and university students. These and many other programs generally offer students opportunities to build projects and compete with their peers.

Of these external projects, many are geared to expose a large number of students to basic science, mathematics, and engineering concepts while others seek to offer experiences to a smaller number of students already motivated in the direction of technical interests. The Junior Conference was created for the latter, where the participants volunteer for a particular experience in science or engineering. It is sponsored solely by an engineering conference and devised to encourage pre-college students to sample how real engineers and scientists do research and present their findings. Although web searches do not readily turn up any similar conferences, we have heard that a couple may be occurring in other countries.

THE JUNIOR ENGINEERING AND SCIENCE CONFERENCE

The conference committee of the IEEE Aerospace Conference developed a novel approach to augmenting children’s science and technical education. Each year, the conference sponsors a Junior Engineering and Science Conference in conjunction with their professional Aerospace Conference. This unique Junior Conference allows students in grades K-12 to make technical presentations in a professional conference setting. The goal of the Junior Conference is to allow students a venue where they can choose their own topic, research it at an appropriate level with professional mentoring,
and present a technical talk with visual aids to a group of engineers and scientists.

The Junior Engineering and Science Conference challenges children at their own level. Younger children investigate a subject appropriate for their grade, although often even more advanced. The older participants usually delve into quite complex topics and do experimental work. The conference is not competitive, encourages each participant to do her or his best, and emphasizes positive feedback from the audience. In general, the participants express a sense of high accomplishment after their presentations. Their self-esteem and confidence soar after they work on a technical project and present their findings to an audience of interested peers, engineers, and scientists.

An interesting side benefit of the conference is the high interest level of the professional conference attendees. The Junior Conference is held during downtimes in the professional conference schedule. Many engineers and scientists attend the Junior Conference, ask questions, and encourage the children. The adults and kids learn and have fun. This is mentoring at its best!

The Junior Conference grew from one participant in 1995 to a high of 21 talks in 2002, the year primarily reported here which was the fifth year that we co-chaired the conference. Figure 1 shows that initial growth was steady except for the 2000 conference when the IEEE Aerospace Conference first moved from Snowmass, Colorado to Big Sky, Montana. Only two of the 21 children that presented in 2002 did not have a parent registered in the professional conference. The expense, missed school, lack of advertising, and travel arrangements associated with the Junior Conference discourage widespread participation by children without parents attending the professional conference.

CONFERENCE PREPARATION

Organizing the Junior Conference is similar to organizing a major engineering conference, except a bit more personal care must be taken in dealing with children. As for most conferences, recruiting speakers who are willing to do appropriate scientific research projects is accomplished in a couple of ways. The first is via a Call for Papers specific to the Junior Conference, embedded in the packet sent to potential Aerospace Conference participants and on the Aerospace Conference website: http://www.aeroconf.org/. At the website, the Junior Conference is advertised both on the general on-line “Call for Papers” as well as on a website set up specifically for the Junior Conference, since the most likely Junior Conference participants are guests of adults who plan to travel to the conference. A second means of recruitment is to send e-mail to registrants of the Aerospace Conference to inform them of the Junior Conference. Word of mouth is also a great recruiting mechanism. When engineers and scientists are told about this Junior Conference, many say “I would love to have my child participate.” The Junior Conference organizers send personal e-mail to children who have participated in previous Junior Conferences. These are the “invited speakers.”

Fig. 1. Growth in the number of presenters at the Junior Engineering and Science Conference

Fig. 2. A kindergarten student gives a PowerPoint presentation in the auditorium

Once children express interest in the Junior Conference, the organizers send encouraging e-mail. We have found that having examples of presentations from prior conferences available on the web (accessible from the IEEE Aerospace Conference site: http://www.aeroconf.org/), helps new participants learn about the type of projects appropriate for presentation. This page then links to pages describing where to start, writing the paper, submitting the paper, an e-mail address for questions, and links to talks from prior years. Students who intend to participate are placed on an e-mail list. E-mail is sent approximately once a month with reminders and words of encouragement. About a month before the conference,
Table 1. Junior Engineering & Science Talks, 2002

<table>
<thead>
<tr>
<th>Age</th>
<th>Grade</th>
<th>Presentation Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>8</td>
<td>Design Process for a Rover</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>Solar Thermal Applications for In-situ Resource Utilization</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Nutrition in Space</td>
</tr>
<tr>
<td>6</td>
<td>K</td>
<td>Machines: Man's Best Friend?</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>Launching a Rocket</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>Detection of Anthrax Spores in Mail</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>Jupiter</td>
</tr>
<tr>
<td>6</td>
<td>K</td>
<td>Wacky Weather</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>The Science and Art of Getting into Orbit around Mars</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
<td>Mathematical Modeling of a Mechanical Turtle</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>Spectral Analysis of Speech</td>
</tr>
<tr>
<td>14</td>
<td>9</td>
<td>Horse Genetics II</td>
</tr>
<tr>
<td>16</td>
<td>11</td>
<td>Literature Search about Leukemia on Children</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>Experiment on Swimming Pool Water Quality</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>Lego Robots and the Arctic</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Why do girls like the color pink?</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>Design and Applications of a MEMS based Quartz Gyroscope</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>Inflatable Structures: Status and in Future ...</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>Study of Acid Rain</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>EM Waves, The Invisible Messenger</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>Sleep Survey</td>
</tr>
</tbody>
</table>

Participants submit hard copies of their slides or viewgraphs. These are collected and assembled into a Junior Conference Proceedings to be distributed to participants at the conference. Acceptance letters are sent to each confirmed participant. Sometimes these letters are necessary for a student to be excused from school to attend the conference.

THE JUNIOR CONFERENCE TALKS

The Junior Conference is held at a time that does not conflict with other talks at the IEEE Aerospace Conference in order to encourage the engineers and scientists to attend the children's talks. About 10–20% of the adults registered in the professional conference attend the Junior Conference. In 2002, there were enough talks that the Junior Conference was split into two sessions on separate days. The dual sessions decreased the audience size at each session.

The presentations are made in similar format to that of scientific and engineering conferences. An auditorium equipped with complete audiovisual equipment is the setting for the conference (Figure 2). The speaker is announced and has a maximum of 15 minutes to present a talk, accompanied with either PowerPoint or transparencies. Over the years, the quality of the visual aids have improved to the point where they are often better than many of the adult talks in the professional conference. The younger children give presentations lasting only a few minutes, while the older children often require the full 15 minutes to present talks on their original research. Most use PowerPoint but a few use viewgraphs. During the 5 minute question and answer period, the participants often demonstrate a high level of knowledge of their topics through the answers to detailed questions posed by professional scientists and engineers. The audience is always supportive and encouraging.

In 2002, a high school student (who is a former conference participant) chaired the sessions and introduced the speakers. Several participants also helped by telling jokes or acting out movie scenes whenever laptop computers had to be switched.

Participants have ranged from preschoolers through high school seniors. The wide range of topics for the 2002 participants are listed in Table 1. There were 21 talks given by 22 participants (a brother/sister team worked together on one of the talks). Twelve of the speakers were girls and ten were boys. Many of the participants had obviously spent a large amount of time in their investigations. The youngest participants had more mentoring, yet most knew their topic well and presented their talks like experts. They add a real
element of "cuteness" to the Junior Conference that professional attendees find entertaining. A first grade girl addressed the question: "Why do girls like the color pink?" She did a beautiful job of introducing the color spectrum, discussing additive vs. subtractive color schemes, introducing the psychology of color preference, then talking about gender socialization. (Of course, she wore a pink dress for her presentation.) A kindergarten boy discussed some simple machines and whether machines were man's best friend or whether the dog still holds that position (see Figure 2). Another kindergarten girl discussed examples of odd weather. These topics are simple but may be the first step in encouraging these children into engineering careers.

Many of the older participants had done original research, with varying levels of adult mentoring, which foreshadows a potential career in science or engineering. One high school sophomore was invited to work in a university laboratory to study the transport of anthrax through the mail. (She did not work with anthrax itself but rather an inert tracing element.) She investigated using intrinsic fluorescence detection techniques to test mail without having to open it. An eighth grade boy traveled from Puerto Rico to present his project involving complex mathematical models of a mechanical turtle. A sixth grader used computer software to do a time frequency analysis of piano and flute scales, voices, and a dog's bark (see Figure 3).

One of the conference participants, a retired engineering professor, commented later how, when he was in graduate school at MIT, that was considered an unmanageable problem. Of course, software advances are what make the difference, yet it is very impressive that an eleven year old girl can now do that sort of project.
Some children discover an area of interest and build on it over the course of several years. An eight year old girl did a project on measuring weather over a period of time, then the following year studied the geographic dependence of Acid Rain by sending sampling equipment to friends and relatives throughout the United States. She now says that she would like to be a meteorologist when she grows up. A high school boy has shown interest in understanding difficult technical issues (Figure 3), giving a talk on Fuzzy Logic in 2001, then investigating the design of MEMS gyroscopes in 2002. He is now a university engineering student.

After the presentations, participants receive a personalized plaque commemorating their participation (see Figure 4) and a Proceedings containing a copy of all the slides presented by the other junior participants. Formerly, they were compiled into a spiral bound booklet with a table of contents. In more recent years, they have been presented in CD-ROM format.

The children are encouraged to socialize with each other. Since they share a common experience, they are able to peer mentor each other and offer words of encouragement. They often sit together at dinner and play together. They meet at the swimming pool or on the ski slopes. One evening, the older participants take the younger children out for pizza and play games afterwards. These activities foster a positive feeling about the conference and the congeniality in engineering and science.

**ASSESSMENT**

After the conference, each participant is sent a letter thanking him or her for participating, including a photo of them giving their presentation. In some years, this also included a survey to evaluate the experience and a release form to allow use of their photos on the Junior Conference website. As noted by Poole, et al. [2], it is difficult to adequately assess K-12 Pre-engineering outreach programs without becoming overzealous and negatively impacting the experience. They recommend assessment consistent with program goals. Here, the program goals are quite different than for traditional learning. The primary goal of the Junior Conference is to give motivated children an opportunity to excel at an individual research project. This goal is more in line with those of programs listed in section 1 and in contrast with the many K-12 programs which instead seek to expose a large population of children to science and engineering. Thus, children being assessed tend to be those who are already motivated in science, mathematics, and technology. In addition, assessment of a program with participants’ grade levels ranging from kindergarten through senior in high school is quite challenging. Within these constraints, our assessment is concentrated in a very simple survey instrument that can be used by participants of all ages. The youngest students may have required help in writing the responses. Questions included time spent on the project (answers ranged from weeks to months), whether the participant had fun with the project (an overwhelming number responded affirmatively), whether the experience enhanced their confidence (89% responded that it did), whether they presented their paper elsewhere prior to the conference (half did), and their intended careers (see Figure 5 for a breakdown of career interests). By the nature of the Junior Conference, it was impossible to do a pre-experience survey to determine if there are any changes in attitudes.

The most interesting aspect of the survey responses were their comments on how they felt about their experience. The results of this qualitative question were extremely positive. In general, the participants are thrilled with the experience. Most
Table 2. The progression of one girl’s scientific talks at the Junior Conference

<table>
<thead>
<tr>
<th>Year</th>
<th>Age</th>
<th>Annotated Topic</th>
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<tbody>
<tr>
<td>1997</td>
<td>9</td>
<td>Pluto: A literature review</td>
</tr>
<tr>
<td>1998</td>
<td>10</td>
<td>Comets: A literature review</td>
</tr>
<tr>
<td>1999</td>
<td>11</td>
<td>Computer Animation: A demonstration of how animated programs make learning more interesting</td>
</tr>
<tr>
<td>2000</td>
<td>12</td>
<td>Fractals: Includes computer demonstrations of measuring a coastline and building a Sierpinski Triangle</td>
</tr>
<tr>
<td>2001</td>
<td>13</td>
<td>Horse Survivor: A genetic algorithm model for horse evolution in different environments</td>
</tr>
<tr>
<td>2002</td>
<td>14</td>
<td>Horse Survivor II: A genetic algorithm model for horse color evolution using actual genetics data</td>
</tr>
</tbody>
</table>

Fig. 6. The same girl presents a talk on Pluto at the age of 9 in 1997 and on Horse Color Genetics as a High School Freshman in 2002

expressed some level of fear prior to giving the talk. However, they universally acknowledged that the experience gave them a heightened level of confidence. Some responses included:

- “This talk gave me more confidence, because I learned that I could have fun giving a talk” (third grader)
- “[This talk has given me more confidence] in public speaking and preparing a research/technical paper” (eleventh grader)
- “I am more confident because I talked in front of a big group” (third grader)
- “I can public speak better” (eighth grader)
- “I am not so scared to talk in front of people anymore” (seventh grader)
- “I know that I’m probably the only one in my school who did it” (fourth grader)
- “I feel better at speaking in front of people” (kindergartner)

Most of the speakers also expressed an interest in pursuing a career in a technical field. In spite of the fact that some of the younger children were looking for careers in sports or
teaching, in the two years surveyed, 79% of participants expressed an interest in a scientific, technical, or medical career (Figure 5).

Why do the children involved in the IEEE Aerospace Junior Conference excel so well at giving their presentations and get so much from the experience? To a large extent, the population of students presenting talks are self-selected from a pool of children with parents interested in science, mathematics, and engineering just by the fact that most are attending an aerospace conference. That, in itself, suggests that parents who are scientists and engineers are more likely to influence their children in this area. Of those children, only those with the greatest interest in careers in science, mathematics, and engineering volunteer to be part of this Junior Conference.

Many of the junior speakers find the experience to be so much fun and so beneficial that they participate multiple years. One girl presented talks for six years. She began when she was in fourth grade with a literature review on Pluto and much parental help in preparing her transparencies. She was quite fearful before that first presentation, but quite proud of herself afterwards. As a high school freshman in 2002, she did a web search for data on horse genetics, deciphered the information herself, wrote a MATLAB subroutine to call a genetic algorithm (which was supplied by mentors), and analyzed the numerical simulation of horse color evolution. She prepared her PowerPoint presentation with no adult involvement and was barely nervous before the presentation. Table 2 shows a progression of her research topics and Figure 6 shows her presenting in 1997 and in 2002. Through these projects she gradually discovered an interest and ability in computer programming and genetics and currently plans a career in computer and genetic engineering. She is just one example of how the children have grown in ability and poise through their Junior Conference experience.

CONCLUSIONS

The Junior Engineering and Science Conference sponsored by the IEEE Aerospace Conference has been successful in motivating young students in the engineering and science professions. The participants learn how to integrate information, gain a deeper understanding of an area of engineering or science, prepare and deliver an oral presentation with visual aids, and experience answering technical questions in front of an audience. They report that it gives them more self-confidence and that it is fun. The experience enhances their self-esteem by demonstrating that they can do a good job at a difficult task.

In addition to the conference participants, many other students are often impacted. Some of the participants practice their talks in their classrooms or with other groups (such as a scouting troop or club) prior to or after the conference, disseminating the experience to a much larger number of children. Other students are able to observe how much one motivated child can accomplish, as well as the fun she/he had learning about science or technology. One of the participants was asked to give her presentation on Flight to her entire school during Engineering Week and was able to reach 300 children. She received a very enthusiastic response from the students and teachers. Another girl gave her talk on Acid Rain to three fourth grade classes at her school. These excellent peer models have the potential to motivate a large number of children to investigate scientific and technological careers.

After the conference, many of the PowerPoint presentations are collected and put on a website for public viewing. Not only are these useful for encouraging future participants, but they are often seen by a wider population looking for scientific information. The authors were contacted by an educator in another part of the country concerning the on-line PowerPoint presentations as an example of how children can do a good job of researching scientific topics and presenting them professionally. Another web surfer contacted us to determine the accuracy of calculations in a talk that compared the number of grains of sand on a beach to the number of observable stars in the sky. He hoped to present those data as a learning activity. We were able to put him in touch with the participant’s father, a mathematics professor.

Many Junior Conference participants express either a continuing or a newfound interest in pursuing a career in the technical fields. We believe this conference gives such children an opportunity to pursue technical interests at a young age and will serve to enhance their interest and ability in technical research. In this way, the IEEE Aerospace Conference Committee hopes to excite the next generation of young engineers and scientists. Perhaps this Junior Conference can serve as a paradigm for other conferences that could sponsor similar opportunities for K-12 participants.

ACKNOWLEDGEMENTS

The authors thank the rest of the Junior Conference Committee members from over the years (Mary Krkorian, who is also the current junior conference chair and kindly provided data on the 2004 conference); Keith Paskett; Yuko Shibato; and Julia Adler) as well as the IEEE Aerospace Conference Committee, particularly Karen and Robert Profett. Karen initiated this Junior Conference in 1995.

REFERENCES


GPS III System Operations Concepts

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Lockheed Martin Corporation
&
Jeff Crum
Infinity Systems Engineering

ABSTRACT

Over the past three years, the Lockheed Martin GPS III team has analyzed potential operational concepts for the Air Force. The completed tasks support the government’s objective of a “realizable and operationally feasible” US Strategic Command (USSTRATCOM) and Air Force Space Command (AFSPC) concept of operations. This paper provides an overview of the operational improvements for the command and control of satellites, the provision of safe, precise navigation and timing services to end-users.

The GPS III system changes existing operational paradigms. Improved operator capabilities are enabled by a new high-speed uplink/downlink and crosslink communication architecture. Continuous connectivity allows operators a “contact one satellite – contact all satellites” concept enabling near-real-time navigation updates and telemetry monitoring. This paper describes potential improvements for the following operations:

- Constellation Monitoring,
- Command and Control,
- Navigation Upload Monitoring,
- Global Service Monitoring,
- Global Service Prediction,
- Civilian Navigation (CNAV) Messaging, and
- Anomaly Detection and Resolution.

This paper also describes future operational improvements as GPS applications continue to proliferate and the need for an improved infrastructure to effectively manage all the systems that affect GPS service grows.

INTRODUCTION

The Global Positioning System (GPS) is the world’s premier satellite-based Position, Velocity, and Timing (PVT) information system. GPS is comprised of three segments:

- the Space Segment,
- the User Segment, and
- the Control Segment.

Figure 1 illustrates the high-level interfaces between the segments.

Space Segment

The Space Segment (SS) is comprised of all operational GPS satellite vehicles (SV) in orbit. The SVs accept uplinked commands and uploads from the Control Segment; downlink telemetry to the Control Segment; crosslink commands, uploads, and telemetry within the Space Segment; and downlink ranging codes and navigation data to the User Segment.

User Segment

The User Segment (US) is comprised of anyone with a properly equipped GPS receiver set. Traditionally, the User Segment interaction with GPS has been via passive reception of ranging codes and navigation data from the Space Segment. This paper will discuss some of the ways the GPS will evolve to offer more active interfaces for the user.

Control Segment

The Control Segment (CS) provides for the command, control, communications, and monitoring of the GPS space segment. The CS is comprised of the Operational Control...
System (OCS), the Operational Support System-Integrated Mission Operations Support Center (OSS-IMOSC), the High Fidelity System Simulator (HFSS), and the GPS Support Facility (GSF). The OCS is further decomposed into additional elements including the Master Control Station (MCS); the Launch, Anomaly Resolution, and Disposal Operations (LADO) facility; the Ground Antenna (GA) network; and the Monitor Station (MS) network. The MCS and LADO have alternate locations to ensure system survivability. These elements, referred to as the AMCS and ALADO, respectively, provide the Air Force with additional operational flexibility.

The current constellation of GPS satellites consists of several different models, or “block” types, each with increased capability and additional features designed to improve end-user service and system operations and maintainability. The Block II and IIA satellites were built by Rockwell International and were launched between 1989 and 1997. The Block IIR satellites were built by General Electric (now Lockheed Martin) and are in the process of being launched for constellation sustainment. The first Block IIR was launched in 1997 and eight are now currently in service. As many as eight IIR satellites will be upgraded to include the new military code (M-code) and a second civilian signal, and will be redesignated IIR-Modernized, or Block IIR-M. The Block IIF satellites are scheduled for first launch in 2006. The Block IIF will have all the capabilities of the IIR-M and will add a third civilian safety-of-life signal on L5.

In May 2000, the Air Force announced plans to pursue the next generation of GPS, designated GPS III. GPS III will provide improvements to the Space Segment and Control Segment to “assure reliable and secure delivery of enhanced position, velocity, and timing signals to serve the evolving needs of military and civil users.” GPS III will look at the entire GPS Architecture to achieve long-term GPS performance goals while managing long-term total ownership costs [1]."

The first formal GPS III work came under the System Architecture and Requirements Definition (SARD) phase from October 2000 to October 2001. As one of the two competitively selected contractors for the SARD phase, Lockheed Martin conducted extensive GPS mission analysis to develop some preliminary operations concepts. Then from April 2002 to November 2002, the Lockheed Martin team participated in the Requirements Analysis Study, and worked shoulder-to-shoulder with United States Strategic Command (USSTRATCOM) and Air Force Space Command (AFSPC) to mature and document GPS III Systems Operations Concepts.

As part of the GPS III effort, Lockheed Martin has developed and refined an extensive set of engineering tools used to document and visualize these emerging operations concepts. Software simulators allow both developers and customers to quickly assess various operations techniques and to show traceability to architecture components and requirements. Control Segment operations are the epicenter for GPS service delivery, so new tools and software applications have been prototyped to illustrate various concepts. The Integrated GPS Simulator (I-GPSS), used to evaluate accuracy availability, dilutions of precision, and satellite outage probabilities, is just one example of the types of tools developed to hone these evolving operations concepts [2].

OVERVIEW OF CURRENT GPS OPERATIONS

The term “GPS operations” can be interpreted on a number of different levels depending on one’s perspective. For the purposes of this paper, “GPS operations” will be loosely split
into two categories: AFSPC operations, and L-band user operations.

AFSPC Operations

This category describes the viewpoint of the men and women within the AFSPC charged with the daily operations of the GPS Space and Control Segments. These operations are conducted 24 hours a day, seven days a week by personnel from the 2nd Space Operations Squadron (2 SOPS) and its reserve component, 19 SOPS, at Schriever Air Force Base (SAFB) near Colorado Springs, Colorado. Each operations flight is composed of a Flight Commander, a Flight Chief, and five system “specialists.” The Satellite Vehicle Operator (SVO) is responsible for monitoring satellite telemetry to assess the health and safety of the various subsystems. The Payload System Operator (PSO) is responsible for monitoring the L-band signal and assessing current navigation performance via range measurements taken from the monitor station network. The Ground System Operator (GSO) monitors all the communications circuits between the MCS and the GA and MS networks. Two Satellite System Operators (SSO) are responsible for establishing S-band contacts between the GA and SV and transmitting all required commands and uploads. These seven-member operations flights are composed of enlisted and commissioned Air Force space operators with technical support from in-house analysis shops and a variety of contractors [3].

Operations within 2 SOPS and 19 SOPS have evolved over the years to take advantage of innovative techniques, tactics, and procedures designed to streamline operator actions without sacrificing checks and balances to ensure satellite safety and mission effectiveness. Nevertheless, limitations within the current architecture necessarily dictate that many operator activities are manually executed. A significant amount of the operators’ time is spent establishing unique S-band contacts between a single GA and a single satellite in order to accomplish the required support activities. These satellite support activities include telemetry monitoring, configuration commanding, and navigation data uploads. 2 SOPS and 19 SOPS may conduct anywhere from 60-100 satellite contacts in a 24-hour period. Daily averages are typically 70 supports per day. Scheduling and executing these contacts is a significant operational burden.

A typical “day in the life” of today’s operations flight consists of 20-25 supports in an 8-hour shift. At the beginning of each support, the GSO manually verifies that communication lines between the MCS and the selected GA are up and functioning. The SSO runs a series of software scripts to establish a line-of-sight S-band contact between the selected GA and satellite. Once contact is made, the satellite telemetry stream is automatically parsed and displayed with the appropriate calibration parameters and units on a series of displays in the MCS. The SSO and SVO manually review up to 15 different computer displays to verify subsystem health and performance. Following the state-of-health, most supports include a data download (dump) of the Nuclear Detonation (NUDET) Detection System (NDS) payload for subsequent analysis. Once the NDS data dump is complete, the PSO runs a script to generate a new navigation upload to provide the most current ephemeris and clock predictions, constellation almanac, and other related parameters for L-band broadcast. The SSO transmits the navigation upload to the satellite, concluding the support requirements for a typical contact. The S-band connection is dropped and the GA returns to its pre-contact state. A typical support like the one described herein takes approximately 30-45 minutes.

Some support activities, such as satellite commanding or data dumps, are time critical and must be accomplished within a specific window. These constraints add some complexity to the contact scheduling process. A separate section within the 2 SOPS is responsible for planning a day’s worth of contact activities, using software programs to ensure satellite support requirements are met within the allotted time. Unplanned constraints, however, such as the loss of communication to a remote GA site, often necessitate real-time shuffling of the contact schedule. This real-time shuffling is a manual process, often complicated by line-of-sight visibility times between a GA and the target satellite.

One of the overarching goals of the Lockheed Martin GPS III operations concept is to design a system that reduces the number of manual actions imposed on the operator. By limiting the amount of time MCS operators spend in the implementation of the system, we can transform those same

![Fig. 2. GPS III Anti-Jam Improvements](image)

operators into GPS mission managers. 2 SOPS and 19 SOPS can focus on the delivery of L-band services, concentrating on the quality of the signal and the accuracy of the positioning and timing product. The need for operations flight positions will remain, but the focus can shift to mission management and understanding how the actions of the OCS affect the end users of the system.

L-Band User Operations

This operations category describes the viewpoint of the individuals and systems that use the GPS broadcast
information to accomplish a mission. This category includes
users of both the Standard Positioning Service (SPS) and the
Precise Positioning Service (PPS). During the SARD Study,
Lockheed Martin examined over 270 user missions ranging

Table 1. GPS III Satellite Characteristics

<table>
<thead>
<tr>
<th>Design Life</th>
<th>15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit Altitude</td>
<td>10,898 nmi</td>
</tr>
<tr>
<td>Orbit Inclination</td>
<td>55°</td>
</tr>
<tr>
<td>Target Weight</td>
<td>3960 lbs</td>
</tr>
<tr>
<td>Launch Profile</td>
<td>Single or Dual Manifest</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>EELV Atlas V or Delta IV</td>
</tr>
<tr>
<td>Payloads</td>
<td>Navigation, NDS</td>
</tr>
<tr>
<td>Broadcast Frequencies</td>
<td>L1, L2, L3, L4, L5, L6</td>
</tr>
</tbody>
</table>

from surveying to time transfer to delivering precision-guided
munitions. The results of this analysis were used to help define
the architecture that best meets the needs of these disparate
missions.

Most L-band user operations have historically been passive
in nature: GPS receiver equipment collects the broadcast
ranging codes and messages for processing. The configuration
of the broadcast has not been under user control. The
modernization and GPS III programs, however, seek to change
this paradigm and provide new taskable features, such as a
high-power signal, in addition to the heritage service.

Other L-band user operations are manual in nature. For
example, users of the PPS must manually load cryptographic
material on a periodic basis to ensure access to the encrypted
portions of the broadcast. Once again, the modernization and
GPS III programs seek to improve the security of the PPS while
reducing L-band user burden. Key management and
distribution will evolve to significantly enhance PPS
flexibility.

GPS III NEED

Air Force Space Command has documented shortcomings
of the Block II-era GPS architecture that limit military,
civilian, and commercial effectiveness. These shortcomings
include signal accuracy, signal availability (anti-jam),
integrity, signal monitoring, constellation configuration
responsiveness, and signal security [4, 5]. As the value of GPS
increases, the need to reduce or eliminate these shortcomings
increases. GPS III seeks to address this need, providing a
transformational architecture that will allow both AFSPC and
L-band user operations to evolve to a more responsive system
with improved mission insight and better system performance.

GPS III ARCHITECTURE

The GPS III architecture preserves the same three segments
that exist today: Space Segment, Control Segment, and User
Segment. Unique attributes of each are highlighted herein.

Space Segment

The GPS III satellites will be designed to meet a 15-year
operational life. Spacecraft size and weight are an important
design consideration because the Air Force has set a
requirement for dual manifest launch. Table I provides some
of the characteristics of the GPS III satellite.

In order to provide the Air Force with the most flexible
launch profile, the system will be designed to launch into any
orbital plane at any time of year. This includes deploying into
either a 3-plane or a 6-plane configuration.

Building on the success of the Block IIR program, Block III
satellite processors will be reprogrammable to provide
maximum flexibility over the operating life. These flexible
processors include the navigation and NDS payloads as well as
the spacecraft bus processor. The bus processor will perform
redundancy management (REDMAN) functions to autonomously execute time-critical hardware configurations
to protect the safety of users and the spacecraft.

Yet another carry-over from the Block IIR program will be a
no-maintenance Electrical Power Subsystem (EPS). Earlier
block models require periodic battery reconditioning, but the
Block IIR and Block III batteries are designed so that this
additional operational burden is eliminated.

There are at least five unique features of the Block III
satellite that distinguish it from previous GPS block types:

• High-speed telemetry, tracking, and commanding
  (TT&C) uplink and downlink

• High-speed, directional crosslink

• High-power NAVWAR spot beam antenna

• Integrity functionality

• Reserved space for additional hosted payloads.

The high-speed TT&C link will provide significantly
increased capacity over today’s data rates. All Block III
models will continue to carry the heritage S-band hardware to
ensure backwards compatibility with the Air Force Satellite
Control Network (AFSCN). Coupling the high-speed TT&C
link with high-bandwidth directional crosslinks, the GPS III
Space Segment will create a network in space, providing
continuous connectivity to all satellites, all the time.

GPS III seeks to provide assured access to GPS services in a
stressed (i.e., jammed) environment [5]. Through modeling
using the GPS Interference and Navigation Tool (GIANT), we
have shown that users achieve equivalent unjammed
performance accuracies in the presence of a jamming threat
with about 38 dB of anti-jam. These “38 dBs of anti-jam” are
achieved through a combination of: 1) boosted signal power
from the satellite; and 2) user equipment (UE) antenna and
processing improvements.

Block III satellites will provide directed, higher power
Military-Unique (MU) signals for up to two specific areas of
operation (AOO) in response to (1), above. The satellites will use a NAVWAR spot beam antenna to boost the MU signals. The remaining "dBs of anti-jam" will come from planned UE improvements such as updated antennas, electronics, and tracking techniques. Figure 2 illustrates the current shortcomings of ECM-code and shows how GPS III meets the military requirements for anti-jam improvements.

Integrity is the ability of the system to provide timely warnings to enable a user to determine when the system should not be used to support the mission or phase of operations. Integrity ensures that the user is notified of signal errors that could be hazardous or economically harmful [5]. The Block III incorporates this integrity functionality to provide greater user assurance.

The Block III satellites will provide additional weight and power margin to support auxiliary payloads [6].

**Control Segment**

The GPS III Control Segment will be designed to gradually evolve from Block II-era operations to Block III-era operations. This transition is critical to the continuity of current GPS services.

At the highest level, the GPS III architecture retains many of the heritage architectural features: the OCS, OSS-IMOSC, HFSS, and GSF all remain. Within the OCS, however, there are several GPS III-unique characteristics. Most notable will be the inclusion of the new high-speed ground antennas (HSGA). At least three HSGA sites, all located within the continental United States (CONUS), will be established. The CONUS location provides improved physical security and reduced maintenance and logistics costs. The MCS will maintain connectivity with all the existing GPS-dedicated S-band sites at Ascension Island, Diego Garcia, Kwajalein Atoll, and Cape Canaveral until the last Block II-era satellite is decommissioned. Air Force Satellite Control Network (AFSCN)-connectivity will be retained indefinitely for emergency backup, satellite launch and early orbit operations, anomaly resolution, and satellite disposal.

The monitor station network will be upgraded to measure and calibrate the high power NAVWAR spot beam. Additional L-band tracking sources will also be used by the MCS for expanded signal integrity monitoring.

The MCS itself will evolve to include new service level summary displays, improved telemetry trending and analysis capabilities, and operator-selectable automation levels. The MCS-to-AMCS connectivity infrastructure will be enhanced to provide better data synchronization for rapid deployment operations. There will be increased interaction with GPS information providers such as the US Coast Guard Navigation Center and the GPS Support Center.

Another architectural change in the Control Segment will be the continuing evolution of the interface between the PPS users and the MCS. This interface is currently in its infancy as the modernization and Selective Availability/Anti-Spoof Module (SAASM) programs introduce new taskable services. The GPS III spot beam will present additional complexity from a resource scheduling, loading, and deconfliction standpoint.

<table>
<thead>
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<tbody>
<tr>
<td>SPS</td>
<td>PPS</td>
<td>SPS</td>
</tr>
<tr>
<td>Horiz</td>
<td>Vert</td>
<td>16 m SEP</td>
</tr>
<tr>
<td>3.7 m</td>
<td>6.6 m</td>
<td>2.1 m</td>
</tr>
<tr>
<td>(worst case threshold)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(global ave)</td>
<td>13 m</td>
<td>22 m</td>
</tr>
</tbody>
</table>

* Assumes "Good" UE and dual frequency
** Assumes "Best" UE and dual frequency
*** Global average not yet specified

The GPS Control Segment will act as the USSTRATCOM agent for evaluating spot beam requests, determining resource allocation, predicting service utility, assessing spot beam impact, executing the request, and evaluating spot beam performance.

In addition to these Block III-unique features, the new architecture will also continue to evolve some of the new modernization features like flexibility in the Military Navigation (MNAV) and Civilian Navigation (CNAV) messages. Continuous ground-to-space links will allow the Control Segment to rapidly configure and update these broadcast navigation messages.

**User Segment**

The objective of the GPS III program is to "assure reliable and secure delivery of enhanced position, velocity, and timing signals to serve the evolving needs of military and civil users [1]." The GPS III-unique features of most interest to users include improved signal performance, the new NAVWAR spot beam, flexible MNAV and CNAV messages, and the new integrity service. The GPS Joint Program Office serves as the lead integrator for these new capabilities.

Table 2 illustrates improvements of GPS III signal accuracy as compared to GPS II. The threshold values shown are for the worst-case location and assume 95% accuracy with service volume availability of 90% with the worst two satellites out. As shown, GPS III will provide significant user improvement.

The NAVWAR spot beam is a significant improvement to the User Segment architecture. Theater commanders will be given the ability to request higher signal power for their AOO. In order to achieve the anti-jam improvements shown earlier in Figure 2, PPS user equipment improvements are required. Coupled with the extra signal power from the spot beam antenna, users should be able to achieve benign-like tracking performance in a jammed environment.

The User Segment will also benefit from the new GPS III integrity service. This service provides signal performance and accuracy assurance.

The flexible MNAV and CNAV data message frames will reduce the length of time required to read the entire broadcast message. The age of data will be significantly reduced, improving positioning and timing accuracies. Furthermore, both messaging services can be expanded to include new message types as user requirements continue to evolve.
collectively, the GPS III-unique features of the Space, Control, and User Segments enumerated above realize the vision of a rapid-response, real-time system focused on service delivery.

GPS III OPERATIONS CONCEPTS

As described earlier, defining operations concepts for the GPS III architecture requires presenting the perspectives of two distinct groups: the AFSPC operators charged with operating and maintaining the Space and Control Segments, and the end-users of the GPS service. The remainder of this paper will present a summary of the work the Lockheed Martin team has completed to date in researching, analyzing, and documenting these concepts.

AFSPC OPERATIONS

The high-speed uplinks, downlinks, and crosslinks revolutionize GPS satellite operations. Once a sufficient number of Block III satellites are on-orbit, the MCS will communicate with the Space Segment via one or more HSGA. A single HSGA will establish line-of-sight contact with a single Block III satellite as it rises over the horizon. This satellite will act as the conduit for all uplinked and downlinked information. Tied to the rest of the Block III constellation via the high-speed crosslinks, the MCS will be able to “contact one satellite, contact all satellites,” as shown in Figure 3. There will be at least three HSGAs to provide redundancy and enable a “make before break” operations concept—a new line-of-sight contact will be established with a rising SV before the existing contact is broken with an SV that is setting out of view. Automated planning software within the MCS will schedule these HSGA contacts to ensure continuous connectivity.

Constellation Monitoring

MCS personnel will have an ever-present TT&C link, providing continuous, real-time insight to telemetry from every SV. In today’s operational environment, SV telemetry analysis is isolated to one or two contacts, totaling 45-90 minutes daily. In the GPS III era, there will be a continuous stream of telemetry. As incoming SV telemetry is received by the MCS, software routines will evaluate the telemetry, comparing it to the expected values contained within a series of vehicle-specific telemetry databases. These databases will contain not only expected values, but also the associated behavior characteristics for each telemetry point. Since MCS software routines will evaluate telemetry, identify out-of-limits conditions, and resolve minor discrepancies, screen-by-screen state-of-health assessments will no longer be required. Consequently, operator workload will be greatly reduced, because only critical alarms will be elevated for response.

In addition to the continuous SV telemetry, the constellation is also monitored via the network of Air Force and NIMA monitor stations that continuously feed data back to the MCS. The MCS L-band monitoring software will report any anomalous behavior to the operations flight, again reducing overall operator workload. Data from Air Force, NIMA, and potentially other sites feed into the Kalman filter and are used to update estimates for the ephemeris and clock states. These states are then used as the basis for the predictions that appear in the broadcast navigation messages.

Command and Control

The omnipresent TT&C link can also be used for command and control of the entire constellation. The “contact one, contact all” paradigm eliminates the restrictions imposed by line-of-sight visibility with a ground antenna. Now satellite configuration and data dumps can be performed at any point in
Personnel within the MCS will maintain a Vehicle Support Requirements (VSR) database that defines all activities that must be performed to ensure proper SV bus and mission operations. This VSR database will contain a listing of each activity, how often the activity should be performed, how long the activity takes to complete, etc. The VSR database then serves as the primary input to the MCS automated scheduling function, Schedule Control. Once the initial database is populated with requirements, it need only be reviewed periodically (e.g., quarterly or even annually) to validate the support activities listed.

Schedule Control software within the MCS will produce a dynamic queue of time-tagged satellite support activities. These activities will be sequenced to ensure that all support requirements are successfully completed in accordance with the rules defined in the VSR. Each activity will be automatically initiated at the designated time with any exceptions reported to the operations flight. The operations flight can invoke manual mode at any time, but the system is designed to give operators the freedom to automate as much of the routine schedule as they desire, providing flexibility in training and transition concepts.

Upload Monitoring

The MCS processes monitor station ranging data and uses a Kalman filter to update satellite orbit and timing parameter estimates every 15 minutes. The current GPS operations concept involves using these Kalman filter estimates to make a prediction of satellite ephemeris and timing information approximately once per day. This prediction is formatted into an upload, transmitted to the satellite, and broadcast as the navigation message. Uploads are SV-specific and must be uploaded via a line-of-sight S-band contact with the target SV.

The GPS III Control Segment will not be limited to uploading each SV only once per day. Using the HSGA and high-speed directional crosslinks, the MCS will be able to uplink Kalman filter estimates more frequently, significantly reducing the constellation-wide age of data (AOD) from today’s average of 12.5 hours. This reduced AOD will translate into improved timing and positioning accuracy.

Global Service Monitoring

The Block II-era Control Segment has limited tools in the following areas:

1. Viewing the current constellation performance
2. Assessing the impact of potential outages or actions
3. Utilizing the external inputs or requests to improve the quality of service.

The GPS III Control Segment will improve the operations toolbox in all of these areas. Displays of current system performance (and, notably, areas of weak performance) will be available in near real-time. An example of a global service monitoring display showing dilution of precision (DOP) metrics is given in Figure 4.

To help the operations flight be more aware of the global impact of either improvements or outages, displays will be provided that show the results of “what if” scenarios and provide pre-commitment information on the adverse or positive impacts of a course of action or failure. For example, the global service impact of setting a satellite unhealthy for maintenance at a particular time will be available. This can then be compared with other maintenance times to limit the impact in specific regions or areas.

The GPS III Control Segment will also benefit from increased interaction capabilities with both civil and military communities. This will eventually allow both an increase in information flow out of the OCS (e.g., service predictions and status changes) as well as an increase in information flow into the OCS (e.g., CNAV messaging inputs).

Global Service Prediction

In addition to reporting real-time performance, the MCS will also be equipped with software tools to perform service prediction. These products will be tailored to specific user need, taking into account differences in user equipment, operational environment, and services used (positioning vs. time transfer, SPS vs. PPS).

CNAV Messaging

The Civilian Navigation (CNAV) message provides a flexible data frame with Forward Error Correction (FEC) and a transmission rate of 25 bits per second. Within each 300-bit CNAV message is a 6-bit message identifier. At present, only message types 1-7 have been defined [8]. As civilian applications grow and new message types are defined, the GPS III capability to rapidly uplink and transmit CNAV messages may be exploited. This can be valuable for navigation service notifications including rapid notification of constellation health and configuration changes. MCS operators will be given an interface to add CNAV messages either manually or automatically based on pre-defined rules. A similar capability for military navigation (MNAV) messages will exist for MCS operators and authorized users.

Anomaly Detection and Resolution

Anomalies are unplanned events that may or may not affect system performance. Anomalies can affect one or more of the three GPS segments simultaneously. A major role of the on-duty operations flight is to detect anomalies as soon as they occur, protect L-band users from any affects, configure the affected component(s) to a “safe” condition, and resolve the anomaly.

The current Block II-era GPS architecture has developed an extensive set of techniques, tactics, and procedures for anomaly detection and resolution. Historical lessons learned will be carried forward and applied to the Block III system. For example, on-board satellite redundancy management -- the ability for the spacecraft processor to detect out-of-limit
conditions and autonomously resolve them — will be an inherent design feature for all future block types.

From an AFSPC operator perspective, anomaly detection will be significantly improved by virtue of the streaming, real-time telemetry input from all GPS III satellites. When the MCS telemetry analysis scripts detect an out-of-limits condition, automated software routines will assess the situation to determine the proper course of action. If the procedure requires operator intervention, an alarm will be sent to the appropriate operator position(s). On-line, hypertext-linked documentation and training material will further facilitate the anomaly investigation and proper resolution.

The GPS III MCS will also support a variety of external interfaces that will assist with anomaly detection and resolution. Connectivity to the FAA and US Coast Guard Navigation Center will ensure that GPS anomalies are rapidly characterized and reported. Inputs from other agencies such as terrestrial and space weather services will be used to help establish root cause. Many anomalies are related to the type of user equipment and location of use, and this information will be centrally pooled to provide the most complete set of anomaly symptoms. Furthermore, anomaly details will be archived; in the event of similar conditions in the future, previous methods of resolution will be rapidly available to assist the MCS operators.

**Spot Beam Operations**

Certainly the most unique GPS III operations concepts deal with the employment of the new NAVWAR spot beam service. The architecture is designed to provide all stakeholders with the requisite information to make decisions about when, where, and how to provide a high-power spot beam. The system provides the tools to determine need, benefit, and impact of use, and leverages the high-speed links to rapidly configure the NAVWAR antenna and monitor its performance.

**L-BAND USER OPERATIONS**

One of the cornerstones of the GPS III program is to preserve backwards compatibility with all existing GPS services. Ideally this means that L-band users will not have to worry about whether the L-band signal is coming from the oldest Block II satellite or the newest Block III in the constellation. The design, manufacture, test, and operation of the GPS III architecture will ensure that this requirement is met.

To only focus on backwards compatibility, however, is to miss a number of opportunities that GPS III brings to the L-band user. Some of those advantages, as well as any changes to L-band user operations concepts, are presented here.

<table>
<thead>
<tr>
<th>Table 4. Terrestrial Service Volume Accuracy Requirements</th>
</tr>
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<tbody>
<tr>
<td><strong>Horizontal</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>3.7 m</td>
</tr>
<tr>
<td>5.6 m</td>
</tr>
<tr>
<td>13.3 ns</td>
</tr>
</tbody>
</table>

**Better Accuracy**

User accuracy metrics are a function of not only the GPS signal in space, but also the user equipment (UE). The GPS III Draft System Specification defines three classes of user equipment termed “Good,” “Better,” and “Best” as shown in Table 3 [6].

Using these assumptions, Table 4 provides the Block III threshold requirements for terrestrial service volume accuracy based on each of the three UE classes [6].

In order to take maximum advantage of GPS III accuracy, users should acquire and track in a dual frequency mode. More frequent uploads will lower the age of data, and flexible MNAV and CNAV messaging will provide more timely ephemeris and clock updates. As a result, user equipment should “read” the broadcast navigation message more frequently than just at the top of every hour.

**Taskable Services**

GPS III provides a new taskable service (spot beam) and significant enhancements to the modernized taskable services of flexible navigation messaging and cryptographic key management. Military users will be able to interact with the Control Segment to request specific GPS services. Once these services have been requested and implemented, the user equipment logic will need to determine things like when and how to look for the spot beam signal instead of the lower power earth-coverage signal.

**Evolving Operations**

GPS applications continue to proliferate, and AFSPC and L-band user operations continue to adapt accordingly. In addition to the GPS III-specific concepts presented in this paper, there are several other efforts underway that seek to transform GPS operations.

AFSPC has drafted a vision for an expanded operational infrastructure that will combine the existing architecture with additional expertise and information centers. This single “effects-based” center is tentatively called the GPS Operations Center (GOC) and will be manned by representatives from across the Department of Defense, Department of Transportation, and allied military forces [9]. The GPS III
architecture design contains sufficient flexibility to seamlessly fit into the GOC concept, gradually evolving to provide expanded capabilities while preserving backwards compatibility.

As these concepts evolve, the focus remains on developing systems that give operators and users real-time access to the most important information used to make critical decisions. For the AFSPC operators, those decisions relate to satellite health, safety, and configuration. For L-band users, those decisions relate to how good the positioning and timing service is now and what its predicted performance will be in the future.

CONCLUSION

The GPS III system offers significant operational advantages to both the AFSPC operators of the Space and Control Segment, as well as the L-band users within the User Segment. The “contact one, contact all” paradigm improves system responsiveness and flexibility. A number of GPS III features will translate into better positioning and timing performance for all users. The NAVWAR spot beam antenna provides the military with improved anti-jam to preserve their use of GPS in a hostile environment. Improved MCS displays and new software tools will transform satellite operators into GPS mission managers. Lockheed Martin will continue to work side-by-side with Air Force and civilian agencies to ensure that GPS operations in the future remain focused on the end user mission accomplishment.

ACKNOWLEDGMENTS

The authors thank the men and women of Lockheed Martin Navigation Systems, especially Tom Reilly, Mel Beebe, Don Speranzini, Phil Farnum, Dean Mancinelli, Jeff Andrews, and Chuck Frey. We also thank the GPS Joint Program Office, particularly LTC Paul Yamaguchi and Art Fernandez for their thorough review and guidance.

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Radar: The Evolution Since World War II

Ralph Strong
Historical Electronics Museum

INTRODUCTION

Radars at the end of World War II depended on antenna beam width and position for angle information and time for range resolution. Most data was presented to an operator on a Pulse Position Indicator (PPI). Radars could display the ground as a crude map or show airborne targets as spots scaled for distance on a presentation refreshed at a slow scan rate. If airborne targets were at the same range as the ground, either in the main lobe or side-lobes, they were obscured by the ground clutter and could not be detected.

Radars flying today are complex multimode systems with the ability to isolate airborne and ground moving targets from ground clutter. Angle resolution is determined not only by the antenna aperture but is enhanced by the Doppler content of the signal. Range resolution is determined by frequency or digitally coded modulation. Complex digital algorithms automatically select optimum modes and processing methods to detect targets in the presence of clutter and to generate high resolution ground maps. Weather radars on executive aircraft make use of similar processing to select the safest and most comfortable routes. Radar information is integrated with navigation subsystems and other sensors and is displayed efficiently. Multimode radar fire control systems detect targets, solve interception geometry problems, and illuminate targets so missiles can home on them while searching for other targets. Reliability improvements have made radars dependable such that they operate for hundreds of hours between maintenance operations.

RADAR IN THE KOREAN WAR

In 1950, about five years after the conclusion of WW II, the Korean conflict caused a scramble to upgrade all avionics in the military inventory. Some development took place in the intervening years, but there had been little development of avionic hardware. Funding increased for radar technology and production to meet the demands of both the Korean War and the Cold War with the USSR. New radars and other avionics were needed for high performance jet airplanes to replace those designed for propeller aircraft.

The USSR manufactured large numbers of long range bombers, including the Tupolev TU-4, copied from Boeing B-29 aircraft. The realization that the USSR had long range nuclear bombing capability demanded development of radar equipped all weather interceptors.

In the Korean War, direct confrontation with the Russians and Chinese was avoided. Harbors were not bombed and material delivered to North Korea were not intercepted. The air war evolved to interdict these supplies during distribution over highways and rail. This strategy required control of the skies to allow ground interdiction and to protect friendly supply lines. This air action took place in daylight and depended upon visual identification. Jet aircraft rapidly replaced propeller-driven aircraft in this role. North American F-86 series aircraft fought against Mikoyan-Gurvich MIG-15’s for air superiority. Airborne radar played a minor role in this air-to-air combat although the F-86 series aircraft used automatic ranging radars to augment optical sights.

North Korean strategic targets were bombed by Boeing B-29 and B-50 aircraft. Daylight bombing was replaced by night bombing as defenses from MIG interceptors and ground
fire became effective. Bomb delivery made use of the World War II AN/APQ-13 radar and Shoran. North Korea and China attempted to stop the night attacks with Mikoyan-Gurvich MiG-15 and Yakovlev YAK-15 interceptors using ground radar for command and control. Douglas F3D-2 all weather jet fighters were found to be the best available airplanes to protect the USAF bombers and this aircraft is credited with the first night victory using radar, without visual identification. F3D-2 aircraft were equipped with the AN/APQ-35 radar which was actually three radars: one for search; one for tracking while the search radar continued to seek new targets; and one for tail warning. This marriage of the three units was the first track-while-scan radar. A photograph of the tracking radar as displayed at the Historical Electronic Museum is shown by Figure 1.

The Hughes AN/APQ-33 radar, part of the Hughes E-1 Fire Control System, was developed for Lockheed F-94 interceptors. This was an integrated all weather system for both gun laying and guided missile fire control. F-94 aircraft were primarily for Continental Air Defense of North America although some were assigned in Korea to defend friendly air bases. F-94’s were not used for bomber escort service in Korea until late in the war because of the concern that the fire control system would fall into Soviet hands.

Advanced versions of the E-1 Fire Control System were developed for the Northrop F-89 and North American F-86D aircraft. These “Low PRF” pulsed radars operated in the X-band (3 cm). Later evolutions introduced improved antennas, higher RF power to improve range performance and reduced susceptibility to jamming. Ground mapping and ranging modes were included for air-to-ground attacks. The evolving systems supported more sophisticated Falcon and newer generation missiles. These radars and missiles have range capability far beyond those permitting visual identification.

WEATHER AND GROUND MAPPING

Military transport and air rescue service aircraft were equipped with ground mapping and weather radars in the Korean War era. These X-band pulsed radars improved safety in severe weather, provided a navigation aid in hostile environments, improved accuracy for dropping paratroops and parachute delivered supplies and were invaluable for search and rescue missions.

At this time, commercial airlines became interested in weather radars. After much study, the airlines adopted C-band radars (6 cm). The longer wave lengths reflect less from rain and attenuation in heavy rain is lower. The compromise choice of frequency gave better penetration of storms for improved mapping of severe weather, but was inferior for ground mapping (a function not required for commercial operations).

COLD WAR BOMBING RADAR

As the Boeing B-29 and B-50 aircraft were replaced, new more powerful and complex bombing radars, integrated with weapons delivery computers, were developed for the North American B-45, Boeing B-47, and Boeing B-52 bombers. These radars required greater range and improved resolution to accommodate higher altitudes. B-52 aircraft were recently upgraded with multimode radars featuring high resolution Doppler mapping modes that are integrated with visible and infrared optical sensors to support complex weapon delivery systems. With the introduction of smart bombs and cruise missiles that are guided by GPS and laser designators, bombing accuracy from high altitude is now a few feet as opposed to hundreds of feet typical of WW II accuracy, revolutionizing the impact of high altitude bombing.

SURVEILLANCE RADAR

General Electric/Hazeltine developed the AN/APS-20A radar for tracking enemy warships, submarines, and aircraft. A more powerful version, the AN/APS-20B, was installed on the Lockheed Constellation aircraft, later identified as EC-121C and D. This radar, for airborne surveillance in remote areas made use of a 17 foot parabolic reflector combined with transmitter peak power of over 2.5 million Watts (peak) at S-band (10 cm). The difficult problem of isolating targets from ground clutter with pulsed radars was somewhat mitigated with improvements of airborne moving target indicators (AMTI). In principle, the aircraft could fly high, extending the range of the radar far over the horizon, but flying at high altitudes increases the clutter to be suppressed.

In 1967, six of the aging EC-121D aircraft were used effectively in the Southeast Asia conflict to detect MiG fighter aircraft deployed from Chinese bases. Early detection was decisive in preventing the Viet Cong from challenging air superiority in South Viet Nam.

RECONNAISSANCE RADAR

In the mid-1950s, high resolution imaging radars were developed for all weather reconnaissance. The Westinghouse AN/APQ-56 was an early example that used a “real aperture” side looking antenna operating at K-band (35 GHz). The antenna was 15 feet long to form a narrow antenna pattern at right angles to the aircraft line of flight, achieving high resolution along the flight path. High cross track resolution was achieved by use of short (0.1 microsecond) transmitter pulses. Along track scan is provided by the aircraft forward motion.

An improved variant was flown by Westinghouse as a commercial venture to collect imagery for Earth resources. Data were collected for governments, oil companies, and mining interests. Since the radar collects images day or night through foliage and clouds, details of geology can be seen that cannot be detected from aerial photography. Parts of South America were mapped where aerial photography was not possible, as the regions were normally cloud covered. Figure 2 is an example of radar images taken by this radar.

Synthetic Aperture Radar (SAR) has generally replaced real aperture radars for imaging. For these radars, a coherent
transmitter is required. High azimuth resolution along track is achieved by collecting the phase history of the received Doppler signal along the path of the flight. Range resolution is achieved by the means of frequency modulation on the transmitted pulses in a process commonly known as "chirp" or a suitable digital code. Along track resolution is a function of the integration time and ambiguity constraints rather than the physical length of the antenna. Synthetic aperture radars quickly became the standard with applications on reconnaissance aircraft, including the Lockheed U-2 and Boeing RB-47's and are now routinely flown in space and atmosphere for Earth resource and oceanographic studies.

PULSED DOPPLER

In the late 1950s, Westinghouse developed X-band Pulsed radars for the Boeing BOMARC-A long range interceptor missile. The missile was developed to intercept hostile Russian aircraft flying over Northern routes. It flew at hypersonic speeds at high altitude (60,000 feet or higher), guided by ground radar. When in range, the target seeker's radar was activated to search, detect, and track targets below the missile. Control of the missile was then given to the radar to steer the missile to the target(s).

The BOMARC-A was effective for high altitude targets but was blind to low targets masked by ground clutter. The AN/DPN-53 Pulsed Doppler target seeker was developed to correct this problem and became the first airborne Pulsed Doppler Radar.

Major design issues were resolved to develop Pulsed Doppler radars. Transmitters must provide pulse to pulse coherence with high fidelity. Long pulses are used for narrower pulse spectrums and to accommodate linear transmitting devices (klystrons). The spectrum of the

![Fig. 2. AN/APQ-97 Radar image of the Baltimore Harbor taken from 20,000 feet in 1964. Source: Historical Electronics Museum](image-url)
radiated/received energy appears as a sequence of lines separated by multiples of the PRF. For “High PRF” modes there will be a clear unambiguous range of frequencies in the received spectrum for detection of Doppler shifted targets. This is shown in Figure 3. Range is ambiguous as many pulses may occur in the round trip time to a target. Since it is not feasible to receive when transmitting, the wide pulses blank or eclipse many targets, so multiple PRF’s are alternated so targets in the search volume are not always eclipsed. Targets flying at right angles to the line of flight will have no Doppler shift and will be undetectable.

Radar detection range is a function of average power on the target during the integration time. In Pulsed radars, magnetrons were used since World War II when they revolutionized radar design by making microwave frequencies practical. In Pulsed Doppler radars, magnetrons cannot be used because they do not yield pulse-to-pulse coherent signals. Klystrons which can be operated as linear amplifiers were developed to produce high average power, although peak power is low. They are used with high duty cycles of about 50% (as opposed to about 1% for Pulsed radars).

**PULSED DOPPLER FOR WEAPONS CONTROL**

The first Pulsed Doppler Radar for fire control in aircraft was the Westinghouse AN/AWG-10 Radar, designed for the

**Table 1. Radar Pulse Repetition Frequency (PRF) Modes**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Characteristics</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low PRF</td>
<td>Range Unambiguous</td>
<td>Ground Mapping</td>
</tr>
<tr>
<td></td>
<td>Doppler Ambiguous</td>
<td>Pulsed Radar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air-to-Air</td>
</tr>
<tr>
<td>Medium PRF</td>
<td>Range Ambiguous</td>
<td>Low Clutter</td>
</tr>
<tr>
<td></td>
<td>Doppler Ambiguous</td>
<td>Maritime</td>
</tr>
<tr>
<td>High PRF</td>
<td>Range Ambiguous</td>
<td>Pulsed Doppler</td>
</tr>
<tr>
<td></td>
<td>Doppler Unambiguous</td>
<td>Tail Chase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulsed Doppler</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air-to-Air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Search Modes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Head-on Air-to-Air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surveillance</td>
</tr>
</tbody>
</table>

**Fig. 5. AN/APG-77 Radar Antenna built for the Lockheed Martin F-22 Aircraft**

*Source: Historical Electronics Museum*

McDonald F-4J airplanes and used by the US Marines. This was an early multimode system that included Pulsed Modes, the fire control computer, plus a Pulsed Doppler mode, which gave the aircraft a “look-down” capability to intercept low flying aircraft. Similar multimode radars, such as developed by Hughes for the Grumman F-14, followed a short time later.

In comparing multimode Pulsed Doppler radars to WW II pulsed radars, the cliché that radars transmit a pulse then measure the time of the return pulse is misleading. Comparing a Pulsed Radar to Pulsed Doppler radar is like comparing a musket to a Vulcan machinegun firing thousands of rounds per
minute. To summarize differences, the Pulsed Doppler radars transmit coherent pulses, normally with about a 50% duty cycle and require multiple PRF’s to avoid eclipsing. Target returns are ambiguous in range, so combinations of multiple PRF’s and transmitter frequency modulation must be used to determine range. Targets must be detected in the areas of the frequency spectrum not saturated with main beam clutter. Finally, means must be found to display the target information to the users as the classic PPI mapping presentation is not appropriate.

Major improvements of multimode radars for fire control were accomplished for the McDonnell Douglas F-15 aircraft in 1972. The radar was produced by Hughes Aircraft. Semiconductor technology made it feasible to fully digitize the radar signal processing. Further, the art of processing radar data had progressed to make sophisticated multimode processing of Pulsed Doppler signals feasible. “Medium PRF” modes (both range and Doppler returns are ambiguous) were introduced to improve performance during tail chase, where the target’s Doppler return lies in the same spectral region as side-lobe clutter. Parabolic antennas were replaced by slotted arrays to reduce side-lobe clutter. Additional clutter canceling makes use of complex digital data processing. Radar Modes used in modern fire control radars are summarized in Table 1.

This radar and those that followed make use of large scale integrated circuits to reduce the size and weight and to drastically improve reliability over earlier analog radar systems. Specialized parallel computers implementing Fast Fourier Transformations (FFTs) make near perfect digital filters which greatly enhanced performance.

MODERN SURVEILLANCE RADAR

In 1977, a new standard was set for airborne surveillance radars; the first AWACS radar was delivered for the Boeing E-3A. The antenna (shown in Figure 4) used an ultra-low side-lobe slotted array installed in a rotating radome. The aircraft operates at high altitudes and provides surveillance
over long ranges. AWACS provided air surveillance for Desert Storm and the Iraq invasion, proving its value in maintaining control of air space to achieve air superiority in remote locations.

AWACS provides comprehensive knowledge of the location of friendly and hostile aircraft and serves as a command and control center for the air war. Air wars are executed on all weather basis at a long distance using air-to-air missiles without opposing fighter pilots making visual contact.

AWACS was followed by Joint Stars, which images the battle situation on the ground. Joint Stars makes use of complex digital processing to image slow moving ground targets from clutter using Pulsed Doppler, clutter cancellation, and SAR techniques. Joint Stars was first used in Desert Storm with remarkable success.

ANTENNA DEVELOPMENTS

Phased arrays, as opposed to parabolic antennas, are now used on high performance radars. Phased arrays give the user more options in beam shape, lower side-lobes, and greater control of the radar beam. Further evolution resulted in Agile Beam Phased Arrays that use transmit-receive modules for each element of the array to form the radar beam. The beam scans without mechanically moving the antenna, and can be pointed instantly between targets. Portions of the array can be used for different purposes. Agile Beam Phased Arrays enhance performance of the latest high performance fighter aircraft. Figure 5 shows a mock-up of the antenna developed by Northrop Grumman for the Lockheed-Martin F-22 aircraft.

SUMMARY: THE RADAR EVOLUTION

Modern radar design has benefited from the evolution of specialized digital processing, allowing high resolution ground mapping, target identification, and target tracking under many conditions. Air-to-air interception makes use of complex decision processes to select from many modes that depend on the clutter backgrounds and flight profiles. Today's multimode radars provide this information for each task while minimizing distractions. Fire control radars support a wide selection of weapons, including cannons and guided missiles. This is possible because of advanced digital processing.

In the interval since WW II, radar design evolved from vacuum tubes to semiconductors and then to massively integrated circuits. Computers specialized for Fast Fourier

Transforms (FFTs) have revolutionized radar data processing. System reliability has improved from a few hours to hundreds of hours. Effective built-in test informs ground maintenance personnel of problems for easy maintenance and low failure rates reduce or eliminate field maintenance benches at forward locations.

Airborne surveillance radars, such as AWACS Joint Stars have changed the nature of warfare. Commanders have virtually full view of enemy and friendly forces. Radars, in combination with other remote sensors, provide precise weapon delivery, reducing collateral damage and making all weapons more effective.

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Optimization of the Ship’s Navigation and Controlling System
With Results of Sea Trials

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ABSTRACT

This paper considers the state-of-the-art information technologies applied to solve the automatic track-keeping problem of the ship on a preset system of straight tacks and on a preset route to the area of hydrographic survey. A navigation-and-controlling system aboard a hydrographic vessel GS-439 was used to provide the fulfillment of the task. The results of the sea trials of control problems are given. They have shown rather good accuracy of the ship track-keeping on a preset system of straight tacks and on a preset route as well as the efficiency of automatic ship passing to the first tack and passing over to the next tacks in surveying the seabed relief, using a multi-channel echo sounder.

INTRODUCTION

The navigation-and-controlling system intended to be used aboard hydrographic vessels must generate navigation and dynamic parameters of a vessel motion with required accuracy and ensure the ship track-keeping on a preset system of tacks over the area of survey. Motion parameters are necessary both for fixing measurements of the echo sounder and other sensors to geographic coordinates with due account for heading, pitch, roll, and for generation of the rudder angle control signal for track-keeping of the ship on a tack and a preset route.

The problems of track-keeping stated in a similar way were considered in [1,2], but no account was taken of uncertainty of ship model parameters and, consequently, adaptation of the control law.

To solve the problem of the ship track-keeping on a tack and on a preset route most efficiently with proper account for the peculiar features mentioned above, the following state-of-the-art information technologies have been applied [3, 4]:

1) a non-invariant approach to estimation of navigation and dynamic parameters for generation of the control;

2) synthesis of the robust control law ensuring the guaranteed value of the quadratic criterion of the control efficiency in the domain of uncertainty of the model parameters;

3) a method for determining a set of models needed for effective adaptation of the control law;

4) multialternative filtering based on the bank of Kalman filters for processing of navigation data, which allows determination of the most adequate model and evaluation of the state vector in the conditions of uncertainty of the ship model parameters and disturbances;

5) selection of weighting coefficients of the optimality criterion on the basis of simulation...
combination of a strapdown inertial navigation system (SINS) integrated with an SNS, log and gyro compass, computer that realizes control problems and a unit intended for conversion and transmission of a control signal to the ship rudder control system.

The system has ensured automatic track-keeping of the ship on a preset system of tacks in surveying the seabed relief with the use of a multi-channel echo sounder as well as stabilization on a preset route to the survey area.

The input data for the navigation filter in the generation of the rudder angle was represented by the coordinates and absolute velocity from the SINS and SNS, the yawing rate and lateral acceleration from the SINS, the heading from the gyro compass and the speed from the water speed log.

The trials were carried out in Autumn 2003 in the Gulf of Finland at different motion speeds:

- **full speed** — a speed of 10-11 kn; the ship motion on a preset route was ensured by two propulsors;

- **slow speed** — a speed of 3-4 kn; the ship motion on a preset system of straight tacks with the use of a multi-channel echo sounder was ensured by one of the two on-board propellers.

The hydrometeorological conditions during the sea trials were as follows: the wind velocity from 5 to 10 m/s, the sea state code up to 3.

The trial results are as follows:

- the ship track-keeping error on the tack did not exceed 2-6 m at a speed of 4-6 kn, on the route — 1-3 m at a speed of 9-11 kn;

- the ship track-keeping error on the tack-to-tack circular arc did not exceed 5-12 m at a speed of 4-6 kn, on the leg-to-leg circular arc of the route did not exceed 3-6 m at a speed of 9-11 kn;

- the error of the ship passing to the initial tack point did not exceed 2-5 m.

It has been found that these errors are 3-5 times less than they are with the ship manual control, when the quality of control depends on the experience of the hydrographer, and 1.5 - 2 times less than they are with the use of a course-keeping PID-type autopilot.

Let us cite some variation of the parameters in the process of ship passing to a preset tack and track-keeping during the sea trials. The following notations are used: \(\theta_{\text{lat}}\) — lateral deviation from the program track or tack in meters; \(\theta_{\text{yaw}}\) — yaw angle in degrees, measured from the course angle of the segment or from the tangent to circle; \(\varphi_{\text{rudder}}\) — rudder angle in degrees; \(W\) — yawing rate in degrees per second; \(V\) — speed of the vehicle in m/s, \(t\) — time in seconds.
Let us estimate the efficiency of the approaches suggested. First, the simulation results of the stabilization problem with the use of the dynamic model of the hydrographic vessel GS-439 have shown that to ensure high-quality control (small values of lateral deviation and yawing at track-keeping), it is necessary to prescribe a sufficiently high coefficient of the yaw angle (p.5). Note that with this, the sensitivity of the control law to the model parameters falls significantly. This fact was proved by the results of the sea trials as well. With this in view, the number of alternative models was reduced to three and it was possible to provide robust characteristics in each of the subdomains (pp. 2, 3), although the uncertainty range of the model parameters was 50% of the first-approximation design model. Automatic identification ensured determination of the most adequate model depending on the ship loading and on the multi-channel echo sounder put down into the water (p. 4). The ship track-keeping on tracks constructed on-line allowed a small error in ship passing to the initial tack point (p. 6).

A peculiar feature of the trial results is that only one of two port and starboard propellers was used to ensure the ship slow speed on a preset system of straight tacks. As this takes place, the movement about the vertical axis is compensated by the movement from the rudder. It is clear that such compensation adversely affects the quality of the transient process, resulting in a track-keeping error of the order of 5-6 m on the leg of the transient process. A similar conclusion can be made for the ship track-keeping on a circular arc.

Trial results have shown that the approach suggested to solve the problem of the ship track-keeping on a preset system of tacks and on a preset route ensure high efficiency of control.

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Up-to-date view on the problem of ship stabilization and its navigational support,

Correspondence (continued from Cover 2)

When he arrived and saw the conditions he was visibly angry. We were later told that he "dropped a dime" on the local Army staff.

Net, the Army has transferred the first 17 acres of the 37 acre historic district. They are removing all the asbestos and removing most of the building interiors to get rid of the mold. They are replacing any WW II windows because the glazing has asbestos. They are replacing the sewers, they have replace the electric feeds and main transformer, replaced the boiler in the Marconi cottages and hotel and they replaced off the copper gutters the contractors had removed to sell for scrap.

Since the August 25, 2005 transfer we have been painting, cleaning, etc. every weekend. I and a dozen persons were there 6-8 hours today. We will spend a few hours there Sunday.

We just got word that NASA will award us a program grant to send three persons to Kennedy Space Center to develop space education programs to implement at the Diana site.

So in all the fighting, Mrs. DeWitt and the goal to secure John DeWitt's papers got lost. I did call her. She was agreeable for me to visit to look at the papers. I am still interested but have no time to visit Nashville.

Now that we can work to improve Camp Evans to save it for items like John DeWitt's papers I am working as hard as I can.

If you have any allies in or near Nashville who can help that would be great.

I still have to write the IEEE Milestone Application. I know exactly what to do and now that the battles appear to be over and some property has transferred it is just a matter of making the time.

As you can guess, I am having a great time, but am exhausted with all this stuff, my full time job and my farm. But saving Camp Evans and it's radar legacy is worth the effort.

A great guy in Chicago has been scanning and mailing us CDs with all the papers from the AN/TPS-3 portable and later mortor locating radar John Marchetti developed with the Zahl tube. Our library and archive is growing. We are getting more organizations involved. We will meet the new General of Fort Monmouth soon. Things are looking better, but still lots of work.

You are invited to help out any way you would like with Camp Evans. Thanks to you we have the great IEEE Award for the Pearl Harbor radar displayed on the mantel of our Marconi cottage. A fellow visited who worked at Fort Shafter and he personally wired the phone system between the radar control center and the remote units. We recorded his interview on tape. Basically, everything was ready on December 7 except no procedures were implemented and not enough staff were trained or scheduled for radar duty.

We also interviewed a fellow who operated a SCR-268 at Anzio. Another fellow who worked on the cavity magnetron and IFF at Camp Evans during the war...

So you can tell we are doing the best we can for a bunch of volunteers.

Thanks,
Fred Carl
Software Approach to Access UWB Interference on GPS Receivers

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Miami University
&
J.B.Y. Tsui, D.M. Lin, M.M. Miller, D. Janning
Air Force Research Laboratory

ABSTRACT

Ever since the FCC approved the use of UWB devices in commercial and federal bands, various agencies whose operations and/or products rely on the integrity of signals within certain “restricted” radio frequency bands have voiced concerns over the potential impact of the UWB interference. GPS signals are among these “restricted” bands. Several groups in the GPS community have conducted experimental studies concerning the impact of UWB interference on the performance of various grades of commercial and aviation GPS receivers.

In this paper, we present a software approach to simulate and evaluate UWB interference on GPS receivers. The software approach provides greater flexibility in the design of testing scenarios, such as the inclusion of a large number of aggregated UWB devices, the generation of new UWB signals and modulation schemes, and the possibility of extending the study to new GPS signals. The paper will discuss a general framework for developing algorithms to evaluate UWB and GPS interference under a wide variety of hardware and software conditions. This framework consists of three classes of components: Input, Processing, and Analysis. The input components are responsible for the generation of UWB signal waveforms and modulation schemes, and GPS signals. The processing components include a simulated model of GPS RF front end and software implementation of GPS processing blocks, such as acquisition, tracking, and post-processing. The Analysis components focus on the study of specific receiver processing component outputs. Both real and simulated UWB signals can be used in the study. The real UWB signals are primarily used to validate the simulation procedure, whereas the simulated UWB signals are used to allow the immediate incorporation of new UWB waveforms and modulations in the evaluations.

This paper will present details of the software components developed and the preliminary results achieved.

INTRODUCTION

In February 2002, the Federal Communication Commission (FCC) approved a Report & Order (R&O) that permitted the commercial use of the ultra-wideband (UWB) technology [11]. Since then, UWB has attracted considerable attention from communications and navigations communities because of several unique advantages as well as potential concerns that are associated with UWB signals. With the potential to offer data transmission rates of 100-500 Mbps at distances of 2-10 meters using average radiated power of a few hundred microwatts, and the possibility of miniaturized mass production at low cost, UWB technology is currently seen by many to be the backbone of future short-range wireless communication systems [2, 3]. In addition, UWB signals have been utilized in imaging radar techniques because of their wall penetration capability, and are being studied for indoor location and navigation purposes because of their performance in multipath environments. With all of these potential applications and advantages, a mass market of many varieties of UWB devices may not be far in the future.

The question remains of the impact of a large number of active UWB devices on existing spectral users, especially for users of the Global Positioning Systems (GPS) whose signal power is far below the noise floor. Several groups have conducted studies of UWB interference and its impact on GPS receiver performance [4, 5, 6, 7]. These studies used various grades of commercial GPS receivers and adopted several approaches in their testing. All of the testing has concluded that UWB signals degrade GPS receiver performance. There are,
Fig. 1. Maximum Allowable UWB EIRPD
Set By FCC in 2002

however, some unanswered questions and certain drawbacks
associated with these testings. First, a wide variety of hardware
and receiver architecture were used in the testing. The
differences in the hardware made it difficult to determine the
dominant factors that contribute to the degradation of receiver
performance under UWB interference. Second, most tests
were concerned with the errors in receiver pseudorange output
or the amount of UWB power that will cause receiver loss of
lock. Third, a limited number of UWB waveforms and discrete
power levels were used in the previous testing reports. This
limitation makes the previous testing results outdated as the
UWB community continues to explore new waveforms and
new modulations schemes. Finally, previous testing results are
limited to a relatively small set of UWB sources. One of the
most important features of UWB techniques is the potential for
a large number of UWB devices to co-exist and operate in a
relatively small area without interfering with each other.

What are the characteristics of a large number of
aggregated UWB interference? What is the impact of the
aggregated UWB devices on the performance of GPS
receivers? Evidently, it is not feasible to obtain answers for
these questions using experiment-based testing as was done in
previous studies.

This paper presents a different approach to evaluate the
impact of UWB interference on GPS receivers. Software GPS
receivers are used in this study to provide greater flexibility in
identifying the interference effect at various stages of the
receiver design. A framework was established for developing
algorithms to evaluate UWB and GPS interference under a
wide variety of hardware and software conditions. This
framework provides great flexibility in the design of testing
schemes while allowing users to focus on the effects of specific
receiver functions. Both real UWB signals and simulated
UWB signals can be used in the study. The real UWB signals
can be used to validate the simulation procedure. Simulated
UWB signals can be used to allow immediate incorporation of
new UWB waveforms and modulations in the evaluations.
Using simulation also made it possible to create a large number
of aggregated UWB signals and testing its impact on GPS
receivers. In this study, a prototype simulated version of a radio
frequency (RF) front end for a software GPS receiver
developed at Air Force Research Laboratory (AFRL) Sensors
Directorate, WPAFB was created. This simulated RF front end
processes input UWB signals (simulated or real) and generates
a digitized output. This output can then be mixed with various
GPS signals (simulated or real) to undergo acquisition,
tracking, and post-processing procedures. By varying the input
UWB parameters, one may study the output at different stages
of the GPS receiver to assess the UWB interference impact on
the GPS signals at those stages.

In the remainder of this paper, a review of the current state
of UWB waveform designs and modulation techniques will be
given, followed by a description of the general framework
established for simulating UWB interference on GPS software
receiver functionality. Detailed software algorithm design for

Fig. 2. Time and frequency characteristics of a
Gaussian monopulse as a short impulse signal

can be used in the study. The real UWB signals
can be used to validate the simulation procedure. Simulated
UWB signals can be used to allow immediate incorporation of
the simulation will then be presented. The preliminary test
results and future works will also be discussed.

CURRENT STATE OF UWB WAVEFORM DESIGN
AND MODULATION SCHEMES

A UWB signal is one whose bandwidth exceeds 0.5 GHz or
whose ~10 dB bandwidth exceeds 20% of its center frequency,
whichever is smaller. To protect certain restricted bands such
as GPS signals from UWB interference, FCC has set maximum
Effective Isotropic Radiated Power Density (EIRPD) for UWB
signals at different frequency bands. Figure 1 shows this
prescribed spectral mask set by the FCC.
The fundamental building blocks of a UWB signal are impulses. The original impulse radio uses short impulses with durations that are no more than 1 ns [8]. Figure 2 shows the well-studied Gaussian monopulse and its normalized power spectral density. Recently, more research has been focused on synthesizing means that can generate more complex waveforms that can more effectively utilize the allotted spectrum, reduce power consumption, achieve more reliable communications, and reduce complexity in receiver hardware design [2]. The IEEE P802.15.3 High Rate (HR) Task Group (TG3) for Wireless Personal Area Networks (WPANs) is chartered to draft and publish a new standard for high-rate (20Mbit/s or greater) WPANs using UWB signals (http://www.ieee802.org/15/pub/TG3.html). Currently, there are two competing proposals, led by Texas Instruments and XtremeSpectrum, Inc., respectively, seeking the standardization of UWB for future WPAN devices.

The proposal led by Texas Instruments uses the Multi-Band Orthogonal Frequency Division Multi-access (OFDM) technique [9]. This proposal divides the 3.1 to 10.6 GHz into multiple bands, each with 528MHz bandwidth to enable multiple modes of device operation. Information is transmitted using OFDM modulation on each band. The proposed data rate ranges from 35 to 480 Mbps with symbol length at 312.5 ns. The proposal led by XtremeSpectrum Inc. [10] uses joint time-frequency wavelet family pulses to transmit and receive signals over two distinct bands (3.1-5.15 GHz and 5.825 to 10.6 GHz), with a proposed data rate from 25 to 450 Mbps. M-ary biothogonal keying is proposed as the modulation scheme.

Since the UWB signals are still undergoing continuous debate, experimental testing of their interference with GPS receivers is not feasible. Testing of aggregated future UWB device impact on GPS receivers is even harder to realize. The software approach described below provides a feasible alternative for the interference evaluation.

FRAMEWORK FOR UWB-GPS INTERFERENCE STUDIES

As discussed previously, UWB technology is undergoing continuous change and evolution. To be able to study the UWB interference impact on GPS receiver performance in a timely manner, it is necessary to establish a general simulation framework that can provide systematic means that can be applied to a wide variety of signal and system designs. Figure 3 shows the basic framework developed for this purpose.

As shown in the figure, this basic framework consists of three main functional blocks: input, processing, and analysis. Each component in the framework can have a variety of implementations. The components interact with each other via defined interfaces. One may replace a particular component with a different internal design and implementation without affecting the set up of the rest of system. Doing so allows one to experiment with any type of data sources, signal forms, processing architecture, and analysis methods with a minimum amount of software redesign and rebuild. For example, the UWB signal input can be simulated waveforms and simulated modulation schemes. It can also be real samples of UWB signals generated by a UWB transmitter. Furthermore, the samples could be taken via conducted path or radiated path. The digitized GPS signal can be simple simulation data, or data generated by a GPS signal simulator, or data taken by a specific GPS RF front end. These different forms of input data give us the flexibility and capability to analyze system response under a wide range of conditions.

In software GPS receivers, some of the functions, such as acquisition and tracking, which are traditionally done using hardware, are also implemented with software. The only hardware is the radio frequency (RF) front end. Figure 4 depicts the block diagram of a typical GPS RF front end consisting of antenna, preamplifier/RF filter, down-converter, intermediate frequency (IF) filter, and analog to digital converter (ADC) [11, 12]. An alternative design involves direct sampling of RF signals without down-conversion [13, 14]. In this project, a simulated RF front end, resembling the design used for a software GPS receiver at AFRL/WPAFB, is created. With the flexibility built into the framework, one may easily replace the simulated RF front end with a new design when needed.

The UWB output from the GPS RF front end can then be mixed with digitized GPS signals and fed to the acquisition stage. There is a number of acquisition algorithms developed over the years [15]. We will be using a software acquisition algorithm developed at AFRL/WPAFB.

The output of the acquisition stage will be analyzed to study the UWB signal's threshold EIPRD at which acquisition fails. This study can be done for a range of GPS signal power levels and various GPS signal conditions. It can also be done for any combination of UWB waveforms and modulation methods.

The AFRL at WPAFB has also developed tracking algorithms for both nominal and weak signals, and post processing algorithms. These algorithms can be used to test the output at each of these processing blocks to determine the UWB impact. Evaluation of tracking algorithms is an on-going project.
Fig. 4. A GPS RF front end

Acquisition, tracking, and post processing algorithms developed at other research and industrial organizations could also be used for testing using this framework. Doing so allows one to evaluate the receiver performance for a wide variety of applications such as the impact of UWB on weak GPS signals, signals under high dynamic conditions, and different noise levels in algorithms. New types of UWB sources can be tested and their impact can be evaluated before they are approved or deployed. Furthermore, one may simulate and test the effect of a theoretical UWB waveform before it is realized in hardware.

SIMULATION RESULTS

A Gaussian monopulse is used to test the GPS front end simulation results. Figure 7 shows the input UWB impulse $x(t)$ and the output at each stage of the simulated front end.

In Figure 5, the horizontal axis is time in unit of $\mu$s. A single pulse with amplitude of 1V and pulse width of 250 picoseconds is used in the simulation. As can be seen from the figure, the antenna output consists of a delayed ringing response of the input pulse, as expected. The down conversion process took some of the higher frequency ringing effect out of the antenna output. The IF filter further filtered out the extreme frequency components and also introduced a delay in the response. For an input with amplitude of 1V, the final sampled output has a peak around 0.2 mV, a 5000 fold reduction in signal strength.

What happens when a sequence of UWB signals are received? How do the impulses interact with each other? Considering that the system being simulated is a linear-time invariant (LTI) system, the response of the system to a sequence of pulses should be the superposition of each individual pulse response, taking into consideration the time delays between each of the pulses. To verify that such an assumption is valid, we generated a sequence of UWB pulses and obtained the simulation output of the sequence at the front end. The result is then compared to the superposition of each individual pulse output with the same time delay. The results are identical. Figure 6 shows the result of a sequence of UWB impulses. The parameters of each individual pulses are the same as those used to generate Figure 5. The variations in the input amplitude in the figure are due to sampling. The

Fig. 5. A UWB impulse and its output at each stage of the simulated GPS front end

sequence uses an absolute random dithering modulation scheme. The PRF is 1 MHz, and the dithering can be up to 50% of 1/PRF.

One of the difficulties associated with the simulation is the size of the input, intermediate, and output signal vectors. Since the input is an infinite sequence of continuous data, one must make an appropriate low-pass filter to get a finite input. Since the output will be combined with the GPS input to undergo the acquisition procedure, at least 1 ms of continuous data is needed for the processing. With a sampling rate of 20 GHz, 1 ms input data consists of 20 million samples. This size is beyond what Matlab can handle. Considering the case of weak GPS signal acquisition, several hundred milliseconds of data may be used for acquisition alone. It is necessary to come up with methods that can break the front end simulation into small segments of data, and then combine them at the output to make the processing feasible.

Table 1. Software GPS Receiver Acquisition Success Rate

<table>
<thead>
<tr>
<th>Pulse Repetition Rate (MHz)</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>55</th>
<th>110</th>
<th>160</th>
<th>200</th>
<th>320</th>
<th>420</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1V</td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
<td>97%</td>
<td>98%</td>
<td>97%</td>
<td>96%</td>
<td>97%</td>
<td>96%</td>
<td>92%</td>
</tr>
<tr>
<td>0.2V</td>
<td>99%</td>
<td>98%</td>
<td>98%</td>
<td>97%</td>
<td>96%</td>
<td>97%</td>
<td>95%</td>
<td>92%</td>
<td>89%</td>
<td>85%</td>
<td>82%</td>
</tr>
</tbody>
</table>
Fig. 6. A sequence of UWB impulse and their outputs at each stage of the simulated GPS front end

A signal superposition method is used to solve this problem. First, we need to know how long it takes for the output of an impulse at the GPS front end to become negligible. We found that this time is determined by the width of the narrow bandpass filter in the front end design. For a bandwidth $BW = 2$ MHz, this time constant is no more than $10/BW = 5\,\mu s$. To be conservative, $10\,\mu s$ is used in our calculation. An algorithm is developed to process long sequences of UWB impulses:

1. Divide the input UWB signals into blocks. Each block has a length of $20/BW = 10\,\mu s$.

2. Take the first half of a block, pad the second half with zeros. Process such a block to generate an output sequence. Divide the output sequence into two equal parts: part1 and part2. The output corresponding to the first part (denoted as out1) is the sum of the current block part1 and the previous blocks part2.

3. Write out1 to data file.

4. Repeat the above process.

We tested the above algorithm using two $10\,\mu s$ block length and found that the output is the same as the result of processing one $20\,\mu s$ block. Using this approach, we were able to process very long sequences of UWB data and store the data for the acquisition stage.

A preliminary test using the simulation model was conducted to examine the impact of a Gaussian monopulse type UWB signal on the software receiver acquisition performance. The UWB power spectral density is a function of both the pulse amplitude and the pulse repetition rate. Table 1 summarizes the success rate of the software GPS receiver acquisition function when simulated GPS and simulated UWB Gaussian monopulses are mixed together as input.

A total of eight simulated satellite signals are included in the GPS inputs. The signal to noise ratio of all eight satellites is $-15$ dB (referenced to the 2MHz GPS CA code bandwidth). The Doppler frequency, carrier phase, and initial CA code phases of the GPS signals are randomly generated within their respective allowable ranges. The average successful rate for the software GPS receiver acquisition is 99% when UWB signals are not present in the input.

UWB pulses with pulse width of 250ps are generated for the simulation. Two different values of the UWB pulse amplitudes are tested: 100mV and 200mV. For each amplitude value, pulse repetition rates ranging from 1MHz to 420 MHz are used to generate a sequence of UWB pulses. Random dithering within 50% of the repetition interval is assumed when generating the pulse sequence. Signals from a total of 100 UWB sources located 6 feet away from the GPS receiver are added to the simulated GPS RF front end. Each data point in Table 1 is the average result of 100 simulation runs. The success rate as shown in the table indicates that for a given pulse amplitude, as the repetition rate increases the acquisition rate declines. The decline is accelerated when the pulse repetition rate approaches the high end of the projected data rate for UWB applications.

CONCLUSIONS AND FUTURE PLANS

This paper presented a simulation model for the GPS RF front end. This simulation model consists of a GPS antenna, RF to IF conversion, CA code bandpass filter, and analog to digital converter. This simulation model incorporated a variety of elements such as the use of experimental data (GPS antenna frequency response), mathematical modeling (down conversion), and signal processing tool boxes (bandpass filter). Several other necessary components were also created in conjunction with the RF front end model. These include the generation of UWB pulses and the algorithm used to handle long sequences of input data.

The simulation model established through this study will provide a framework for studying the impact of any combination of future UWB signals on GPS receivers at various stages. It has the advantage of having the flexibility to work with a variety of GPS receiver architectures and allows a closer look into the fundamental aspects of interference and performance degradation. It can be a valuable tool for the GPS and UWB community to study a signal of interest before deploying it into the mass market.
There are several follow up projects:

1. GPS RF front end simulation model validation using real UWB signals.

2. UWB source simulation. As new UWB sources are being proposed, approved, and implemented, we can simulate these signals and use them in the interference evaluations.

3. More acquisition stage impact analysis. The preliminary results only examined the interference of the Gaussian monopulse using random dithering as the modulation scheme. More realistic signals and modulation schemes should be used in future research.

4. Interference study at the tracking and post processing stages.

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Data Fusion in Biometrics

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ABSTRACT

Any biometric system has drawbacks and cannot warranty 100% identification rates, nor 0% False Acceptance and Rejection Rates. One way to overcome the limitations is through a combination of different biometric systems. In addition, a multimodal biometric recognition is more difficult to fool than a single biometric system, because it is more unlikely to defeat two or three biometric systems than one. This paper summarizes the different data fusion levels, and how it must be performed in order to improve the results of each combined system on its own.

INTRODUCTION

All biometric systems have some weaknesses [1], so it is difficult to obtain a biometric system that accomplishes the four most desirable points for a biometric-based security system:

- **Universality:**
  All the persons should have the selected biometric identifier.

- **Distinctiveness:**
  Two persons with a biometric characteristic too close to be confused should not exist.

- **Permanence:**
  The biometric identifier should remain the same for long periods of time, enabling the user authentication years after the registration of the user in the database.

- **Collectability:**
  The biometric should be measurable quantitatively.

Fig. 1. Fingerprint of a 75-year-old and a typical fingerprint

Although for most users and operational environments there are not great problems, several scenarios and users difficult to manage exist. Table 1 summarizes some drawbacks of the well-known biometric systems. This list skips those situations where the user is not collaborative enough, or some unavoidable environment changes take place (different illumination, ambient noise, etc.). Obviously in these situations, data fusion can also facilitate the recognition process.

Another problem is a hacker trying to illegally access a biometric system relying on a single biometric characteristic. A single biometric system can be fooled in several ways, as described in [2]. The combination of different systems can improve the security level of only one system. For example, in a biometric system consisting of a fingerprint and voice analysis it is more difficult to imitate the fingerprint and voice of a given user, than just using one biometric characteristic, or if a person presents low-quality fingerprints, he can be recognized by means of his voice. Figure 1 shows the fingerprint of a 75-year-old acquired with the best effort to obtain the highest possible quality, and a typical fingerprint with enough quality.
Table 1. Drawbacks of the Main Biometric System

<table>
<thead>
<tr>
<th>Biometric Technology</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingerprint</td>
<td>Certain users do not have fingerprints (elder people, some Asian populations [1], manual workers with acid, cement, etc.)</td>
</tr>
<tr>
<td></td>
<td>Some fingerprint scanners cannot acquire fingerprints that are too oily, dry, wet, warm, etc.</td>
</tr>
<tr>
<td></td>
<td>Temporal or permanent damages can make fingerprint recognition impossible.</td>
</tr>
<tr>
<td>Face</td>
<td>Changes in hairstyle, makeup, facial hair, etc.</td>
</tr>
<tr>
<td></td>
<td>Addition or removal of glasses, hats, scarves, etc.</td>
</tr>
<tr>
<td></td>
<td>Dramatic variations of weight, skin color change due to sun exposure, etc.</td>
</tr>
<tr>
<td>Iris</td>
<td>Eye trauma is rarely present, but still possible. Although this system is quite robust, it is not popular – nor are the sensors widely-introduced.</td>
</tr>
<tr>
<td>Voice</td>
<td>Illness can modify the voice (cold, flu, aphonia, etc.)</td>
</tr>
<tr>
<td></td>
<td>Acquisition devices and environments can vary significantly, for instance, in mobile phone access. This degrades the recognition rates.</td>
</tr>
<tr>
<td>Hand Geometry</td>
<td>Weight increases or decreases, injuries, swelling, water retention, etc., can make recognition impossible.</td>
</tr>
<tr>
<td></td>
<td>Some users can be unable to locate the hand geometry due to paralysis, arthrosis, etc.</td>
</tr>
</tbody>
</table>

The key point to overcome these drawbacks, or at least to mitigate them, is using a combination of different informations. This is done by live beings in order to improve our knowledge of the surrounding world. Some examples are:

- The combination of the information sensed by two ears lets us identify the arrival direction of the sound, two eyes let us identify the depth of the scene, and obtain a three-dimensional image.

- Simultaneously touching and looking at an object yields more information than just using only one sense.

- In democracy, the final decision of who the governor is consists of the combination of millions of people’s decisions.

A similar strategy can be adopted to improve a biometric system. Figure 2 shows the scheme of a general biometric system. Four main parts corresponding to different data fusion levels can be identified.

In all cases, the system can be classified as [3]:

- **Unimodal biometric system:** it relies on a single biometric characteristic.

- **Multimodal biometric system:** It uses multiple biometric characteristics, like voice plus fingerprint; or face plus iris.

Usually the unimodal systems are easier to install, the computational burden is typically smaller, they are easier to use, and cheaper because just one sensor (or several sensors of the same kind) are needed. On the other hand, a multimodal system can overcome the limitations of a single biometric characteristic.

### DATA FUSION LEVELS

Considering the main blocks plotted in Figure 2, the following levels can be defined:

- **1. Sensor level:**
  In this level, the digital input signal is the result of sensing the same biometric characteristic with two or more sensors. Thus, it is related to unimodal biometrics. Figure 3 shows an example of sensor fusion that consists of sensing a speech signal simultaneously with two different microphones. The combination of the input signals can provide noise cancellation, blind source separation [4], etc.

Another example is face recognition using multiple cameras that are used to acquire frontal and profile images in order to obtain a three-dimensional face model, which is used for feature extraction.

Although this fusion level is useful in several scenarios, it is not the most usual one.
2. Feature level:
This level can apply to the extraction of different features over a single biometric signal (unimodal system) and the combination of feature levels extracted from different biometric characteristics (multimodal system). An example of a unimodal system is the combination of instantaneous and transitional information for speaker recognition [5].

Figure 4 shows an example that consists of a combination of face and fingerprint at the feature level.

This combination strategy is usually done by a concatenation of the feature vectors extracted by each feature extractor. This yields an extended size vector set.

Some drawbacks of this fusion approach are:

- There is little control over the contribution of each vector component on the final result, and the augmented feature space can imply a more difficult classifier design, the need for more training and testing data, etc.

- Both feature extractors should provide identical vector rates. This is not a problem for the combination of speech and fingerprint, because one vector per acquisition is obtained. However,
Fig. 6. Example of trained rule for opinion fusion. It combines two different speaker recognition classifiers

it can be a problem for combining voice with another biometric characteristic, due to the high number of vectors that depend on the test sentence length.

Although it is a common belief that the earlier the combination is done, the better result is achieved, state-of-the-art data fusion relies mainly on the opinion and decision levels.

* 3. Opinion level:
This kind of fusion is also known as confidence level. It consists of the combination of the scores provided by each matcher. The matcher just provides a distance measure or a similarity measure between the input features and the models stored on the database.

It is possible to combine several classifiers working with the same biometric characteristic (unimodal systems) or to combine different ones. Figure 5 shows an example of multimodal combination of face and iris.

Before opinion fusion, normalization must be done. For instance, if the measures of the first classifier are similarity measures that lie on the [0, 1] range, and the measures of the second classifier are distance measures that range on [0, 100] two normalizations must be done:

* 1) The similarity measures must be converted into distance measures (or vice versa).

* 2) The location and scale parameters of the similarity scores from the individual classifiers must be shifted to a common range. For instance, see [6] for detailed formulation.

After the normalization procedure, several combination schemes can be applied [7].

The combination strategies can be classified into three main groups:

* Fixed rules: All the classifiers have the same relevance. An example is the sum of the outputs of the classifiers;

* Trained rules: Some classifiers should have more relevance on the final result. This is achieved by means of some weighting factors computed using a training sequence. (Figure 6 shows an example of a trained rule that consists of the combination of two different classifiers for speech recognition. It is interesting to observe that for \( \alpha_1 = 1 \) (83.8% identification rate) just the first classifier is considered, while for \( \alpha_1 = 0 \) (79.2% identification rate) just the second classifier has relevance. For intermediate values, higher identification rates are achieved (84.8%)); and

* Adaptive rules: The relevance of each classifier depends on the instant time. This is interesting for variable environments. (For instance, a system that combines speech and face can detect those situations where the background noise increases and then reduce the speech classifier weight. Similarly, the face classifier weight is decreased when the illumination degrades or there is no evidence that a frontal face is present).

![Diagram of opinion fusion using classifier trees](image)

Fig. 7. Example of opinion fusion using classifier trees

The most popular combination schemes are: Weighted sum, Weighted product, and decision trees (based on if-then-else
4. Decision level:
At this level, each classifier provides a decision. On verification applications, it is an accepted/rejected decision. On identification systems, it is the identified person or a ranked list with the most probable person on its top. In this last case, the Borda count method [8] can be used for combining the classifiers’ outputs. This approach overcomes the scores normalization that was mandatory for the opinion fusion level. Figure 8 shows an example of the Borda count. The Borda count assigns a score that is equal to the number of classes ranked below the given class.

One problem that appears with decision level fusion is the possibility of ties. For verification applications, at least three classifiers are needed (at least two will agree and there is no tie), but for identification scenarios, the number of classifiers should be higher than the number of classes. This is not a realistic situation, so this combination level is usually applied to verification scenarios.

An important combination scheme at the decision level is the serial and parallel combination, also known as “AND” and “OR” combinations. Figure 9 shows the block diagram. In the first case, a positive verification must be achieved in both systems, while access is achieved in the second one if the user is accepted by one of the systems.

The AND combination improves the False Acceptance Ratio (FAR) while the OR combination improves the False Rejection Ratio (FRR). Simultaneously combining serial and parallel systems, it is possible to improve both rates. For instance, [9] reports the combination of two different biometric systems offering three trials in each one (similar to the PIN keystore on ATM cashiers). In this case, if each system on its own yields a 1% False Acceptance Ratio (FAR) and 1% False Rejection Ratio (FRR), the combined system yields FAR = 0.0882% and FRR = 0.0002%.

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FROM THE EDITOR-IN-CHIEF

Evelyn H. Hirt

New Fellows; Conference Proceedings & How're We Doing?

Fellows Class of 2005 — I congratulate all who advanced to the grade of Fellow in 2005. IEEE Fellows are a distinguished group with an extraordinary record of accomplishments in any IEEE field of interest. According to IEEE Bylaw 1-30.8.2, "The total number of Fellow recommendations in any one year must not exceed one-tenth percent of the total Institute membership, exclusive of Students and Associates, on record as of 31 December of the year preceding." This translates to IEEE Fellows being less than 2% of the total IEEE membership in any year. AESS Fellows will be listed in a succeeding issue.

Fellow Nominations for Class of 2006 — Nominations are being accepted for the 2006 class of IEEE Fellows. For the second year, nominations, references, and endorsements may be submitted electronically; deadline is 1 March 2005.

At its June 2003 meeting, the IEEE Board of Directors approved changes to the process for nominating and electing IEEE members to Fellow; the change established a nomination category for individual contributions, with the goal of increasing nominations for members in industry and encouraging nominations of application engineers or engineering practitioners who have made contributions of unusual distinction to the profession. The Board also established a Fellow Nomination Resource Center to help locate the required number of references. To nominate an IEEE senior member or learn more about the Fellow program, visit <www.ieee.org/fellows>.

Reminder: New Conference Proceedings Electronic Submission Requirements in Effect in 2005 — To optimize the online usage of IEEE conference proceedings, IEEE has implemented new requirements for the electronic submission of proceedings in PDF format. These requirements, first established in 2002, are mandatory for all sponsored and co-sponsored 2005 conferences. As of the second quarter of 2005, files that do not comply with the PDF requirements will incur production charges (this applies to all conferences held in 2005 and beyond).

To help all IEEE conferences develop compatible files, a new online tool called IEEE PDF-eXpress is freely available. IEEE PDF-eXpress can convert files to the correct specifications from a number of different publishing platforms, or verify the correct formatting of existing PDFs. The IEEE PDF-eXpress tool is customized for each conference requesting its use. Conferences are encouraged to register for IEEE PDF-eXpress by contacting: <pub-proceedings@ieee.org>.

Further information on the preparation and submission of compatible PDFs can be found at: <http://www.ieee.org/portal/pages/pubs/confpubcenter/instructions.html>.

How’re We Doing? — Over the last year, I've worked to broaden the content of Systems and provide more information to AESS members, volunteers, and Chapters. What I need to know from you is: Are we meeting your needs and expectations? Go to the eJournalPress web-based submission system at: <http://sysmes.mathui.net/> to submit your correspondence or article to IEEE Aerospace and Electronic Systems Magazine. Correspondence can be sent hard-copy to the Administrative Editor.

— Evelyn Hirt

CANDIDATES FOR ELECTION TO AESS BOARD OF GOVERNORS

Eight AESS members will be elected to three-year terms (2004-2006) as members of the AESS BoG at their meeting in March 2004. The Nominating Committee is responsible for developing a slate of nominees with the broadest representation of geographic diversity and technical interests of AESS membership. We need your help! We encourage members to suggest candidates with strong professional credentials and dedicated interest in our society's success. All suggestions are considered. The nominations for nomination, besides membership in AESS, are the capability and resources to attend at least two BoG meetings per year and to devote several hours per month to AESS affairs.

Please send suggestions by February 28, 2004, to Russ Lefever, Nominating Committee Chair, or any officer of BoG member. Addresses, e-mail, and phone numbers for Russ Lefever and other AESS officials are on the inside back cover of this magazine.

IEEE DENNIS J. PICARD MEDAL FOR RADAR TECHNOLOGIES & APPLICATIONS

Sponsored by Raytheon Company — Nominations Wanted

The IEEE Dennis J. Picard Medal for Radar Technologies and Applications was established in 1999 for outstanding accomplishments in advancing the fields of radar technologies to an individual or group of up to three. Selection is administered by the IEEE Awards Board through its Medals Council. A Picard Medal Evaluation Committee, consisting of representatives from the AESS, Antennas and Propagation Society, Circuits and Systems Society, Electron Devices Society, Geoscience and Remote Sensing Society, Microwave Theory and Techniques Society, Signal Processing Society and Ultrasomics, Ferroelectrics, and Frequency Control Society, reviews nominations and forwards a recommendation to the Medals Council. Criteria considered by the Evaluation Committee include leadership in the field of radar technologies and applications; originality, breadth, inventive value and duration of individual and/or group contributions; publications and patents; society activities and awards; industry recognition and honors; and nomination quality. The award consists of a gold medal, certificate, and cash prize.

Information on the Medal and the nominations forms may be found at: <http://www.ieee.org/aboutawards/smaps/picard.htm>.

Nomination Deadline: 1 July 2005
Eastern Canada AESS Lectures

Myron Kayton
AESS Distinguished Lecturer

During June 2004, I spoke in several cities in eastern Canada, one of the most peaceful, civilized countries on Earth, riveled perhaps only by Switzerland and Scandinavia. It has an underlying population of English and French ancestry overlain with immigrants from throughout the world. Virtually all have adopted the extreme politeness that characterizes the Canadian way of life.

Lectures were preceded by information about IEEE and the Aerospace and Electronic Systems Society, using current geographic membership distributions furnished by Barbara Della Salla of IEEE Conference Services.

My lecture Navigation; Land, Sea, Air, and Space, given to the IEEE Montreal Section covered navigation sensors, their processing, and details about radio aids and dead-reckoning. I focused on GPS satellites and the differential aids that detect errors quickly, and projected the future of navigation aids. The evening lecture was at Concordia University, organized by Prof. Reza Soleymani, IEEE Montreal Section Chair, assisted by graduate student, Mohsen Ghotbi. About 35 attended: EE students, faculty, and working engineers. Prof. Omair Ahmad, Chair of the Informatics Department, briefly visited the meeting. Interest was so high that the one-hour lecture stretched to 2+ hours and included questions and discussion.

Montreal, Canada's second city and major industrial center, is, in my opinion, the most cultured city in North America, whose competition is Boston, Washington, and New York.

At Trois Rivieres, halfway between Quebec City and Montreal, I lectured to the Saint Maurice Section about the Evolution of Aircraft Avionics, showing how radio navigation and communications evolved; how computers, displays, and data buses evolved on aircraft; and how flight controls evolved. I compare aircraft avionics to automotive electronics.] The lecture was on the University of Quebec campus with students and faculty. Prof. Adam Skorek, organizer, was out of town; his alternate, Prof. Elo Ngandui, had a family emergency and stayed home, leaving Prof. Pierre Sirod and retired Prof. "Raja" Rajakopalan in charge.

Trois Rivieres is located at the mouth of the St. Maurice River, opening into the St. Lawrence with three channels, hence the name. Begun in 1634 as an access to the forested interior for furs and timber it exported to France in exchange for manufactured goods. The first iron smelter and forge in North America, (now a multi-building museum), were established just upriver in 1730. The Trois Rivieres campus of the University of Quebec specializes in paper processing. The teaching is almost entirely in French (the other language is Spanish); hence the school attracts many students from Francophone Africa. Though they don't work in avionics, the students were intensely interested in aircraft avionics and asked many questions.

At Quebec City, the provincial capital and first city of New France, I addressed the Quebec City Section of IEEE at the Defense Research and Development Centre (DRDC), northwest of the old city, on One Hundred Years of Inertial Navigation. I spoke about the antecedents (e.g., the gyrocompass), modern instruments, gimbal sets, strap-down packages, analog and digital computers, computer software, and calibration/alignment. I peered into the future to be shaped by GPS and Galileo. About 75 attended, including employees of DRDC and engineers from other organizations. There were many questions from this expert audience; the event was organized by Prof. Xavier Malague of Université Laval (former President of the IEEE Quebec City Section). Prof. André Morin of Université Laval (current President of the Quebec City Section) attended; he was my co-host in 1999 when I lectured on Large-Scale System Engineering.

My fourth lecture: Avionics for Manned Spacecraft, to the Canadian Atlantic Section was at a dinner attended by 35 engineers and students. My topic covered the earliest spacecraft through the Shuttle, in which I described on-board
avionics and ground comm-tracking systems that evolved to support manned operations.

Halifax is Canada’s ice-free port on the Atlantic with a fine Maritime Museum, a Naval Museum, and many marine industries. Mr. Mah, (Chairman of the Section), for example, designs buoys that collect ocean data and relay them via Iridium comsats. Until World War I, Nova Scotia was the isolated home of fishermen, more closely connected to Maine than to Ottawa. Catholic Gaelic settlers tended to populate the agricultural maritime provinces while Protestants (mainly lowland Scots) favored the St. Lawrence Valley where Canada’s industry is now concentrated. Ethnic differences are still visible; for example, in the Gaelic music so popular in Nova Scotia. I had the pleasure of attending a ceilidh (pronounced kay-lee) on Cape Breton Island. The musicians were local music school teachers and the singer was a bridge constructor. The townspeople formed squares and the oldest man in each square seemed to do the calling. Similar music was brought to the American Appalachians by Scots-Irish settlers.

Dr. Ferial el-Hawary, Student Activities Chair of the Eastern Canada Council, suggested the multi-city series but was traveling so the lecture was organized by Kenneth Mah (Chairman of the Canadian Atlantic Section) with backup from Scott Melvin (Vice Chair). One of the students, Marc Murphy, was nice enough to write me a thank-you e-mail.

Per Dr. el-Hawary’s initial plan, I was supposed to lecture in Newfoundland but the section was unable to organize the event in time. Instead, they invited me to their Lobster Bake on Canada Day – an invitation I had to regrettably decline.

Few people outside Canada have studied the history of this fascinating country. This was my third exposure to New France versus New England. New France was the original European colony on the Atlantic coast (1608), preceding Jamestown (1619) and Plymouth (1620). Northeastern Canada is the first landfall when island-hopping along the edge of the ice on the shortest distance path from northern Europe. When explorers Cabot (1497) and Cartier (1534) arrived, they found Basque, Norman, and Breton fishermen taking cod from the Grand Banks. These fishermen cleaned and dried their fish, repaired their boats, and sought shelter from the storms. They fished there since Viking times (circa 1000) after which the magnetic compass allowed long voyages in cloudy weather. Champlain established the first permanent European settlement at Quebec City in 1608. The French had difficulty attracting European settlers to the harsh Canadian environment; the English readily populated New England with religious dissenters fleeing the consequences of an established religion. In. New York and Virginia, the English encouraged indentured workers to come to North America. To populate the Carolinas, whose coast was a malarial swamp, they “transported” prisoners for trivial offenses, in the same way Russians forcibly populated Siberia. The French sent occasional bateau of female orphans to Quebec, equipped with substantial dowries at the king’s expense. Nevertheless, the French strip of land from the Atlantic southwest alone the St. Lawrence to Detroit and south to New Orleans was too lightly inhabited by Indians and Europeans to resist pressure by the expanding English colonists. In 1758, the English captured Louisburg, the French fortress on Cape Breton Island. A year later, they sailed up the St. Lawrence River and took Quebec. Montreal, knowing it had lost its supply route, surrendered and modern Canada was born, beginning as a collection of British colonies that slowly unified and expanded west to Vancouver Island on the Pacific Ocean.

It is interesting to speculate about the political composition of North America had the French kings taken a stronger interest in populating their North American colonies! I suspect that the British would have been trapped east of the Appalachians; the French would have governed a strip from the east coast of Canada to the mid-West and south along the Mississippi Valley (the future Louisiana Purchase). The Spanish (after 1821, the independent Mexicans), would have governed the southwest. Russians would probably have expanded south from Alaska to govern the entire northwest of present-day Canada and the United States. North America would have been a quadrilingual collection of small countries, independent of their European founders by 2004, but emulating Europe in their linguistic and religious rivalries. France’s disinterest ensured that the United States and Canada would exist as they do today.

I recommend a visit to Canada. Perhaps you could synchronize it with one of my lectures – if you could put up with listening to it!
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 AESS Society will cover up to $500 of the speaker’s expenses for travel in North America, with any remaining amount normally covered by the AES Chapter or Section or by the speaker’s organization. For travel outside North America, the AES Society will cover half of the speaker’s expenses per trip, up to a maximum of $1500. The procedure for obtaining a speaker is as follows: If a Chapter or Section has an interest in inviting one of the speakers, it should first contact the speaker directly in order to obtain his agreement to give the lecture on a particular date. After this is accomplished, and if the Chapter or Section wishes to request financial support from the AESS, it should contact James R. Huddle on (818) 715-3264, F (818) 715-3976, jhuddle@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.

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Contact Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications of Formal Methods in System Design</td>
<td>James F. Peters, III, <em>Univ. of Manitoba</em></td>
<td>(204) 474-7419 (204) 261-4693 F</td>
</tr>
<tr>
<td>Avionics for Manned Spacecraft</td>
<td>Dr. Myron Kayton, <em>Kayton Engineering Co.</em></td>
<td>(310) 393-1819 (310) 393-1261 F</td>
</tr>
<tr>
<td>Evolution of Aircraft Avionics</td>
<td></td>
<td><a href="mailto:m.kayton@ieee.org">m.kayton@ieee.org</a></td>
</tr>
<tr>
<td>Navigation: Land, Sea, Air and Space</td>
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<td>One Hundred Years of Inertial Navigation</td>
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<td>Practitioner’s View of System Engineering</td>
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<tr>
<td>Synthetic Aperture Radar</td>
<td></td>
<td>+44-20-7388-7325 F</td>
</tr>
<tr>
<td>Current Advances in Radar Technology</td>
<td>Robert T. Hill, <em>Consultant and Lecturer</em></td>
<td>(301) 262-8792 (V&amp;F)</td>
</tr>
<tr>
<td>Multisensor Data Fusion</td>
<td>Dr. Pranod Varshney, <em>Syracuse University</em></td>
<td>(315) 443-4013 (315) 443-2583 F</td>
</tr>
<tr>
<td>National Missile Defense and Early Warning Radars</td>
<td>Larry Chasteen, <em>University of Texas at Dallas</em></td>
<td>(972) 234-3170 (972) 883-2799</td>
</tr>
<tr>
<td>Novel Orbits &amp; Satellite Constellations</td>
<td>Dr. Daniele Mortari, <em>Texas A&amp;M University</em></td>
<td>(979) 845-0734 (979) 845-6051 F</td>
</tr>
<tr>
<td>Planetary Exploration with Spacecraft — to Jupiter, Saturn, Uranus, Neptune and Beyond</td>
<td>Dr. William W. Ward, <em>Consultant &amp; Lecturer</em></td>
<td>(617) 527-5311 (V&amp;F)</td>
</tr>
<tr>
<td>Radar — Past, Present and Future</td>
<td>Dr. Eli Brookner, <em>Raytheon</em></td>
<td>(978) 440-4007 (978) 440-4040 F</td>
</tr>
<tr>
<td>Satellite Communication Systems</td>
<td>Dr. S.H. Durrani, <em>Consulting Engineer</em></td>
<td><a href="mailto:Eh_Brookner@res.raytheon.com">Eh_Brookner@res.raytheon.com</a></td>
</tr>
<tr>
<td>System Engineering for International Development</td>
<td>Paul Gartz, <em>Boeing Co.</em></td>
<td>(301) 774-4607 (V&amp;F)</td>
</tr>
<tr>
<td>Target Tracking and Data Fusion: How to Get the Most Out of Your Sensors</td>
<td>Dr. Yaakov Bar-Shalom, <em>Univ. of Connecticut</em></td>
<td>(860) 486-8283 (860) 486-2285 F</td>
</tr>
<tr>
<td>The Evolution of Inertial Navigation</td>
<td>Dr. Itzhack Bar-Itzhack</td>
<td>+972-4-829-3196 +972-4-829-2030 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:ibaritz@technion.ac.il">ibaritz@technion.ac.il</a></td>
</tr>
</tbody>
</table>

All data on this page is under the purview of Walter D. Downing, VP-Member Affairs. Please send all corrections and omissions to him at the address on the inside back cover.
The Harry Rowe Mimno Award for 2003 was presented to C. Sanchez-Avila, R. Sanchez-Reillo and D. de Martin Roche for their article *Iris-Based Biometric Recognition using Dyadic Wavelet Transform*, which appeared in the October 2003 issue of this journal [17, 10 (October 2003) 3-6].

The Harry Rowe Mimno Award for 2004 was presented to S.J. Krol Jr., and G.M. Rao for their article *Hubble Performance On-Orbit*, which appeared in the February 2004 issue of this journal [18, 2 (February 2003) 13-17].

Established in 1977, the purpose of this award is to encourage and recognize excellence in clear communication of technical material of widespread interest to AESS members. In so doing, this award honors Harry Rowe Mimno's more than thirty years of contributions to the IEEE; it is presented to the author of a primarily tutorial, survey, or speculative contribution, or one which advocates new ideas or principles tending to promote debate.

### Nominate a Senior Member

IEEE recognized 190 members that were elevated to Senior Member status in September 2004. The following persons were either nominated by AESS Chapters or are affiliated with AESS.

<table>
<thead>
<tr>
<th>Region</th>
<th>Section</th>
<th>Name</th>
<th>Nominated by</th>
<th>Technical Affiliation</th>
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<tbody>
<tr>
<td>1</td>
<td>Boston</td>
<td>William S. Song</td>
<td>AESS</td>
<td>AESS</td>
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<tr>
<td>1</td>
<td>Boston</td>
<td>Grant H. Stokes</td>
<td>AESS</td>
<td>AESS</td>
</tr>
<tr>
<td>1</td>
<td>Mohawk Valley</td>
<td>Paul Antonik</td>
<td>Mohawk Valley Section</td>
<td>AESS</td>
</tr>
<tr>
<td>2</td>
<td>Northern Virginia</td>
<td>Daniel S. Purdy</td>
<td>Washington Section</td>
<td>AESS</td>
</tr>
<tr>
<td>2</td>
<td>Southern New Jersey</td>
<td>Joseph F. Burns</td>
<td>Southern New Jersey Section</td>
<td>AESS</td>
</tr>
</tbody>
</table>

To see a complete list of new senior members, go to: <http://www.ieee.org/ra/md/finishdates.html>.

As of September 2004, 28 AESS members have been elevated to senior status. During this period, 7 IEEE Senior Members were nominated by AESS Chapters.

For information on how your Chapter can earn cash rewards for nominating Senior Member candidates, see Nominate a Senior Member Initiative at: <http://www.ieee.org/ra/md/sminitiative.html>.
IEEE AEROSPACE & ELECTRONIC SYSTEMS SOCIETY ORGANIZATION

IEEE/AESS Website: http://www.eewh.ieee.org/aess

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STANDING COMMITTEES

Accomplishments Search - W. Cooper
Awards, Erwin C. Gangl
* M. Barry Carlton Award, W. Dale Blair
* Harry Rowe Minno Award, Ron Schriner
* Warren D. White, Mark Davis
* Pioneer Award, Erwin C. Gangl
* Judith Renik IEEE Field Award, Erwin C. Gangl
Chapters, Zafar Tagiy (Chapters, Zafar Tagiy)

Constitution, Organization & Bylaws, Charles C. Gager
Distinguished Lecturers, James R. Huddle
Education, Sajjad H. Durrani
Strategic Planning, Paul F. Gartz
Fellow Evaluation, Fritz Steudel
Fellow Search, Elliot M. Ashkin
History, Henry Oman
International Activities, Hugh D. Griffiths
Nominations, Russell J. Lefevre

Professional Activities, M. Cardinale
Public Relations, James R. Huddle
Publication Editors:
* Systems, Evelyn H. Hirt
* Transactions, W. Dale Blair
* Standards, Jose R. Bolanos

Social Implications - Technical, Open
Standards, Arnold M. Greenspan
Student Activities, Jose R. Bolanos

TECHNICAL PANELS

Formal Methods in System Design
Gyro and Accelerometer - Randy Cucy
Integrated Avionics Systems - Glen T. Logan
Radar Systems - James Day
Satellite Navigation Systems - Open
Space Systems - Marina Ruggieri
Large-Scale Systems & System Engineering - Paul Gartz
Target Tracking & Sensor Fusion - Dale Blair

IEEE PUBLICATIONS REPRESENTATIVES

IEEE Press - R. Lefevre
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Transactions Committee - D. Blair
Journal of Lightwave Technology
Transactions on Pattern Analysis & Machine Intelligence

IEEE CONFERENCES REPRESENTATIVES

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Information Fusion - W.D. Blair
International Energy Conversion Engineering Conference (IEECE)
Radar - M. Davis
Position Location & Navigation (PLANS) - J.R. Huddle

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Sensors Council - M. Wicks

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Energy Policy - H. Oman
PACE - M. Cardinale
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IEEE SCC-20 - A. Greenspan

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Association of Old Crows - E. Gangl
French Institute of Navigation - J.R. Huddl
German Institute of Navigation (DGM) - J.R. Huddl
Institution of Electrical Engineers (UK) RSN PN
Institute of Navigation (USA) - J.R. Huddl
International Council on System Engineering (INCOSE) - G. Friedman

IEEE A&E SYSTEMS MAGAZINE, JANUARY 2005
Indexing Changes to AESS Journals

Starting in 2004, IEEE AESS has issued a combined index of all serial publications. This index appeared in the last Transactions issue of the year (October). Titles included are: IEEE Transactions on Aerospace and Electronic Systems, 40, and IEEE Aerospace and Electronic Systems Magazine, 19, including Tutorials issued during 2004.

IEEE Aerospace & Electronic Systems Magazine was, and will continue to be, indexed in December of each year.

An Antecedent Chart accompanies the combined index for assistance in identification and sequencing of references; it portrays the (inter)relationship of the many IEEE/IRE/AIEE transactions that constitute our “family tree.”


To bridge the gap from the 50 Year Cumulative Index to the present, an index to IEEE Aerospace & Electronic Systems Magazine, 15-18, 2000-2003, is included in the October 2004 Transactions.

Many conferences were included and indexed as a portion of the Transactions in the early years. For the totality of AES Society publications, there must be availability and the indexing of all conferences held under the auspices of any portion of the “family tree” This is currently being researched for future availability.

Giveaways Available for Chapters and Lecturers

Copies of back issues of Systems, Transactions, the Wright Brothers Issue, and Tutorials are available for use by chapters and lecturers as hand-outs and for membership.

Each AESS publication has copies printed for use by members for AESS-related activities. They are available —free! — as long as available. Request — by fax or letter — what you would like; include a complete ground shipping address (No PO Box) with contact numbers from the Administrative Editor — address on inside back cover. Be sure to allow adequate time for processing and shipment.

These freely-distributed issues have been very well-received at AESS conferences.
IEEE AEROSPACE AND ELECTRONIC SYSTEMS SOCIETY CHAPTERS

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Rhode Island, http://ewh.ieee.org/1/rhode_island
Mohawk Valley, http://ewh.ieee.org/1/mohawk_valley
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Syracuse, http://ewh.ieee.org/1/syracuse

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Huntsville, http://home.att.net/~atlanta/evolution/html

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Fort Worth, http://ewh.ieee.org/5/fort_worth
St. Louis, http://ewh.ieee.org/5/stlouis

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Ottawa, http://members.adam.org/~sofiau/AESS.html

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Central & South Italy, http://ewh.ieee.org/8/italy
Greece
Israel, http://www.esc.tau.ac.il/~ieee
Poland, http://www.ii.pwr.poznan.pl/~iiene
Russia (N. West)
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New Delhi, India          tokyo@ieee.org          agroup@hosei.ac.jp          chanpark@ms.ac.kr          mark.prezio@dra.defence.gov.au

IEEE A & E SYSTEMS MAGAZINE, JANUARY 2005
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IEEE-NANO 2005
5th IEEE Conference on Nanotechnology
July 11-15, 2005
(Day of Tutorials: July 11, 2005, Day of Tours: July 15, 2005)
Nagoya Congress Center, Nagoya, Japan
Sponsored by the IEEE Nanotechnology Council

http://www.mein.nagoya-u.ac.jp/IEEE-NANO/

The emphasis of this conference will be on fusions of several different fields and applications of nanoscience and nanotechnology. As the potential of nanotechnology is significant and wide ranging, the conference focus will be on engineering issues related to nanoelectronics, circuits, architectures, sensor systems, integration, reliability and manufacturing in addition to fundamental issues such as modeling, growth/synthesis, characterization, etc. The conference will feature Plenary, Invited, and Contributed papers (oral and poster sessions) thematically arranged according to the following topics. Contributed papers are welcome in the following and related topics:

- Nanoelectronics, Molecular Electronics
- Nano-optics
- Circuits and Architectures
- Nanosensors, Actuators
- Nanomaterials: Synthesis, Characterization
- Inorganic Nanowires, Nanocrystals, Quantum Dots
- Nanofabrication, Nanolithography
- Nanophotonics, Nano-Optoelectronics
- Spintronics, Nanomagnetics
- Nano-Robotics, Manufacturing Issues, Reliability
- System Integration (Nano/Micro/Macro), NEMS (Nano Electro Mechanical Systems)
- Carbon Nanotube Based Technologies
- Nano-bio Fusion
- Modeling and Simulation

Abstract & Paper SUBMISSION

Paper submission Due Date: February 28, 2005, up to 4 pages (Format will be announced at WEB page)
Final camera-ready (accepted paper) Due Date: May 13, 2005, up to 4 pages

Advisory Council Honorary Chair: Toshio Fukuda, Nagoya University
General Chair: Fumihito Arai, Nagoya University, arai@mein.nagoya-u.ac.jp
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