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<td>May 9–12, 2005</td>
<td>IEEE International Radar Conference</td>
<td>Arlington, VA</td>
<td>T. Fujii, (916) 318-2321</td>
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<tr>
<td></td>
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<td>(503) 378-6674 P</td>
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<td>12th International Conference on</td>
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<td></td>
<td>Integrated Navigation Systems</td>
<td>St. Petersburg, Russia</td>
<td>G.T. Schmuck, (67) 282-361</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(<a href="mailto:geoff.schmuck@us.army.mil">geoff.schmuck@us.army.mil</a>)</td>
</tr>
<tr>
<td>July 9–11, 2005</td>
<td>2005 AIAA International Conference</td>
<td>Istanbul, Turkey</td>
<td>M. Song, (913) 894-9570</td>
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<tr>
<td></td>
<td>on Recent Advances in Space</td>
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<td>(0212) 508-5450</td>
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<td>on Information Fusion (FUSION 2005)</td>
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<td>(<a href="mailto:j.schrader@ieee.org">j.schrader@ieee.org</a>)</td>
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<td>Engineering Conference - IEECE 2006</td>
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<td>Aug 29 - September 1, 2005</td>
<td>2005 21st International Conference on</td>
<td>Sendai, Japan</td>
<td>G.A. Davis, (957) 984-6012</td>
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<td>(512) 221-5797 P</td>
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<td>(212) 228-8553 P</td>
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<tr>
<td>September 18–21, 2006</td>
<td>Aeronautica 2006</td>
<td>Asheville, CA</td>
<td>R. Shafer, (410) 965-5212</td>
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<td></td>
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<td>(410) 965-5212 P</td>
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<tr>
<td>April 17–20, 2007</td>
<td>IEEE Radar Conference 2007</td>
<td>Boston, MA</td>
<td>TBA</td>
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</table>

**OTHER SOCIETY MEETINGS OF AESS INTEREST**

- May 18–21, 2005 - The International Scientific Conference "The 150th Anniversary of Radio Invention"
- June 11–17, 2005 - IEEE MTT-S International Microwave Symposium
- September 6–9, 2005 - International Radar Symposium 2005
Correspondence

Editor:

Subject: International Radar Symposium India (IRSI)

See: Call for Papers, page 45, March 2005 issue.

There have been changes in dates and venue:


For Venue: Hotel Grand Ashok – READ: National Science Seminar Complex (NSSC), Indian Institute of Science (IISc), Bangalore

Last Date to Submit: 15 April 2005

You are requested to kindly do the needful so that the event can be published correctly in IEEE / AESS Systems Magazine.

Inconvenience is regretted.

Yours sincerely,

D. Rajagopal, Coordinator IRSI-05
IRSI Secretariat, PO Box 9159,
CV Raman Nagar, (PO), Bangalore, 560 095, India
Phone: +91-80-22543986; Fax: +91-80-22547829
E-mail: irsi@radarindia.com, or www.radarindia.com

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IEEE AEROSPACE & ELECTRONIC SYSTEMS MAGAZINE®

Readers are encouraged to send feedback to the Editor-in-Chief or to the Associate Editor responsible for their area of interest. Information about the Editor-in-Chief and Associate Editors is available at the IEEE Web site, www.ieee.org.

HARRIET HEPPLESTON, Managing Editor

This Month’s Cover

photographs were taken at Camp Evans, a portion of the US Army Signal Corps, Fort Monmouth, NJ installation. Camp Evans, home of Project Diana, the 1947 Moon radar project, is being turned into a National Historic Site, partially through the diligence of Fred Newby of the New Jersey Coast Chapter of IEEE/AESS.

A detailed “take of what has transpired on the rocky road to today” may be found in our January 2005 Correspondence, in the letter from Fred. In an effort to help turn this area into something more than a plaque on a wall, many are contributing time and effort to facilitate this project at Camp Evans. This is best detailed in a letter in our March 2005 Correspondence (from Steve Johnston) regarding the archiving of papers from one of the “Evans-ies.”
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Radioisotope Detection and Identification at High Speeds using Passive Sensors

A network of radiation sensors for the protection of a military base against radiological/nuclear threats has been integrated in a testbed. Two key subsystems of this network are the array of sensitive radiation detectors and the subsystem for notifying the operators of radiation events. The alarm/alert notification subsystem automatically issues notifications to the command post in real-time. The resulting reporting to the command post appears to be adequate for non-technical operational personnel. The CONOPS for the protection system relies on the sensitive detection and identification of all radioactive sources well before the transporting vehicles reach the base gates. This is a unique feature of this protection system. Discriminating sodium-iodide detectors, in conjunction with plastic scintillators and neutron detectors comprise a high-performance detection subsystem. The use of various correlation techniques has permitted the demonstration of the detection of source strengths of tens of μCi moving at highway speeds and at several meters separation. A companion algorithm identifies the detected radioisotope when sufficient counts are available.

An Alternative to Traditional Software Rehosting

This paper will describe one alternative to rehosting TPS software to newer computer platforms. It will describe the solution that Southwest Research Institute (SwRI) used to solve a problem with re-engineering legacy software into a modern object-oriented language. The advantages gained by this method are more advanced instruction to the operator (such as pictures and movies), flexible reporting scheme to diagnose system problems, and ease of software maintenance. This solution uses commercially available products including National Instruments® TestStand™ and LabVIEW® and Microsoft® Visual Basic®. The system is a four-tiered architecture to drive all test execution. The user interface is written in Visual Basic and allows the user to interact with the test execution when needed. This user interface in turn calls tests that are written in TestStand, and finally the individual tests call driver functions written in LabVIEW. A database serves as a repository for all test results, displays, and test limits. The use of this database allows for easy querying of measurement data to analyze trends in failures that help diagnose specific problems. By using this database, all test limits and test displays are contained in one central location that enables engineers to change these displays and limits on the fly without needing to change or even understand any test code. One other benefit of this data containment is that all Government classified data is separated out of the code and stored as one file, instead of in various locations as it was in the original source code.

Technological Evaluation of Two AFIS Systems

This paper provides a technological evaluation of two Automatic Fingerprint Identification Systems (AFIS) used in forensic applications. Both are installed and working in Spanish police premises. The first is a Printrak AFIS 2000 system with a database of more than 450,000 fingerprints, while the second is a NEC AFIS 21 SAID NG-LEXS Release 2.4.4 with a database of more than 15 million fingerprints.

Our experiments reveal that, although both systems can manage inkless fingerprints, the latest one offers better experimental results.

Sustainment of Legacy Automatic Test Systems: Lessons Learned on TPS Transportability

Sustainment of legacy Automatic Test Systems (ATS) saves cost through the re-use of software and hardware. The ATS consists of the Automatic Test Equipment (ATE), the Test Program Sets (TPSs), and associated software. The associated software includes the architecture the TPSs run on, known as the control software or test station Test Executive. In some cases, to sustain the legacy ATS, it is more practical to develop a replacement ATE with the latest instrumentation, often in the form of Commercial Off-the-Shelf (COTS) hardware and software. The existing TPSs, including their hardware and test programs, will then need to be transported, or translated, to the new test station.

In order to understand how to sustain a legacy ATS by translating TPSs, one must realize the full architecture of the legacy ATS to be replaced. It must be understood that TPS transportability does not only include translating the original TPS from an existing language (such as ATLAS) to a new language (such as “C”) to run on a new test station, but includes transporting the run-time environment created by the legacy ATS. This paper will examine the similarities and differences of legacy ATE and modern COTS ATE architectures, how the ATS testing philosophy impacts the ease of TPS transportability from legacy ATE to modern-day platforms, and what SEI has done to address the issues that arise out of TPS transportability.
Radioisotope Detection and Identification at High Speeds using Passive Sensors

C.R. Jones & R.E. Evans

ABSTRACT

A network of radiation sensors for the protection of a military base against radiological/nuclear threats has been integrated in a testbed. Two key subsystems of this network are the array of sensitive radiation detectors and the subsystem for notifying the operators of radiation events. The alarm/alert notification subsystem automatically issues notifications to the command post in real-time. The resulting reporting to the command post appears to be adequate for non-technical operational personnel. The CONOPS for the protection system relies on the sensitive detection and identification of all radioactive sources well before the transporting vehicles reach the base gates. This is a unique feature of this protection system. Discriminating sodium-iodide detectors, in conjunction with plastic scintillators and neutron detectors comprise a high-performance detection subsystem. The use of various correlation techniques has permitted the demonstration of the detection of source strengths of tens of μCi moving at highway speeds and at several meters separation. A companion algorithm identifies the detected radioisotope when sufficient counts are available.

INTRODUCTION

The Unconventional Nuclear Weapon Defense (UNWD) program seeks to develop and demonstrate technology required for protecting a military installation from an unconventional nuclear or radiological (RN) attack. Under development by the Defense Threat Reduction Agency (DTRA), this technology will be useful for protecting any defined geographic region anywhere from such a threat. The developed system may be thought of as a special case of a physical protection system (PPS), which has in large measure been an engineering discipline practiced largely by the US DOE national laboratories [1]. The ARA concept of operations (CONOPS) requires a layered defense or defense in depth.

It was recognized early in the program that it is not sufficient to simply detect a threat approaching the protected facility (although this part is a major technical challenge). The sensor network must interact with the response forces in a useful manner, which broadly implies that the forces must know when and how to respond, and do so in a timely manner. The alarm/alert notification system (AA) is designed to provide that operator-friendly information needed by response forces for every detection event.

Early in the program it became clear that no notification system appropriate to this (or similar) physical protection scenario had been previously developed. While the AA system described below is designed specifically for RN threats, the decision logic and other elements appear to be broadly applicable to other threats that have associated observable phenomena detectable early in a threat scenario (real-time signatures).

SYSTEM OVERVIEW

The ARA UNWD testbed is comprised of approximately 10 on-base and off-base radiation sensor sites. The CONOPS relies critically on the detection of ingressing RN threats in 3 geographical sensor layers or rings encircling the installation. The outer ring (Sites 1 and 2) provides the first detection and threat identification at a distance of 30 and 25 miles, respectively, from the main gate. The middle layer (Sites 3, 4, 11, and 12) provides detection of sources (but no identification) for the principal purpose of tracking a threat. The inner layer is comprised of the main-gate sensors. In this testbed, sites are also located on the water and on a rail line for the purpose of more completely evaluating the technology. Responders must react quickly and appropriately to real threats, which must be detected with extremely few false negatives (leakers). Also very important to this design, as in any protection system, is minimization of the false alarm rate (FAR).

Adequate protection is enhanced through the integration of civilian and military emergency response activities. Both military and civilian responders should be prepared to react to
Fig. 1. Large NaI, plastic, and He-3 detectors are located beside a highway leading to the base (Site 1)

Fig. 2. The NaI detector system is comprised of two large detectors, associated electronics and special analysis software

an off-base emergency. In this arrangement, a detected RN threat at outlying sites may result in first contact by civilian responders.

RADIATION DETECTORS

A unique feature of the ARA UNWD system is the reliable detection of weak radioisotopes passing by the detectors at highway speeds [2]. Three different types of detectors, all large for high sensitivity and custom-designed by ARA for the required CONOPS, were deployed. A photograph of the passive gamma/neutron sensor suite at the outermost station (Site 1) is shown in Figure 1.

Sensitive detection and identification of rapidly moving radioactive sources has been demonstrated as part of a prototype system developed for real-time detection and notification of unauthorized radioactive material movement. A radiation detection system employing large-volume radiation sensors for pass-by detection of radioactive sources has been designed, assembled, tested, and modeled. The custom system uses a variety of commercially available detector and electronic components in combination with special analysis software developed by ARA. Tests have been conducted using sources placed in vehicles traveling along highways over a range of speeds and separations between detector and source. The system reliably detected and identified in real-time sources that were part of the testing procedure, in addition to several other industrial and medical sources. This has been accomplished at full vehicle speeds up to 70 miles/hour at stand-off distances of 6 – 21 feet.

Several test series have been conducted to prove performance of the system. Table 1 summarizes a portion of the results for the sodium-iodide (NaI) detector system during high-speed drive-by tests on Kirtland AFB during December 2002. The system on the roadside detected and identified (ID) sources driven by at full highway speeds in real-time. Similar detections were observed for both large plastic scintillators and neutron detectors. During the testbed demonstration, results were obtained on 25 February 2003 for two sites monitoring highway traffic approaching the military installation. The NaI detector data show that the test drive-by (using Cs-137 and Co-60 sources) was detected 100% of the time and the source correctly identified for 92% of the drive-bys. A photo of one of the NaI detector systems is shown in Figure 2.

These data demonstrate an extremely sensitive, discriminating detection system for pass-by radionuclide detection and identification. Further improvements, including a substantial increase in the number of isotopes that the NaI system can detect and identify in real-time, have been implemented and tested. Approximately 30 isotopes are currently in the NaI library. Extensive testing, as discussed below, shows that innocent isotopes and dirty bomb materials are correctly identified in most cases. Much of our current effort is directed toward improvement in identification fidelity.

ALARM/ALERT SUBSYSTEM

Because radioactivity has numerous legitimate uses today and is of increasing prevalence in developed nations, it is clear that most detections of radiation sources cannot be threat indicators. For example, Sites 1 and 2 in our testbed register several gamma detections a day, most of which are in vivo medical sources. Other categories of nuisance sources are industrial and naturally occurring. Only special cases of detection can be considered threat indicators.

Gamma rays are emitted by hundreds of radioactive sources, almost all of which are non-threatening. Neutrons are emitted by very few radioactive sources, many of which are threat (SNM) materials. The principal materials of nuclear weapons are uranium (U) and plutonium (Pu), which emit neutrons. Therefore, the detection of neutrons, but not gamma rays, in normal vehicle traffic is treated very seriously.

Unfortunately, the soil density/moisture gauge (SDG), a very common industrial source used extensively at construction sites, emits both gamma and neutron radiation. If these instruments did not exist, the detection of neutrons would
Table 1. Results for drive-by detection and ID of test radioisotopes

![Table with results for drive-by detection and ID of test radioisotopes]

Fig. 3. Generic logic flow used in developing decision tree

![Decision tree diagram]

Fig. 4. Decision tree is used to issue appropriate notifications (PASS, ALERT, or ALARM) to the control center when there is a radiation event. Note that colors have no significance

be sufficient cause for an alarm, because the (few) other legitimate sources of neutrons are extremely rare in normal civilian traffic and the resulting FAR would be tolerable. Because the neutron field of this gauge is usually detected as it passes at highway speeds and thousands of these devices travel the public highways, neutron detection alone should not be permitted to generate an alarm. Fortunately, SDG's also emit unique and recognizable gamma spectra, so identification algorithms based on gamma and neutron radiation can be constructed.

In addition to indicating the presence of a radiation source, some of the UNWD detectors must discriminate threat from nuisance sources. This requirement means that a detected source must be characterized physically through passive measurement of its radiation signature (i.e., gamma and neutron emissions). Adequate characterization is difficult in many cases, because of similarities in emission from various sources. Each type of detector provides a subset of data on the emission, and therefore, the source. Combining data from multiple detectors was clearly necessary. The underlying logic flow shown in Figure 3 was used to generate a decision tree.

The resulting decision tree uses a variety of gamma and neutron parameters to issue, in near real-time, an appropriate notification to the law enforcement control center. Three notifications are possible when a radiation event occurs at Sites 1 and 2 (outer-layer discriminating detector suites):

- **PASS** — detected source is not a threat,
- **ALERT** — detected source is a possible threat,
- **ALARM** — detected source is a real threat.

The decision tree, which is implemented in XML logic in the system computer as the Decision Support System (DSS), analyzes each event and issues one of these notifications to the Automated Control and Response System (ACRS), where it appears on a display. In addition, digital images of the suspect vehicle and its license plate are displayed. (It should be noted that all vehicles causing a radiation detection event, usually having a medical-patient occupant, are registered and images recorded, but the display clearly identifies them in the PASS category if the source is judged to be innocent.) Also, the display map in the control center has icons denoting the location of the sensors on the highway and other locations. The appropriate icon blinks when an event occurs.
allows for the possibility of a nuclear weapon not emitting detectable neutrons, which may occur with a U weapon. This side of the tree is primarily dedicated to determining whether a source not emitting neutrons is an RDD. The lower part of the chart tests for one parameter in a source profile – gamma counts. Extensive data logs will permit a solid statistical characterization of common sources, e.g., SDG’s. If a detected source emits within a predetermined count range, it is most likely legitimate. Other profile parameters, e.g., vehicle weight, will be added at a later date.

**XML Representation of Decision Tree**

Figure 5 illustrates the basic functionality of the DSS, which consists of a software component, the Decision Engine, and an

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Detector</th>
<th>Description</th>
<th>Now in use?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrons detected?</td>
<td>He-3 (n)</td>
<td>Were neutrons (above the pre-set count threshold) detected by the He-3 tubes?</td>
<td>Y</td>
</tr>
<tr>
<td>Nal event?</td>
<td>Nal (g)</td>
<td>Were gammas (above the pre-set count threshold) detected by the Nal?</td>
<td>Y</td>
</tr>
<tr>
<td>High-energy gammas?</td>
<td>Nal (g)</td>
<td>SNM has high-energy gammas (&gt; 1 MeV) not associated with almost any other source</td>
<td>N (hard-coded to “no”)</td>
</tr>
<tr>
<td>SNM probability</td>
<td>Nal (g)</td>
<td>Does the recorded gamma spectrum indicate a significant SNM probability?</td>
<td>N (hard-coded to &lt; 0.2)</td>
</tr>
<tr>
<td>Isotope ID</td>
<td>Nal (g)</td>
<td>The Nal detector system identifies the source based on its gamma spectrum.</td>
<td>Y</td>
</tr>
<tr>
<td>ID probability</td>
<td>Nal (g)</td>
<td>Is the source identified with high confidence? (Weak detection may result in low confidence of correct ID.)</td>
<td>Y</td>
</tr>
<tr>
<td>In range/out of range</td>
<td>Nal (g)</td>
<td>Intensity or gamma counts are (not) in the range expected from a legitimate source</td>
<td>Y</td>
</tr>
<tr>
<td>RDD source indicated?</td>
<td>Nal (g)</td>
<td>Cs-137, Co-60, Ir-192, and Sr-90 are the most likely RDD materials</td>
<td>Y</td>
</tr>
</tbody>
</table>
Fig. 6. Decision tree and its XML representation (not all XML elements are shown and elements preceded by a "+") have been collapsed for display purposes.

Table 3. Notification test results for the ARA NaI/He-3 detection system

<table>
<thead>
<tr>
<th>Test source</th>
<th>ID reported</th>
<th>Notification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-137</td>
<td>Cs-137</td>
<td>PASS</td>
<td></td>
</tr>
<tr>
<td>Co-60</td>
<td>Co-60</td>
<td>PASS</td>
<td></td>
</tr>
<tr>
<td>Mix</td>
<td>I-131</td>
<td>PASS</td>
<td>No immediate plans to add mixed sources to ARA NaI library, although these are important. (Should be alarm or alert probably, because of few legitimate mixed sources.)</td>
</tr>
<tr>
<td>Soil gauge³</td>
<td>SG01</td>
<td>PASS</td>
<td>(See Figure 8.)</td>
</tr>
<tr>
<td>Co-60</td>
<td>Co-60</td>
<td>PASS</td>
<td></td>
</tr>
<tr>
<td>Mix</td>
<td>Unknown*</td>
<td>PASS</td>
<td>Ho-166 will be added to NaI library soon</td>
</tr>
<tr>
<td>Ho-166m</td>
<td>Unknown*</td>
<td>PASS</td>
<td></td>
</tr>
</tbody>
</table>

³This is correct ID report in that these sources are not in library.

decision logic can be changed without having to change the software.

2. *A high level of flexibility.* It is possible to make each decision unique, i.e., one can specify a unique action, notification recipient, and message for each decision.

3. *Support for multiple trees.* Each sensor can reference a unique tree and embed a tree within a tree. A sensor can also refer to more than one tree to provide more than one decision, thus allowing different decisions for different operators (e.g., a researcher versus an operational user).

4. *The decision model can easily be validated.* The definition of the “Property” element implies that each branch of the tree must lead to a “Decision” node, i.e., each path in the tree must lead to a decision. The XML document will not validate using the schema described above if this condition is not satisfied.

Integration into ACRS

Detection by a system sensor will result in a submission of an event message in XML format to the ACRS. The Decision Engine will receive this message, extract all Result elements from the message and determine which decision tree is applicable to the sensor type specified by the message. The following is a typical instance of a Result element:

```
<Resultvalue="PeakCount" value="428" units="counts"/>
```

TEST RESULTS

The detectors and alarm/alert system has been tested at the base testbed and at the DTRA TEAMs Test Site on KAFB. The
most important figure of merit for performance is that the control center receives the correct basic notification (PASS, ALERT, and ALARM) for any radiation event. The system has been tested using a number of test sources, including medical sources and candidate RDD materials. Note that the decision tree contains provisions for profiling nuisance sources. This feature permits data logs to be used to establish normal bounds for sources, and detected nuisance sources falling within these bounds will be issued a PASS. A good example of the use of source profiling is the SDG. Most gauges use Cs-137 and Cf-252 (or AmBe) sources, which are retracted inside a lead shield during transport and storage. Data logs collected in both testing and operational use provide a gamma and neutron count profile of these gauges. Therefore, a threshold count rate, seen in the lower part of the decision tree, is set in the XML system. If a source drives by that looks otherwise completely like an SDG, but the gamma intensity exceeds this pre-set count rate, the system will ALARM. Otherwise, an SDG is given an automatic PASS, necessary because of their prevalence.

Table 3 shows results of a series of test runs conducted at TEAMS in April 2004. Several sources were driven by the detectors, giving the results shown.

Note that the SDG was reported as SG01, which is our code number for this model of SDG. When other gauges are added to the NaI library, they will be assigned similar codes.

The message appearing on the display for one of the dozens of events recorded during the TEAMS testing is shown in Figure 7. Note that in this test event the SDG [4] was reported as SG01 and the notification was PASS. An electronic camera image of the offending vehicle (not shown) is displayed in addition to the message text.

An exercise was held at the protected base in October 2003 during which a surrogate RDD was driven by the sensors on toward the base. All 5 tested off-base sensors detected the 70-μCi Cs-137 source, which was driven at normal highway speed. The gamma count threshold, the profile parameter discussed above, was artificially reduced by 2 orders of magnitude in order to ensure that this surrogate threat appeared to the ACRS system as a threat. ALARMS were issued when the source passed Sites 1 and 2. Other RDD candidates would also ALARM if their detection exceeded this threshold. Isotopes not identified as serious RDD threats do not have a count threshold. This is particularly important for medical isotopes, which can be very intense.

**SUMMARY**

We have developed and implemented alarm/alert notification in a protection system testbed at a military base. This notification system appears to be the first of its kind developed for physical protection. The underlying decision tree permits radiation detector data to be linearly combined to optimize the use of the limited information available on detected sources. Data from other sensors can be accommodated in a straightforward manner. The system has undergone testing at the TEAMS test site on KAFB and at the base, and has been shown to perform adequately. Upgrades to the decision tree, which are straightforward to make, will be implemented in the future as additional test results and sensor data become available.

**ACKNOWLEDGEMENTS**

This work was supported by the Defense Threat Reduction Agency, Combat Support Nuclear Programs Division (DTRA/CNBP) under the Unconventional Nuclear Weapon Defense (UNWD) Program. The authors thank Sandia National Laboratories, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory for participating in workshops and other discussions on the RN threat notification system. These national laboratories have major roles in the UNWD testbed.

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An Alternative to Traditional Software Rehosting

Kenny Ham
Southwest Research Institute

ABSTRACT

This paper will describe one alternative to rehosting TPS software to newer computer platforms. It will describe the solution that Southwest Research Institute (SwRI) used to solve a problem with re-engineering legacy software into a modern object-oriented language. The advantages gained by this method are more advanced instruction to the operator (such as pictures and movies), flexible reporting scheme to diagnose system problems, and ease of software maintenance. This solution uses commercially available products including National Instruments\textsuperscript{TM} TestStand\textsuperscript{TM} and LabVIEW\textsuperscript{TM} and Microsoft\textsuperscript{®} Visual Basic\textsuperscript{®}. The system is a four-tiered architecture to drive all test execution. The user interface is written in Visual Basic and allows the user to interact with the test execution when needed. This user interface in turn calls tests that are written in TestStand, and finally the individual tests call driver functions written in LabVIEW. A database serves as a repository for all test results, displays, and test limits. The use of this database allows for easy querying of measurement data to analyze trends in failures that help diagnose specific problems. By using this database, all test limits and test displays are contained in one central location that enables engineers to change these displays and limits on the fly without needing to change or even understand any test code. One other benefit of this data containment is that all Government classified data is separated out of the code and stored as one file, instead of in various locations as it was in the original source code.

INTRODUCTION

Several methods could be used to accomplish moving a software system to a new platform. Sometimes it is possible to transfer the software onto the new system by just moving the same code over to the new system and by running it through a translator, or rehosting the software. This has the disadvantage of using the same software without reducing any of the inherent problems that are traditionally found in legacy software. Many times old software architecture methods are used instead of newer object oriented methodologies; so some type of re-write of the software would be a wise investment to help in maintainability and upgradeability costs to improve the products life cycle costs.

This paper intends to describe the journey that SwRI took to migrate a test station over to new object-oriented code and leveraging Commercial off-the-shelf (COTS) software packages.

STATION HISTORY

The test station SwRI was tasked to upgrade was a countermeasures test set station. The support software was originally written in HPBasic and was later rehosted to a modern PC platform and run under the HTPBasic program. SwRI also accomplished this rehosting effort. The Government originally wanted to rewrite the software, but it was thought the cost would be too high and the effort too large for their schedule. Subsequently, the task was given to SwRI to re-write the software in increments. One of the requirements was that the software be written in Microsoft Visual Basic. We then researched the options available in the marketplace and discovered National Instruments TestStand as a newly available option to develop and run the Test Program Sets (TPSs). Using the TestStand software, we designed an architecture that we named TPS Guide as the new software system shown in Figure 1.

ARCHITECTURE OF TPS GUIDE

TPS Guide is a test executive and design environment that combines custom and third-party software. A central database is used to supply tests with test limits, display instructions, help displays, and the archival of test history. Tests can be grouped into logical categories and executed as individual tests in a user-defined sequence or as a defined end-to-end testing sequence. Virtual software instrument front panels contain the current state of all test equipment to aid in troubleshooting and to allow the technician to change settings while the test is running. TPS Guide can be logically divided into four distinct layers. These layers are an Operator Interface Layer, Data
Layer, Test Sequence Layer, and Instrument Driver Layer. SwRI found that componentizing the code in this way allows for the maximum amount of reusable code, while making the test algorithms easy to read and maintain.

**Operator Interface Layer**

The operator interface layer is an object-oriented based program written in Visual Basic. It includes a test and a development environment (see Figure 2). All test data is formatted in HTML—providing the capability to take advantage of colors, tables, and graphics for easy to read displays. By using the dynamic nature of HTML, results can be hidden or displayed with just a click of the mouse. Links can take the user to a particular measurement section in the test display and can link to instrument front panels simply by clicking on the links in the left pane. Context-sensitive help is also accessed by the hyperlinks in the left windowpane. The operator interface includes testing features, such as test history and reports that allow users to recall the results of previously-run tests. These features make the reporting capabilities a welcomed addition; since important test data exists until a session is deleted and can be easily recalled and saved to HTML-formatted files or can be printed for a hard copy.

**Data Layer**

The data layer is used to store all test data in a Microsoft Access database. Other types of databases such as XML and INI files can be used for small auxiliary data sets, such as classified data.

Test data includes all test names, test limits, instructions, menus, dependencies, troubleshooting, and test history (test statuses, failing data, technician notes, etc.), and all classified data. All classified numbers and words are stripped from the code and stored in a small, detached database. This separate, classified database is then merged into the larger database at runtime. Therefore, all code and most of the data layer are unclassified, making them easier to maintain and deliver.

**Test Sequence Layer**

The test sequence layer includes the collection of test algorithms needed to replace all TPSs for the test station. All test algorithms are written in TestStand. The algorithms are basically just test controllers that determine program flow. Most of the other lower-level code (such as instrument communications, database access, and operator interaction) is
handled in other layers to make the test sequencing a lightweight layer that is easily read and maintained. These test sequences are on the same basic level of complexity as ATLAS modules.

Instrument Driver Layer

The instrument driver layer includes instrument drivers for all instruments in the test station and handles all communication with the test instrumentation. The instrument drivers can be written in any language that provides a standard windows interface; however, LabVIEW and LabWindows/CVI are the preferred languages for a couple of reasons. LabVIEW or LabWindows/CVI drivers are typically provided by the instrument manufacturers for free, thereby significantly reducing development costs for this layer. These drivers sometimes include an instrument front panel that make it easy for operators to manipulate instrument states from the desktop. These software front panels are then integrated into the TPS Guide product so they can be easily opened by clicking a link associated with the currently running test.

ADVANTAGES TO USING TPS GUIDE

TPS Guide is written using a combination of state-of-the-art high order languages (HOL). These languages include Visual Basic, LabVIEW, and TestStand. TestStand is a product developed by National Instruments to be a flexible, easy to maintain test controller. It is flexible because it provides built-in hooks that allow TPS developers to use functions written in many other HOL, such as LabVIEW, LabWindows/CVI, C++ , DLLs, and Visual Basic. It is easy to maintain because it provides a way to completely separate the test algorithms from the operator interface, test data (limits, instruction strings, etc.), and instrument driver code. By writing TPS Guide in a combination of HOLs, we are able to create a product that is capable of taking advantage of windows features in a cost-effective way. The TPS Guide operator interface allows the operator to interact with several TPS Guide windows at the same time. For example, an operator can run a test and build a test report for a previously run test at the same time. This approach also makes the product flexible so new features can be easily embedded at any time.

Maintenance costs can be reduced in several ways. First, TPS Guide provides a way to integrate all the TPS software together, which allows many redundancies among the individual TPSs to be eliminated. This approach reduces the amount of code to maintain. Second, unlike other existing legacy programs, TPS Guide is designed to be easily read and maintained.

Training

Training costs can be reduced in situations where technicians and engineers are required to know how to run TPSs on multiple test stations running in different test environments. TPS Guide is designed to be able to integrate test software for many different test stations without modifying the operator interface or “look-and-feel” of the test environment. Using this feature eliminates the requirement to learn multiple test environments, thereby reducing training costs. Furthermore, TPS Guide provides training and help features that are not available in the existing test programs.
These features include digital pictures and training videos for test setups that are difficult to understand and include help tutorials describing how to use the operator interface. Access to electronic versions of technical manuals required to run the test station is also integrated into the operator interface.

**Test Development Environment**

The test development environment consists of custom software as well as COTS software provided by National Instruments, namely TestStand and LabVIEW. The test flow and algorithms are sequences of steps that comprise the actual test. Test engineers can construct tests by organizing new steps to call LabVIEW instrument drivers, user interface interaction, and many other testing capabilities. By using the TestStand test development architecture, SwRI is able to provide the developers with great expandability for the future and for legacy software. TPS Guide has support for .DLLs, .executable files, ActiveX, LabVIEW VIs, CVI, and HP VEE. It also supports instrument interfaces like GPIB and RS-232 as well as newer technologies like PXI, VXI, VXI plug-play, IVI drivers, and CVI function panels.

**Database**

The database used within TPS Guide is the backbone to the entire system. It provides tests with data to run tests, and supplies information to the user to make informed decisions if needed during testing and the ability to view data after testing to help diagnose problems. Capabilities exist to keep instructions, test limits, and picture displays all in a database instead of hard coded into the test code. All of these facets can be changed without changing any test code and without having any programming knowledge. In addition to these, the entire test ordering structure and grouping is maintained in the database and is manipulated through a tool called the Test Wizard (see Figure 4).

Within this Test Wizard, all failing data is maintained and is able to be queried for analysis of component failures in the system and for tracking to determine possible solutions to any problems. Other data throughout the system that can be manipulated through the Test Wizard are the modification and creation of new user groups that can have varying levels of permissions within the software. Using this feature, it is possible to allow engineers the flexibility to change test ordering and structure and only allow the technician or user the ability to just run the tests and view and create reports.

**CONCLUSION**

Rehosting legacy software to a newer system can be a lengthy and costly process, especially in the long-term support and life cycle of that station and the supporting software.

This paper has given an alternate solution to rehosting legacy software over to a new system. It is possible to move to a new system and have a flexible, updated software suite available to use with little or no additional cost compared to the long-term costs of rehosting software.

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[3] VEE and HPBasic™ are trademarks of the Hewlett Packard Corporation.

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Technological Evaluation of Two AFIS Systems

Marcos Faundez-Zanuy
Escola Universitaria Politècnica de Mataró

ABSTRACT

This paper provides a technological evaluation of two Automatic Fingerprint Identification Systems (AFIS) used in forensic applications. Both are installed and working in Spanish police premises. The first is a Printrak AFIS 2000 system with a database of more than 450,000 fingerprints, while the second is a NEC AFIS 21 SAID NT-LEXS Release 2.4.4 with a database of more than 15 million fingerprints.

Our experiments reveal that, although both systems can manage inkless fingerprints, the latest one offers better experimental results.

FINGERPRINT RECOGNITION

According to comparative market shares of different biometric technologies, fingerprint is one of the most mature and leading edge by far. Figure 1 compares the revenues generated by several different biometric technologies [1] and their evolution along time. We can observe the high number of commercial applications that rely on fingerprint authentication.

Although police fingerprint applications rely on rolled fingerprint acquisition, and civil commercial applications use flat fingerprint acquisition, we showed [2] that it is possible to combine both worlds. Mainly, we checked the possibility to match a flat fingerprint acquired with an inkless optical sensor with an ink-rolled fingerprint. In [3], we dealt with an operational report of a civilian fingerprint-based door-opening system described in detail in [4]. We also stated the importance of getting comparative studies from impartial entities without economical interests on a given product. Herein, we present a technological evaluation of two different Automatic Fingerprint Identification Systems (AFIS), which are fully operative in Spain for forensic applications:

1. Printrak AFIS 2000 system (Printrak International was acquired by Motorola in 2000 [5]) with a database of more than 450,000 fingerprints. It is used by the Catalan State Police Policia-Mossos d’Esquadra.
2. NEC AFIS 21 SAID NT-LEXS Release 2.4.4 [6] with a database of more than 15 million fingerprints. It is used by the Spanish Guardia Civil. This same system is shared with the Spanish Dirección General de Policía.

As a reference, it is interesting to note that the AFIS system at FBI consists of a large database of 46 million “ten prints” and conducts, on average, approximately 50,000 searches per day [7].

One of the goals of this study has been to recommend which seems to be a more powerful supporting tool for forensic scientists in their fight against crime.

This kind of test is intrinsically more difficult to perform than the civilian tests, due to the restricted amount of installed systems, which are much more priced valued and restricted to civilian researchers without special permission.

Fig. 1. Biometric market report ©International Biometric Group along several years. These figures exclude AFIS revenues (Note that AFIS are used in forensic applications).
It is unable to successfully extract the characteristic points of the fingerprints (minutiae) in a fully automatic fashion, so they must be manually introduced by a forensic expert. This should not be a surprise. According to [7], many AFIS operations are currently supervised by human experts. The FBI can process ~16% of the test images in the "lights out" mode – accept AFIS decisions without any manual inspection.

It cannot accept .bmp files. Thus, fingerprints must be entered with a scanning procedure using a high resolution camera.

The NEC system, shown in Figure 2, does not present these restrictions, so more experiments can be done.

RESULTS

We have worked out two different sets of experiments:

- **Technological evaluation of both AFIS:**
  The first experiment consists of the technological evaluation in conditions supported by both AFIS. This implies that the .bmp files obtained with the inkless sensor Uare.U [9] are printed on paper and, then they enter the system by means of a scanning procedure. This scanning is based on a video camera and a scanner (which is a commercial scanner for documents) for the Printrak and NEC AFIS systems, respectively. This situation is analogous to those latent fingerprints lifted from crime scenes found on ocular inspections. In these cases, a photo is taken from the fingerprint and enters the AFIS through a scanning procedure.

- **Study of the relevance of the scanning procedure:**
  The second consists of the comparison between a fully automatic mode, where the .bmp file obtained with the inkless sensor Uare.U enters the AFIS, rather than being printed and scanned. This study has only been done with the NEC system. This situation is suitable for remote identification applications, such as those stated in [2].

In all situations, the machine has been operated by a policeman, who is an expert on fingerprint recognition (each system by its own operator). It is important to take into account that the fingerprints that do not belong to the genuine person used for the test are different in both databases (different number and different identities).

TECHNOLOGICAL EVALUATION

While the Printrak AFIS system was unable to extract the minutiae points and yield a satisfactory result, this has not been
a problem for the NEC system. However, according to the forensic scientist, although machines are faster to obtain this set of points, human operators outperform machines, which frequently fail to differentiate ridge endings due to low quality acquisition/fingerprint from real endings. Thus, automatic extraction implied a high set of minutiae, some of them being wrong detections. Taking into account the satisfactory results of the automatic extraction of the NEC AFIS, we have not performed any manual extraction or supervision in this system, which should suppose even better results for the NEC AFIS. Figure 3 shows a snapshot of the NEC AFIS screen.

Table 1 compares the scores obtained in each test for the fingerprint, and the score of the next one. The experiment with the Printrak AFIS has been performed with a database of 450,000 fingerprints (we have used the 10 fingers per person contained in the database). The experiment with the NEC AFIS has been performed with a database of 1,500,000 fingerprints (we just used the index finger of each person contained in the database). These databases belong to different individuals, because they have been obtained independently.

Table 1. Comparison of the scores for the different trials. The input column shows the score obtained by the input trial. For the correct identified fingerprint, the next option means the second candidate. For incorrect, it means the first candidate

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Printrak</th>
<th></th>
<th></th>
<th>NEC</th>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>input</td>
<td>Next option</td>
<td>Correct?</td>
<td>input</td>
<td>Next option</td>
<td>Correct?</td>
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<tr>
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<td>Yes</td>
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<td>1190</td>
<td>Yes</td>
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<tr>
<td>3</td>
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<td>1695</td>
<td>No</td>
<td>2179</td>
<td>507</td>
<td>Yes</td>
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<tr>
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<td>1870</td>
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<td>3408</td>
<td>967</td>
<td>Yes</td>
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<tr>
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<td>1909</td>
<td>Yes</td>
<td>6047</td>
<td>785</td>
<td>Yes</td>
</tr>
<tr>
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<td>5279</td>
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<td>1675</td>
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<td>4306</td>
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<td>3105</td>
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<td>Yes</td>
<td>5236</td>
<td>1409</td>
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</tr>
</tbody>
</table>
Table 2. Comparison of the scores for the different trials, using the .bmp file acquired with the scanner as input. The input column shows the score obtained by the input trial. Next option means the second candidate, except for the first trial

<table>
<thead>
<tr>
<th>Trial #</th>
<th>NEC 15,000,000 input</th>
<th>NEC 15,000,000 Next option</th>
<th>NEC 1,500,000 (fully automatic) input</th>
<th>NEC 1,500,000 (fully automatic) Next option</th>
<th>NEC 1,500,000 (manual supervision) input</th>
<th>NEC 1,500,000 (manual supervision) Next option</th>
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<td>1</td>
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<td>316</td>
<td>552</td>
<td>3213</td>
<td>1116</td>
<td></td>
</tr>
<tr>
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<td>1311</td>
<td>1479</td>
<td>819</td>
<td>9999</td>
<td>1708</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>842</td>
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<td>484</td>
<td>9999</td>
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<td></td>
</tr>
</tbody>
</table>

between the 30 highest scores, so it is wrongly assigned to another person). This test is not showed in Table 1.

- While the NEC AFIS can correctly assign the identity of the genuine person, the Printtrak fails in 3 of 9 tests. However, these results can be improved by the skill of the human operator for the Printtrak AFIS, at least in some trials.

- The scores obtained with Printtrak are lower than and closer to the next candidate, so the result of the NEC system offers more reliability as to whom the input fingerprint belongs.

- Although all the fingerprints used for testing look similar (see Figure 3 of AES [2]) it seems clear that there are certainly differences on the scores obtained, especially for the fully automatic operation mode of NEC AFIS. Thus, the correlation between consecutive acquisitions of a same finger is not as high as common sense dictates. Consequently, it seems interesting for fingerprint applications to perform several acquisitions rather than rely on a single acquisition.

STUDY OF THE RELEVANCE OF THE SCANNING PROCEDURE, HUMAN SUPERVISION, AND THE DATABASE SIZE

Another set of experiments has consisted of the evaluation of the relevance of database size, the scanning procedure, and the intervention of a human supervisor. We have used the .bmp files provided by the U.are.U optical sensor, and tried to match them to the whole database (1,500,000 people) using 10 fingers per person (15,000,000 comparisons) and just the index finger (1,500,000 comparisons). We also studied a fully automatic method without human supervision, and with a set of features manually extracted by a forensic scientist.

The main conclusions of this experiment are:

- There is a slightly better performance when directly using the .bmp files (compare Tables 1 and 2). Even Trial #1 that failed with the scanning procedure is close to be solved (the genuine identity is ranked on the fifth position, while the scanning procedure did not include it among the first 30 positions).

- The database size has relevance on the scores of the next candidates, but in our case, it has not reduced the ability of the system to identify the correct person.

- Comparing the last columns of Table 2, it is clear that a human operator outperforms the automatic mode. Thus, the state-of-the-art systems are a powerful tool to help human beings, but they cannot replace us. The necessity of an intervention by a human operator is expected to last for a long time.

ACKNOWLEDGEMENTS

I want to acknowledge Santi G. Tugores, Jordi Costa, Gabriel Costa-Tarrida, and Xavier G. de Linares from the Catalan Policia-Mossos d’Esquadra, and the criminalistic team from the Spanish Guardia Civil for their support and
collaboration at the police premises. Indeed, this project would not be possible without their contributions.

CONCLUSIONS

Taking into account the results of our experiments, we think that the NEC system offers better identification success and more flexibility for entering fingerprints from the real world, at least for the tested versions of both systems. The state police were thinking of updating their system, so our recommendation is to adopt the NEC system. This same system has been adopted in 37 central sites in North America and other countries worldwide [10].

Our experiments confirm, in a more scientific way, the personal feeling of the forensic scientist from the Spanish Police.

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Sustainment of Legacy Automatic Test Systems: 
*Lessons Learned on TPS Transportability*

Cathleen Kennedy
*Systems & Electronics, Inc.*

**ABSTRACT**

Sustainment of legacy Automatic Test Systems (ATS) saves cost through the re-use of software and hardware. The ATS consists of the Automatic Test Equipment (ATE), the Test Program Sets (TPSs), and associated software. The associated software includes the architecture the TPSs run on, known as the control software or test station Test Executive. In some cases, to sustain the legacy ATS, it is more practical to develop a replacement ATE with the latest instrumentation, often in the form of Commercial Off-the-Shelf (COTS) hardware and software. The existing TPSs, including their hardware and test programs, will then need to be transported, or translated, to the new test station.

In order to understand how to sustain a legacy ATS by translating TPSs, one must realize the full architecture of the legacy ATS to be replaced. It must be understood that TPS transportability does not only include translating the original TPS from an existing language (such as ATLAS) to a new language (such as “C”) to run on a new test station, but includes transporting the run-time environment created by the legacy ATS. This paper will examine the similarities and differences of legacy ATE and modern COTS ATE architectures, how the ATS testing philosophy impacts the ease of TPS transportability from legacy ATE to modern-day platforms, and what SEI has done to address the issues that arise out of TPS transportability.

**BACKGROUND**

To transport a TPS is to re-use the existing TPS hardware, such as the Interface Test Adapter (ITA) and the Interface Device (ID), as well as associated cables and to utilize the existing Test Program software, either directly or through a translation process, on replacement ATE. Figure 1 shows the relationship between the ATE, TPS, and ATS.

The control interface and instrumentation programming commands executed by the computer change when the Test Station is updated by modern equipment. A modern station controller will require a new Test Executive (TE). The test program(s) will need to be translated into a format that will be compatible with the new TE.

The test program translation process can be performed entirely by hand or through an automated process (i.e. a software translator). Either way, both options introduce the same issues of replicating the original test environment and capabilities of the legacy tester.

**PHILOSOPHY OF ATE TESTING**

The purpose of ATE is to ascertain whether a Unit-Under-Test (UUT) is operating correctly and, if not, identify what part of the unit is faulty and should be removed and replaced. To do this automatically, test programs are developed based on the UUT's requirements and thresholds. The test programs will apply signals to the UUT using stimulus instrumentation and will measure expected values using measurement instrumentation. The test program may have upper and/or lower limits imposed on a test to detect a fault.

In some cases, the station operator may desire more control over a test than just running end-to-end. Therefore, an environment is desired that allows single-stepping through
Fig. 1. Relationship Between ATE, TPS, and ATS

each statement, or sub-test, halting when the test fails, printing and/or logging the results of tests, and a quick reset of the entire station. Test programs are structured assuming the control offered by this environment will be available.

The architecture of the legacy ATE should be studied in order to replicate and sustain the equipment with modern ATE. There are many issues to consider when transporting a TPS, specifically the test program, from a legacy ATE to a modern ATE and its new architecture.

ARCHITECTURE OF ATE

The architecture of the test station hardware between legacy ATE and modern ATE has remained relatively the same, although the size of the Test Station and its instrumentation has decreased dramatically. However, the architecture of the modern ATE software that resides on the station computer has changed due to technological advancements.

SOFTWARE ARCHITECTURE OF LEGACY ATE

The typical physical architecture of legacy ATE consists of several bays of instrumentation that communicate via a station controller using a standard protocol, such as General Purpose Interface Bus (GPIB). The station controller is not always a Personal Computer (PC). The TE on the controller may be either proprietary software written specifically for that ATE or COTS software. In either case, the TE has unique capabilities, such as its user interface, modes of operation and instrument control. Often, legacy ATE uses custom drivers for communication between the TE and the instruments. The test program that is loaded by the TE typically determines the sequencing of tests.

Fig. 2. Legacy ATE Software Architecture
The TE enables the station operator to control the Test Program. The TE is also responsible for the communication with the instrumentation on the station. The TE will either translate the Test Program statements into understandable commands accepted by the instrument being programmed, or will pass a standardized programming command to a hardware module (such as a Test Module Adapter (TMA)) on the station that translates the command for the instrument. The TE is tightly coupled to the implementation language of the test program. Figure 2 shows the software architecture and its communication interface for legacy ATE.

The test program is run by legacy Test Executives in one of three ways: Executed, Interpreted, or Intermediate.

**Executed**

Executed test programs are those that compile into machine instructions that are executed directly by the processor.

**Interpreted**

Interpreted test programs are those in which the TE parses and uses the source code directly to execute the program. They do not require compilation.

**Intermediate**

Intermediate test programs fall between Executed and Interpreted. The source is typically compiled into byte-codes and executed by the TE.

From SEI’s experience, most legacy test programs are Intermediate, and typically written in Abbreviated Test Language for Avionics Systems (ATLAS).

The TE provides the desired environment to control the execution of the Test Program. Often, the operator will want to halt the test when a measurement fails to meet its limits, therefore the TE’s “HALT ON NOGO” functionality will be used. Other times the operator may want to skip tests or repeat a test several times. This functionality is also offered by the TE.

When transporting TPSs from a legacy ATS to modern ATS, the translation of the Test Program must take into account the new test environment of the modern ATE.

**SOFTWARE ARCHITECTURE OF MODERN ATE**

Modern ATE contains various instrumentation types, from VXI and PXI to synthetic instrumentation and often utilizes Commercial Off-the-Shelf instrumentation and software. Among the advantages of COTS equipment is higher performance, cost savings, more flexibility, and open architecture, and ease of interchangeability. The modern ATE system architecture is becoming more standardized through the use of IVI, SCPI, and Plug & Play and is primarily PC-based. The computer's operating system is also standardized.

Many COTS instruments are delivered with a software driver that offers a library of function calls that will automate the communication process with the instrument over its supported bus (such as IEEE-488 or PXI). Other commercial software that sequences tests is also implemented to execute a test program. Figure 3 shows a generalized software architecture and communication interface for modern ATE.

In order to translate the original Test Program used on the legacy ATE to one meaningful to the new station, a run-time environment must be defined. To save costs associated with updating operator manuals and training, the run-time environment will need to reflect the same control options and will have the same requirements as the existing TE to provide the same look and feel of the graphical user interface for operator interaction.

One might be inclined to use the COTS Test Sequencer exclusively to run the Test Program, but COTS sequencers do not offer a 1:1 correlation to uniquely developed legacy ATE and this approach would not be in accordance with the philosophy of ATE Testing.

**DILEMMAS OF TPS TRANSPORTING**

Design decisions must be made when transporting test programs from legacy ATE to modern ATE. When considering a target environment based on the requirements of the modern ATS, several issues arise. The main dilemmas of TPS transporting are designing a translation process for the test program and building a run-time environment for the modern ATE that mimics that of the legacy ATE.

**THE RUN-TIME ENVIRONMENT**

The run-time environment includes the COTS sequencer and its interface to the test program and instrument drivers as well as the user interface.

When using a COTS sequencer, the test program must be translated into sequence files formatted for the specific sequencer. The sequence file will have the constraints of the sequencer’s functionality, such as modes, debugging, and user interface. Depending on the requirements, these constraints may not be acceptable.
THE TRANSLATION PROCESS

Once the run-time environment and interface has been developed, the translation process from the legacy test program to the new test program can begin. The magnitude of difficulty of this task depends on the complexity and dependencies of the original test program.

Each of the legacy test program types has a cost factor associated with its translation process. Executed test programs are tightly coupled to the system processor and hardware, whereas interpreted and intermediate test programs are tightly coupled to the legacy TE. The test programs executed by a processor were often run on hardware that is now obsolete. The intermediate test programs were written in various languages, often ATLAS. Although several IEEE ATLAS standards were developed, ATLAS implementations were extended by using Non-ATLAS Modules (NAMs).

ATLAS programs must be compiled into an object file and other implementation-dependent supporting files and the TE must use various configuration files to determine the connections and instruments that are used in each test statement. Tests written in a language that has many dependencies on other configuration files and often that uses more descriptive language will require a more rigorous translating scheme. The interface between the test program and the sequencer must also play into the translation procedure. In some cases, requirements imposed on the modern ATE may limit the translation process of the test program.

SEI has encountered these issues and successfully employed a translator when upgrading from a legacy ATS, the E8205, to a modern ATS, the S9205, that reuses the original TPSs and translated test programs.

S9205 CASE STUDY

The test programs for the E8205 were developed in Emerson Test Language (ETL). The run-time environment provided for various test modes of operation such as Auto, Semi-Auto, Monitor, and Interrupt as well as print modes of operation consisting of Non, Programmed Print, All, and No-Go. The test display could be controlled to show status, measured value, limits, modes, and operator instructions.

Due to the requirements imposed by the legacy test environment, the COTS sequencer alone would not be sufficient. Therefore, SEI developed a run-time engine that was responsible for interfacing to the test program and utilizing the sequencing capabilities of the COTS sequencer to provide all the required functions.

The ETL run-time engine for the S9205 was designed to provide the same control over modes of operation, print modes, and display modes as that of the E8205.

The original ETL test programs were compiled into a file that could be read and executed by the E8205 TE. An ETL translator was developed by SEI to read the ETL source (pre-compiled) code and translate it into C source-code format that could be compiled by a COTS C compiler and executed by the S9205 ETL engine. An example ETL statement to program a Waveform Analyzer on the E8205 is shown below:

- 034, RA1300T0,
- AP0022+0,
- BP0111+0,
- ST90%A1-,
- SP10%A1-,
- AM01P99P,
- BM01P99P.

After going through the ETL translator, the new statement looks as follows:

- SPM034("RA1300T0"),
- "AP0022+0",
- "BP0111+0",
- "ST90%A1-",
- "SP10%A1-",
- "AM01P99P",
- "BM01P99P".
The translated statement takes the form of a function in the "C" programming language. The format of the function call was made to look like the ETL statement to minimize re-training and program manual modification efforts. The translated test program is comprised of a series of these functions. Because the ETL engine was implemented, the translated test program did not have to conform to the sequence file format.

These various statements, like that shown above, make up individual tests in the test program which are loaded into the COTS test sequencer by the ETL run-time engine.

The replacement instruments used in the S9205 consist of VXI, PXI and IEEE-488 instruments. The instrument drivers installed on the station computer are used by the run-time environment to program the instrument according to parameters in the translated ETL statements.

In order to facilitate future upgrades of instruments, an instrument programming bridge was added to the back-end of the engine. The bridge is responsible for making the function calls to the instrument drivers based on the particular test statement. When an instrument is upgraded and its instrument driver is replaced, the instrument bridge need be the only entity modified to redirect communication to the new instrument. Figure 4 shows the software architecture of the S9205 system.

The TPS transportation from the E8205 to the S9205 was successful because the legacy architecture was examined, the run-time environment was carefully planned, and the interface between the engine and the test program was well-defined. The translator consists of a straightforward design, due in a significant part to the simplistic nature of the ETL language.

LESSONS LEARNED

Design decisions must be made when transporting test programs from a legacy ATS to a modern system. SEI has found that translating to a sequence file alone would not meet the requirements imposed on the transported stations. Therefore, SEI made the decision to develop a run-time engine that would provide the operator interface of the legacy systems.

The type of test program utilized by the legacy tester – executed, interpreted, or intermediate – must be determined as well as the specific cost factors related to transporting the test program. Legacy ATE software was more uniquely tied to the station hardware whereas modern ATE often utilizes a lower level software layer that allows the TE and test programs to be less dependant on the type of physical connections to the hardware (such as GPIB, VXI, and PXI).

For each legacy system transported to modern ATE, a target file type, such as a DLL, a sequence file, or a proprietary file type, must be decided upon. The amount of system environment preservation must also be determined. When faced with test programs that utilize a non-standard statement (such as embedded assembly code or NAMs) the decision of hand translating or implementing subsystem support must be made. Legacy test program languages that have rigid syntax are more favorable to successful translation. Many times the driving force of the translation process is cost.

In all, SEI has learned that each transportation process from a legacy ATS to a modern system is unique. There is a set of common design decisions that must be made when translating test programs. Varying requirements impact these design decisions and target system environment.

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Radar System Analysis and Modeling

David K. Barton
Artech House, Norwood, MA, USA
2005, 545 pages, Hard cover,
ISBN 1-58053-681-6

During the past four or five years we have been told by the media, particularly through television channels, that military technology is declining; we should not waste our money in developing new weapon systems, and that the former threats posed by unforeseen major international conflicts have passed away. It is far beyond the competence of this reviewer (or the review itself) to figure out if such argumentation is really valid, but regardless, we have seen that at least radar issues are still a topic of continuously increasing scientific and tactical discussion. Naturally, this is at least partly due to the obvious challenges and possibilities created by the anti-terrorist actions but also the civilian applications of radar systems and devices are all the time increasing. As more affordable components and modules have appeared on the commercial market and higher carrier frequencies become feasible, previously rejected radar-like projects (for example in the process industry or in robotic automation) have been scooped up from the files. As our readers may have observed, the interest in radar has been reflected in the publication sector, too. 2003 and 2004 saw more than twenty international items relevant to this topical area and the trend seems to continue, so a reviewer has plenty to choose from. However, when rumors about a soon-to-come upgraded version of David Barton’s Radar System Analysis reached this reviewer’s ears sometime during last summer, certain re-arrangements of personal reading schedules became mandatory and slight excitement was in the air. It was already a moment of certain embarrassment when, in 2004, a friendly letter – triggered by one not-too-accurate book review – signed by M.I. Skolnik arrived. What was now to come from one of the remaining founders of our current radar knowledge. How can one review a book based on such long and wide experience?

Here I have it in my hands, just from the publishers’ rotary press, Radar System Analysis and Modeling, authored by David K. Barton and published by Artech House officially in 2005 (although it is December 2004 at the moment of writing). The book has 545 pages plus a CD-ROM. After the Preface, there are nine main chapters, a list of index items containing about 1000 words for searching, a List of Symbols, and a List of Acronyms. Every chapter has its own list of references, the total number of which in the entire book is about 168. The engineering-type approach favors graphs and illustrations (total number approximately 260) but there are also 569 equations that do not require complicated mathematical processing from the reader’s side. Actually, most of the key expressions are available as ready-to-use code on the CD, which has about 100 solution tools for various radar evaluation tasks. Classroom use is supported by 95 problems, roughly 10 in each individual chapter.

Chapter 1 discusses the fundamental radar range equation in different environments and for various applications, particularly for search radar and if intentional jamming or clutter are to be regarded as the main limiting factors. Next, Chapter 2 is about target detection. Here, we read typical factors related to the processing of pulse trains, fluctuating targets, and get a basic treatment of constant false alarm rate or CFAR. Chapter 3 is entitled: “Targets and Interference.” It contains a treatment of radar cross section in general, that of expected targets, and, finally, clutter. A very brief section of jamming issues is included as well. About fifty pages are devoted to radar antennas in Chapter 4. The main topics are radar antenna basics, arrays, ultra-low-sidelobe antennas, and multiple-beam constructions. Radar signal processing has been given another fifty pages in Chapter 5. There are three main areas of interest, namely, pulse compression, moving target indicator (MTI), and pulse Doppler. Chapter 6 is a condensed treatment of radar wave propagation and focuses on attenuation, diffraction, and refraction. Chapters 7, 8 and 9 are very much system-oriented. Radar surveillance is discussed in Chapter 7, with an emphasis on 2-D and 3-D processes and various physical realizations suitable for such tasks either in ground-based or maritime equipment. Some jamming-related material has been added here as well. Radar-based tracking and measurement is the field of Chapter 8, which naturally implies such items as angular and distance errors, speed measurement, and tracking challenges during hostile jamming. The final chapter gives a systematic way to handle the radar loss budget, logically assembled from the individual elements involved. Some typical examples of pre-computer losses are given, too. The associated CD contains radar system analysis tools in Mathcad® II environment. The total number of such files is about 100 and for users of other computation engines HTML-versions are given as well. The tools cover
detectability computation, RCS and clutter, MTI and Doppler, coverage and power computation for surveillance radars, tracking errors, and loss budget estimation.

Very many, if not almost all of our readers have long ago come to know the author, David K. Barton, as a respected specialist in the field of radar systems. His scientific journal articles and particularly the books such as Radar System Analysis (1964), Radar Technology Encyclopedia (1999), Handbook of Radar Measurement (1969 and 1984), Radars (several volumes, 1978), Modern Radar System Analysis (1988) and Modern Radar Systems Analysis Software (1993) are frequently used by our radar community as authoritative references and sources of essential fundamentals. At present, Barton is a radar system consultant in New Hampshire, USA. He was born in Greenwich, Connecticut in 1927 and attended Harvard from 1944 to 1949, but worked for two years in the US Army White Sands Test Range in-between. After completing his studies in physics, Mr. Barton returned to White Sands and moved from there to Fort Monmouth in 1953 to trigger the development of the first true monopulse measuring radar for the Signal Corps. In US military jargon, the device was given the code AN/TPS-16. As we understand it, Mr. Barton moved already in 1955 to RCA where he continued this development and participated in the field trials as well. A couple of years later he was given the first David Sarnoff Medal for Outstanding Achievement in Engineering based on this particular project. In 1960, Barton and his team fielded the design as the AN/FPS-49, which was a key component in the Ballistic Missile Early Warning System for 40 years – both in Alaska and in Great Britain. After this task was successfully completed, he joined Raytheon, where his role in the design of the US Air Force radar landing system, called AN/TPS-19 was vital. Besides this, he was involved during those twenty years in a number of other radar and guided missile studies. From 1984 to 2004, he worked at ANRO Engineering in the field of radar systems.

Mr. Barton is an IEEE Fellow since 1972 and was elected to the National Academy of Engineering in 1997. He was given the IEEE Dennis Picard Medal for Radar Technologies and Applications in 2002. We can easily guess his impact in such bodies and institutions as the scientific advisory board of the US Air Force, the US Defense Intelligence Agency, and the Army Research Laboratories. Artech House, the publisher of his books, has also already in 1975 selected Mr. Barton as their Radar Library Editor. That series of valuable books today contains about 140 titles.

After going through the contents and author data, we now proceed to the more difficult analytical part of this review. It might have been possible to perform some comparison between this book and its earlier versions or forefathers, dating back to 1964. I made a conscious decision not to do this. Instead, let’s look at the entity as it is now. Very apparently, the author has at least partly wanted to create an educational tool, because every chapter contains a number of problems to be solved by students (there are even answers and solutions available). The second target audience must be somewhere among radar system engineers, as there is so much in-depth material about various challenges in real-life radar work and detailed examples of completed practical radar projects. Very different items are included, covering wave propagation, digital signal processing, target and platform kinematics, and so on. Indeed, we can speak about a true system-level book.

When trying to take a newcomer’s attitude (which is not difficult at all – Barton was designing radars well before I was born), I feel happy with the book’s easy approach.

- First, we seldom see experienced engineering authors who want and can select their writing style in this friendly way. Even if I had never before heard about MTI or clutter, reading through Mr. Barton’s chapters readily gives efficient ways to proceed.

- Second, the problems have clearly been thought through before printing, because solutions exist. As our readers may have found out, it is not so rare in many other academic textbooks to have unsolvable student problems creating despair and amusement in the classroom. Rookies may find the detailed List of Symbols very attractive, because it also has a cross-referencing feature whereby readers can find the place in the book where that mysterious letter or subscript first pops up.

Changing my student cap to the warmer and more conservative project manager’s clothing, my point-of-view must be adjusted accordingly. If I have been working for some time in the radar business (as is the case), much of the individual topics look pretty familiar (as they should) – there is not that much new available. However, the entire compilation makes sense, because a working radar engineer can search for many professional refreshing items from this one book, instead of having half a dozen volumes on his desk. Besides, a professional can readily use the provided pieces of software on the system level. The entire treatment, that is – the written book and the software examples – is strong in the areas of detection and signal processing, and in the evaluation of surveillance and tracking concepts.

Although I might now be pushed down from the cliff, I want to say some words of criticism as well. A minor detail is the fact that a number of illustrations are simply smudged photocopies from earlier publications. The reason to this is hard to accept, because, at times, readability is really marginal. The majority of graphics though is crisp and clear and gives true additional value to the text. Knowing the author’s very long experience in the field of radar and the fact that many basic aspects stay as they once were, it is understandable that a considerable amount of the references in Radar System Analysis and Modeling dates back to 1970s, 1960s and even 1950s. A rapid counting action indicates that more than 90 out of the 164 references have first appeared before 1980. On the
other hand, as the number of international conferences close to radar topics and the number of journal articles discussing radar has been high throughout the decades, one might assume that some new details have come up. The reader may expect that a distinguished author has included such knowledge in the text, but it is not readily visible in the list of References. In some cases, a relatively fresh-looking reference might be misleading as well. For example, in Chapter 3 about targets and interference, the author has listed Shirman’s book Computer Simulation of Aerial Target Scattering, Recognition, Detection and Tracking published by Artech House in 2002 as a reference. Having that book on my desk, I made a random check which suggests that most of the data in Shirman’s fine book has initially been available in Russian in the 1960-1970 era. Especially those areas of radar design where the advance in semiconductor technology may or may not have had substantial effect should be considered carefully. For example, when the author uses a graph from 1982 as typical oscillator noise sideband data in Chapter 5, a cautious reader might wonder if more recent oscillator concepts show different performance characteristics. A digital receiver beam-forming block example from 1978 or a T/R module from 1977 could also cause discussion, despite the fact that procedures may have been quite stable since those days.

Another difficulty has been caused by the very wide scope the author covered in his book. First, the book’s title suggests a thorough treatment of all radar concepts – an impossibility in itself. In reality, the book’s focus is in pulse Doppler radars for the surveillance and tracking of airborne targets, preferably hundreds of miles away. Other users, such as maritime or battlefield units, are briefly explained but without much enthusiasm. Already in the initial definitions in Table 1.3 of this book only military use of radar is expected. That might not be so severe unless due to this millimeter frequencies (the main band for collision avoidance radars in cars and for industrial robotics) have practically been excluded from the remaining discussions. The same unbalanced nature is found on the lower levels of hierarchy. Chapter 4 does not contain so much engineering information about reflector antennas, as one might assume, and even in the References, there is, in fact, only one related book for further reading. Antenna arrays are very much emphasized and therefore a first-time reader might get a biased view.

It looks as if somehow the story has been inadvertently cut just when the author should have started describing, for instance, reflector feed structures and achievable illuminations. This is later a drawback when monopulse feeds are discussed in Chapter 8. Although the author mentions in Chapter 6 that propagation-related material is readily available, the entire treatment in this book is relatively weak. Here, the focus seems to have been in ground-to-air applications (on land or sea) only. Radar hardware, especially transmitter and receiver modules appear only in very coarse block diagrams and one might discuss the general importance of some older constructions. For example, issues related to frequency stability in Doppler processing are very well documented, but practically nothing is said about how such things are approached in real hardware. Finally, electronic warfare aspects (ECM and ECCM) of this book are broadly advertised by the publisher, but the content is more a good basic course treatment of mostly well-known subjects. Of course, it could be nothing else from a patriotic author, otherwise it would no more be ECM or ECCM!

Some things are naturally a simple matter of taste. When I first found the Blake pulse radar range worksheet in section 1.2.8 as a pasted photocopy image, I was a bit upset indeed, but after some thinking, I can understand how and why the author has come to this approach. There is obviously no point in inventing the wheel over and over again. However, I see the Blake worksheet more as a technician-level practical list – not as a real tool for the design of new radar systems or as a motivating element toward creative thinking. For academic education, I would use the more analytical parts of that chapter. Another example of things suitable for the coffee hour discussions is the author’s choice of the computation engine. Barton is quite right when he points out the open and straightforward self-documenting feature of Mathcad. Unfortunately, many radar performance tools and tasks currently run in the more complicated, and, apparently, awkward matrix-format once heavily pushed through by the Matlab community. That might have been an alternative for mature project engineers and scientists. Of course, a classroom start-up with Mathcad is faster; but, What if...?

As a summary, I feel a bit desperate now. With such an immense professional background and remarkable career, Mr. Barton certainly deserves our full respect and appreciation. His publication record is long and comprehensive and based on true practical and outstanding radar implementations. Radar System Analysis and Modeling in its third or fourth generation is a nice book, its facts are correct and it covers many topics. However, contrary to the publisher’s claims, it is not really a thorough update of the entire field – more a collection of detection and signal processing methods and a compilation of design procedures and Mathcad routines for pulse Doppler radar, based on comprehensive expertise from the past 50 years or so. The book is suitable for educational purposes. Individuals interested in the evolution of radar knowledge or needing a cross-referencing handbook and not possessing any of the previous versions certainly find it worth purchasing as well.

Reviewed by Pekka Eskelinen
New Technology Starts New Era of Space Exploration

Henry Oman  
Editor-in-Chief Emeritus

Fifteen years ago a spacecraft’s battery life was just a few thousand charge/discharge cycles. Propulsion energy was limited by the mass that rocket fuel and oxidizer tanks had to be lifted out of the Earth’s gravity field. Duration of photovoltaic power in spacecraft was limited by the lifetime of solar cells in a radiation environment. The possibility of nuclear propulsion was rarely mentioned.

Becoming available are new developments like lithium batteries that contain no liquid electrolyte, and have lifetimes up to 70,000 charge/discharge-cycles. This corresponds to 63 years of life if discharged and recharged three times per day. Available for powering spacecraft with ion propulsion are new high-efficiency Stirling engines that contain no rubbing surfaces. They can even generate power for electromagnetic rocket engines. These developments have opened new opportunities for exploring deep space, as well as the surfaces of planets that range from Mercury to Pluto. Manned exploration on the surfaces of Mars, Venus, our moon, and even on a moon that orbits Saturn, are in planning stages. Already Rover vehicles wander over the hills and plains on the surface of Mars, looking for signs of water. Commanders on Earth are going to direct vehicles that roam on the surface of Venus and drill rocks to get chips for chemical composition analysis.

Space exploration planning by government agencies, and the latest developments in energy efficiency and useful lifetime of power producing components and systems, were key topics in many of the 279 presentations at the International Energy Conversion Engineering Conference (IECEC). This conference was held in Providence, Rhode Island on August 16 to 19, 2004. Our IEEE Aerospace and Electronic Systems Society is now a participant in the planning and conduct of these annual energy and power conferences.

US CONGRESS APPROVES NEW SPACE EXPLORATION PROGRAM

Three months after the 2004 IECEC closed a “lame duck” US Congress completed work on the Fiscal Year 2005 budget with a $388 billion appropriations bill. The National Aeronautics and Space Administration (NASA) emerged as one of the few winners, with $16.1 billion allocated for fiscal year 2005. This is 4.5% more than last year. NASA’s windfall allows it to get the Space Shuttle back into flight next year, resume construction of the Space Station, and embark on moon and Mars programs. The US Department of Energy’s (DoE) Office of Science was a modest winner of $3.6 billion, which is 2.8% more than last year. This office’s programs include high energy physics, fusion research, nuclear physics, and basic energy sciences.

In this report we describe the plans of the United States and other governments for developing deep space exploration programs. The latest energy conversion, power generation, and energy storage developments, described in the IECEC’s 80 engineering presentations, make these plans achievable.

NEW ERA OF SPACE EXPLORATION ARRIVES

Available today for storing energy in spacecraft are lightweight lithium-ion batteries that have long charge/discharge lifetimes in energy storage service. One battery in a life test had lost only 20% of its capacity after 50,000 charge/discharge cycles! No previously available battery could match this cycle life. The electrolyte between the anode and cathode of a lithium-ion cell can now be a thin sheet of lithium, rather than a liquid, so specific orientation is required during spacecraft acceleration or deceleration.

Power for spacecraft operation in the absence of bright sunlight was once generated by thermoelectric junctions that were heated by a package of decaying radioisotopes, which had a half-life of a few years. However, the thermoelectric converters had efficiencies that were less than 20%, so much costly isotope had to be launched and carried. Stirling cycle engines were available, but pistons moving in cylinders wear out. Now becoming available are Stirling cycle engine generators that have absolutely no parts that rub on each other, so lubricants are not required. K. Mellott from NASA Glenn Research Center described a helium-charged kinematic Stirling heat-to-electric power converter that is designed for a Venus surface mission [1]. Its heat source is a nuclear General Purpose Heat Source (GPHS). It was designed to cool electronics as well as deliver 100 watts of electricity. Its estimated total efficiency was 23.4%.
S. Qiu from Stirling Technology Company in Kennewick, Washington, described a prototype high efficiency radioisotope generator for potential NASA space missions. Early demonstrations of the converter proved it to be very robust during more than two years of testing and evaluation. He described progress in improved Stirling design, and predicted that weight reductions of 74% are possible and a power density of 50 W/kg would be achieved [2].

In a presentation, J. Wood of Sunpower and C. Carroll of Boeing predicted that a specific power of 100 W/kg could be attained, and a single GPFS could deliver enough heat to generate over 80 W of electric power [3]. A 14-year life of a generator heated by a single GPFS becomes feasible.

RENEWABLE ENERGY FOR SUPPORTING PLANETARY EXPLORERS

Planets and moons have been studied by orbiting satellites during the last 40 years. These satellites explored our moon and planets Mercury, Venus, and Mars. Silicon solar cells converted solar radiation to electric power for the instruments and radio transmitters that resumed the observations and data to Earth.

Human beings will have the opportunity to explore moons and planets before the end of this century. Y. Sun came from the University of Texas to outline problems that must be solved before such missions to other planets can begin [4]. For missions that might last a year, the cost of shipping the mass of a fuel-consuming power source would be prohibitive, so renewable energy sources and their limits need to be evaluated. For example, Venus has a dense atmosphere and is cloud covered, so wind and waterfall power sources might be practical. The Spirit and Opportunity rovers are exploring the surface of Mars, looking for signs of water, which if found could be a source of hydropower. On our moon, solar power is plentiful, but the long nights might require radioisotope heat sources for keeping the explorers warm. Sun described possible energy sources for planetary exploration.

SOLAR POWERED FLIGHT OVER VENUS

A rover was already being designed for exploring in very hot weather the surface of Venus while A. Colozza from the Analex Corporation in Cleveland was delivering his paper that described the solar-powered vehicle that was to fly over Venus [5]. The surface-exploring vehicles on Venus need an above-clouds relay station that can deliver their collected data to Earth headquarters and pass commands from headquarters to Venus' surface vehicles.

This flying vehicle would carry a solar array that generates 72.5 kW from a 9 x 1.8 meter wing on which the Venus solar intensity is 2600 watts per square meter. Corrosion was not a problem because Venus has a carbon-dioxide atmosphere! Also, days are long because Venus rotates very slowly. A 50-earth-day test period was adopted for the program so that the airplane could cruise above the clouds over a ground station for one Venus day. The solar array was designed to deliver the required altitude-maintaining power to the 90% efficient motor that drives a 3-meter diameter two-bladed propeller.

SOLVING A FREQUENCY SHIFT PROBLEM ON THE HUYGENS PROBE DURING ITS FLIGHT TO SATURN

NASA's 6-ton Cassini spacecraft began orbiting Saturn after a 3.5 billion kilometer, seven-year journey from Earth. It had already sent back pictures of the planet, its rings, and its 30 moons. Its four year tour of Saturn's neighborhood began in June of 2004.

An important exploration started in January 2005 when Cassini released the 3-meter diameter Huygens probe for its descent to the surface of Saturn's largest moon, Titan. Titan is even larger than the planet Mercury. The cameras on Huygens will photograph the moon's cloud cover and surface. The probe descended through an atmosphere rich in nitrogen, contains 6% methane, and its thickness is 1.5 times that of Earth's atmosphere. Clouds of soupy methane cover the surface of Titan, so Huygens camera is equipped with special filters for peering through these clouds. A microphone will listen to the moon's wind. Instruments will report back to Cassini the chemical, thermal, and electric properties of Titan's atmosphere. After the probe lands it will send back photographs and data that describe the moon's surface.

The Huygens probe could not carry enough battery power for sending all the way to Earth the data it gathers during its descent and landing. Consequently, the data gathered by Huygens instruments will be transmitted through its antenna to the Cassini spacecraft for relaying to Earth by Cassini's powerful radio transmitter.

HUYGENS-TO-CASSINI COMMUNICATION PROBLEM

Shortly after Cassini was launched, Boris Smeds, an electrical communications engineer, was examining the mission plans. He discovered a crippling communication problem in the microwave delivery of photographs and data from the Huygens probe. The significance of this discovery is described by James Oberg in the October 2004 issue of IEEE Spectrum [6]. The probe is fitted with cameras pointing down and sideways, plus instruments designed to unlock the atmosphere's chemical secrets, and a microphone that picks up wind speeds. Investigators speculated that there might be seas of liquid methane and ethane on Titan, so Huygens was designed to float after landing. Although its batteries will be nearly exhausted by the time it reaches Titan's surface, researchers hope Huygens will be able to make a few measurements of the physical composition of the landing site.

Transmitting Huygen's once-in-a-lifetime readings and observations back to Earth is a two-stage process. Huygens is too small to be equipped with a radio transmitter that is powerful enough to reach Earth, so a receiver on-board Cassini
GOING THROUGH A PHASE: Huygens’s telemetry is sent to Cassini using a technique known as binary phase-shift keying. In the simple two-phase example above, a stream of bits [top] is encoded onto a carrier wave [middle] by modulating the phase of the wave [bottom]. To represent a 1, the modulated signal is in phase with the unmodulated carrier wave, and to represent a 0, the modulated wave is 180 degrees out of phase with the unmodulated wave. Decoding the modulated signal requires precise timing, as the incoming wave is compared with an unmodulated wave at precise intervals to determine each bit’s phase and whether the bit is a 1 or a 0.

Fig. 1. “Going Through a Phase” in a Huygens’s FM telemetry transmission from Venus (page 30, October 2004 IEEE Spectrum)

will pick up Huygen’s transmissions, which are in binary phase-shift keying. Cassini’s powerful transmitter would relay these messages through a 4-meter main antenna to Earth where scientists await this data.

Smeds discovered that the Huygens probe, as it continues its descent to the Titan moon, would be unable to send data via the Cassini spacecraft, while Cassini continues orbiting Saturn. The problem that Smeds discovered was the phase shifts of the signals received at Cassini from Huygens. These shifts resulted from differences in velocity of the two vehicles. The effect of velocity differences on the phase-shift radio transmission of data is shown in Figure 1.

The Doppler shift in the pulses received at the fast-moving Cassini spacecraft from the slower moving Huygens transmitter, would have disabled Cassini’s computer, which then could not prepare clear messages for transmission to Earth.

The Cassini project management at first ignored Smeds’ comments, but he persisted, so a costly test was planned and conducted. In early 2000, a 34-meter antenna, like the one shown in Figure 2, was used to transmit to Cassini the test signal that revealed Cassini-Huygens’s communications problems. The test showed that Smeds was correct. The Cassini team then created response plans that centered on reducing the Doppler shift sufficiently to keep the data signal within the recognition range of the receiver. They accomplished this by altering the planned trajectory of the Cassini spacecraft. Consequently, Cassini will be much further from Titan when Huygens enters Titan’s atmosphere. As a result of this geometrical rearrangement, the spacecraft’s travel direction will be perpendicular to the Huygens-Cassini’s line of sight, rather than mostly along it. This simple change sidesteps the Doppler shift problem, as the radio waves will arrive perpendicular to Cassini’s direction of motion, and will be neither stretched nor compressed.

Interplanetary experts laboriously developed Cassini’s multi-year flight plan to maximize the number of visits to Saturn’s moons. There were to be 44 close flyby passes of Titan, close passes to smaller moons, and between 50 and 100 more distant passes of other moons. Reconstructing this celestial ballet from scratch would have been prohibitively expensive.

The spacecraft navigators therefore designed a trajectory in which Cassini initially enters a lower and faster orbit around Saturn, drops off Huygens, and then hits a specified point in space that coincides with a point on top of the previously planned path. There, Cassini fires its rocket engine again to get back on the original course. During this altered period it will make three orbits of Saturn instead of the originally planned two, but the extra rocket fuel needed to make the changes is available because Cassini’s navigation is so precise that a lot of fuel allocated to coarse corrections was not used.
Earth satellites, is available for a solar-powered airplane that
flies above Venus' clouds. The planet rotates slowly, so
continuous daylight over a surface exploration site will last for
50 earth-days before darkness begins. No solar power would
be available for airplane propulsion during the next 50
earth-days. The planet's cloud layers range from 45 km to 64
km above the planet's surface. Above the clouds the
atmosphere's pressure is around 0.1 bar and the temperature
around 35°C. This pressure corresponds to the pressure at an
altitude of 16 km (5250 feet) above Earth. Although high, this
altitude is well within the range of modern aircraft and flight
dynamics, so the aerodynamics within this regime are well
understood.

The slow rotation of Venus, approximately 13.4 km per
hour, presents a unique opportunity for a solar-powered
airplane that flies above the clouds. The airplane will remain
within the sunlit side of Venus during the entire 50-day
exploration mission. However, wind speeds can be high at this
altitude, so to remain over the surface exploration area, the
solar cell array on the wing surface will have to generate for the
propeller-driving motor enough power for overcoming the
highest wind speed. A rechargeable silver zinc battery is
required for regulating the output power from the solar array to
provide continuous power at a near constant voltage to the
main power bus in the aircraft.

A vehicle that explores the surface of Venus will need
power for operating its instruments and radio transmitter sends
scientific reports through the clouds to the airplane to relay
them to control headquarters on Earth. This vehicle needs
propulsion power for traveling through uncharted terrain to
photograph and collect samples for analysis. For example,
samples will need to be scraped from rocks on cliffs for
electrochemical analysis. The most practical energy source for
this surface exploring vehicle is a radioisotope heat source.
The heat-to-electricity conversion efficiency is limited
because it has to operate in a 460°C atmosphere.

Complex systems engineering analyses were required for
optimizing the design of the data-relaying airplane and
Venus-surface exploring vehicles. Authors of four papers
presented at the IIEC described these thorough analyses.

SOLAR-POWERED AIRPLANE
FOR FLYING OVER VENUS

The unique requirements of a solar-powered airplane that
flies above the clouds on Venus were described by Anthony
Colozza [7]. The airplane would perform the following
functions:

- Collect atmospheric properties over a region of
  the atmosphere.
- Direct the sampling of the atmosphere for its
  makeup, and search for biogenic gasses.
- Map the available portions of the planet's
  magnetic field.

Fig. 2. Desert Dish at NASA's Deep Space Network
facility at Goldstone in California's Mojave Desert
(From James Oberg's "Titan Calling,"
page 31, October 2004 IEEE Spectrum)

The 705-pound Huygens lander was separated from Cassini
on December 24, 2001, and was scheduled to touch Titan
January 14, 2005. The original designers of the Huygens
lander faced tremendous engineering challenges because it had
to venture into unknown conditions of Titan's atmosphere and
surface.

Solving the Doppler-shift problem required changing
Cassini's flight plan and delaying its Saturn arrival from
December 24, 2004 to January 2005. It reduced Cassini's flight
duration in orbiting Saturn and also reduced photographing of
all Saturn's 30 moons.

UNIQUE PROBLEMS IN VENUS EXPLORATION

Venus is a planet about the same size as Earth, but in other
respects its environment is very challenging to the designer of
vehicles that will explore it. Sun-orbiting satellites such as
Magellan and spacecraft flybys, were the only means of
exploring this planet. For example, Venus is close to the sun so
its sunlight, which has 1.9 times the intensity of sunlight on
Fig. 3. Solar-powered airplane will fly above the clouds of Venus to relay data from the surface stations to researchers on Earth.

Fig. 4. The heat energy for running the Stirling engine comes from the radioisotope package on top of its cylinder. Its crankcase is coupled to the heat pump that cools the electronics in the probe that explores the surface of Venus.

- Collect and transmit visual imagery.
- Relay commands to surface vehicles and landers, and relay data back to Earth headquarters.

Colozza described how he and his associates evaluated the options for the airplane in their systems engineering analysis at Analex Corporation, and he described the adopted airplane design. For example, the cloud layer on Venus extends from 45...
km to 64 km above the planet's surface. At the top of the cloud layer the pressure is around 0.1 bar. This atmospheric pressure corresponds to that at an altitude of 16 km (52,500 feet) above the surface on Earth. The slow rotation of Venus at this altitude corresponds to 13.4 km/hour, so the solar-powered airplane can remain in operation throughout a 50-Earth-day mission without needing to store propulsion energy in batteries. However, a rechargeable battery is needed for powering aircraft control and communication equipment.

The solar array must at all times generate the power needed to produce the required propulsion thrust, and the operational power for the communications system, flight control, and payload. The required solar array output depends on the latitude-location of the airplane at the time of the year, and any atmospheric attenuation due to clouds or dust. A solar cell efficiency of 18% at 20°C, a fill factor of 80%, and a power conditioning efficiency of 95% were adopted in the solar array design. The adopted solar-powered airplane design for Venus use is shown in Figure 3.

POWER FOR THE RESEARCH STATION ON THE HOT CLOUD-COVERED VENUS SURFACE

A scientific-data gathering planetary probe is to be delivered on the surface of Venus. Operating a probe on the cloud-covered surface of Venus requires a lightweight and reliable energy source. It must be capable of operating in the 460°C temperature in the planet's dense atmosphere that is mostly carbon dioxide. Not practical energy sources are fuel burning engines that need oxygen, nor are batteries that need charging power. Kenneth D. Mellott described a program at NASA Glenn Research Center which had, by December 2003, adopted the conceptual design of a helium-charged kinematic Sterling converter powered by General Purpose Heat Source (GPHS) modules [8]. The kinematic Sterling power converter's cross-section is configured to also drive an electronics sensor's cooler, in addition to a generator for electric power, as shown in Figure 4. Its energy comes from decaying radioisotopes in the GPHS.

The Sterling converter uses the heat energy from the GPHS to drive a generator that delivers 100 watts of electric power and also delivers 400 watts of mechanical power for driving the heat pump that cools scientific instruments and electronic equipment in the probe [9]. The Sterling converter's total efficiency is 23.4%, even though it has to reject its waste heat into a 500°C environment.

ADAPTING A STIRLING-CYCLE ENGINE FOR POWERING SPACE PROBES

Rev. Robert Stirling was only one year out of divinity school in 1816 when he invented the Stirling engine which is one of the heat-to-mechanical-power converters limited in efficiency by the Carnot cycle. Thirty years later, Sadi Carnot derived the equation that established the efficiency limit of heat engines; thus Stirling engines powered a few warships and living room fans in the 1920s. Simpler steam engines have powered the big ships and spark-ignition Otto-cycle engines are powering cars even though they are limited in efficiency. Today, the Stirling cycle engine is a viable candidate for powering space exploration probes in regions where strong sunlight is not available.

The operation of a Stirling engine is explained in Figure 5. As piston p-2 raises, it compresses cold gas. The power stroke follows in which both pistons travel downward together, pushed by compressed gas that is being heated by the "regenerator" and further heated by the "heater." At the end of the power stroke, piston p-1 moves upward pushing the
expanded gas through the “regenerator” where it deposits high-temperature heat, before being cooled by the “cooler.” The cycle starts again with piston p-2 recompressing the gas for the next power stroke. The crankshaft drives each piston with an individual arm to get the required piston motions.

With today’s technology, the Stirling engine performance for spacecraft is being achieved with a lightweight design that achieves high efficiency with long lifetimes. The pistons are spring disks on a shaft that oscillates back and forth at a distance of a few hundredths of an inch. Passages, through which the gas flows, are permanently sealed from the outside environment. On the alternator end of the oscillating shaft are magnets that oscillate within alternator coils, converting the energy delivered by the oscillating shaft into high frequency electric power. This Stirling engine is started by oscillating the shaft with a high frequency current delivered to the stator of the linear alternator. The resulting Carnot-cycle generator has no wearing parts and can last as long as its radioisotope heat source delivers heat energy. This can take many years, so a long lifetime power source is available for deep space exploration.

MARS EXPLORATIONS SET HISTORIC RECORD

Unmanned Mars rovers, Spirit and Opportunity, successfully landed on Mars and explored its surface during 2004. They sent back to Earth scientists—a huge volume of data that was so important that the November 2004 issue of Science magazine published 34 pages of articles describing these data and the resulting analyses. New insights into the history of Mars and its present environment were developed, making 2004 one of the greatest in astronomical accomplishments. This achievement was made possible because the aerospace industry developed lightweight lithium-ion batteries that can survive thousands of charge/discharge cycles and do not need liquid electrolytes.

The first Mars exploration rover was Spirit, which was launched June 20, 2003, and, after traveling over 302 million miles, landed on Mars. It then spent more than a week unfolding its solar panels, setting up its sensing packages, and checking its surroundings. On January 15, 2004 it drove off of its platform and began exploration on the surface of Mars.

Opportunity, the second rover, was launched July 7, 2003. It reached Mars January 24, 2004 and began exploration. The required high reliability of the rovers was confirmed by tests in simulated environments of space travel, as well as travel on Mars-type areas where roads and bridges are not available. The design features of these successful planet exploration rovers were described in six papers presented at the 2004 IECEC.

BATTERY REQUIREMENTS FOR A MARS MISSION

Delivering and operating a Mars rover requires two kinds of batteries, which were described by B.V. Ratnakumar, from the Jet Propulsion Laboratory, where the batteries were tested [10].

On each rover the primary energy source is a deployable solar array that has triple-junction GaInP/GaAs solar cells. A rover carries two parallel lithium-ion batteries, each with eight 10-ampere-hour cells connected in series. Each battery was designed to deliver 24 to 36 volts whenever battery power is required. The operating temperature range of these batteries is -30°C to +40°C. During spacecraft launch, 200 watt-hours (Wh) of energy had to be delivered, and during the cruise to Mars 160 Wh was needed for supporting the spacecraft’s trajectory control maneuvers. During a required life of 300 charge/discharge cycles in Mars surface operations, the per-cycle energy required was 283 Wh.

Landing a rover from a Mars-orbiting spacecraft required electric power during critical entry, descent, and landing maneuvers of the Lander, which was designed only to carry the rover. For this requirement, lithium-sulfur-dioxide batteries were carried in the pedals of the Lander.

The success of the very costly Mars exploration program depended on reliable batteries that supply power for at least 90 days of travel on the planet. They had to operate in a -20°C to +40°C temperature range, withstand long storage periods during interplanetary cruise, operate in an inverted position, and support high currents during pyro-firing events. Meeting the unique requirements of high power and long life in terms of charge/discharge cycles on the surface of Mars was confirmed by tests described by M. Smart [11]. Lithium-ion cells for meeting these requirements were developed and fabricated by Yardney Technical Products, Inc., and tested at the Jet Propulsion Laboratory. The cells met all requirements in tests and in performance on Mars.

ROVER ACHIEVEMENTS ON MARS

NASA representatives reported that, for the first time in history, two mobile robots were exploring another planet simultaneously. Spirit’s initial task was to explore clues in rocks and soil around the landing site’s environment and determine if it had ever been watery and suitable for sustaining life. Opportunity landed halfway around the planet from its twin at a site within an outcropping of mineral called gray hematite, which forms in the presence of water.

Both rovers successfully completed their 3-month primary missions and their first mission extensions. They began second extensions of their missions October 1, 2004. Jim Erickson, the rover project manager at NASA’s Jet Propulsion Laboratory, observed: “Both Spirit and Opportunity have only minor problems, and there is no way of knowing how much longer they will keep operating. However, we are optimistic about their conditions, and we have just been given a new lease on life for them—a six-month extended mission. These machines are already past their design life; while they are healthy we’ll keep them working as hard as possible.”

Since their deployment, the rovers have sent more than 50,000 images that provide a treasury of scientific information on the “Red Planet.” Incidentally, the planet’s “redness” is not produced by high temperature at its south pole. There, the “snow” is frozen carbon dioxide!
MARS WEATHER IS UNIQUE AND REQUIRES HUMAN EXPLORERS TO BE SPECIALLY EQUIPPED

Scientists and engineers are preparing to send humans to Mars in 2050. Spacecraft orbiting Mars, as well as the rovers that are exploring the planet’s surface features, are delivering data that will be important in the design of surface facilities and tools for the explorers. For example, François Forget analyzed data supplied by the NASA Mars Global Surveyor and Mars Odyssey missions, and most recently by the European Space Agency’s Mars Express spacecraft [12].

The key data came from the gamma-ray spectrometer on the Mars Odyssey. Its photograph (from 1500 km altitude) showed that in the spring, the south pole of Mars is still covered by light-reflecting “ice.” Spectrograms showed that this “ice” is frozen carbon dioxide (CO₂). The brightest region at the pole is the perennial ice cap, which remains covered by CO₂ all year. Part of this region, the “cryptic region,” which appears dark like bare ground, could be a region covered with transparent ice. Other areas are puzzling in appearance.

The gamma-ray spectrometer on the Mars Odyssey spacecraft measured an enhancement of atmospheric argon over southern high latitudes during autumn, followed by dissipation during winter and spring [13]. Argon does not freeze at temperatures normal for the southern winter (around 145 kelvin), so it is left in the atmosphere where it is enriched relative to CO₂ as the southern seasonal gap of CO₂ frost accumulates. Calculations of seasonal transport of argon, into and out of the southern high latitudes, suggests meridional (north-south) mixing throughout southern winter and spring.

FUTURE SOLAR SYSTEM EXPLORATION WITH NEW TOOLS

The new United States 2005 budget for NASA contains funds for developing vehicles with which the environments on all solar system planets can be effectively explored. For example, Uranus is so far away that the only practical way a spacecraft can get there is to loop closely around the sun to gain the acceleration needed for travel to Uranus. An important recent development is the ion propulsion engine. Existing spacecraft were accelerated from ground into Earth orbit and further-out destinations by launchers that were propelled by huge fuel-burning rockets that consumed fuel and oxygen from tanks on the launcher. The men who landed on the Earth’s Moon had to be accompanied by a rocket engine plus fuel and oxidizer for this engine which subsequently lifted them off the Moon. This engine then accelerated their vehicle to the velocity needed for rendezvousing with the moon-orbiting spacecraft, which they boarded for their return to Earth.

A conventionally-powered spacecraft carrying human explorers to Mars would need to be equipped with rocket engines, plus the fuel and oxidizer consumed in accelerating the spacecraft out of Earth’s gravity field, and months later
decelerating to a Mars-orbiting velocity. The spacecraft would also need to carry a rocket-propelled Mars Lander, plus the fuel it consumes in decelerating to the Mars-landing velocity. More fuel and oxidizer would be required later for accelerating back to Earth. The spacecraft and the Mars Lander would also need to carry breathing oxygen, drinking water, and food to be consumed by the crew during the round trip that begins with the departure from Earth and ends with the crew’s return to Earth.

Rarely discussed is the efficiency of the rocket engine that delivers the force to overcome the force of gravity on its cargo. The engine accelerates this cargo plus engine mass, and the fuel and oxidizer tanks. Part of the fuel energy accelerates the spacecraft; the rest departs in the exhaust flame and in the exhaust clouds left behind the accelerating vehicle.

HIGH-EFFICIENCY ION ENGINE FOR SPACECRAFT PROPULSION

Now-available ion-based propulsion technology is already making rocket propulsion obsolete for space travel. Ions can be accelerated to nearly the speed of light photons with electromagnetic energy. The force that an accelerated-ion applies to the vehicle from which it departs approaches infinity as the ion’s departure speed approaches that of light. In our automobiles, the energy for charging the storage battery that starts the engine is carried into the gasoline tank. In a planet-to-planet cruising spacecraft, the ion-propulsion energy need not be hauled into Earth orbit by rocket-powered boosters. This energy is available in the sunlight through which the spacecraft travels.

The mass of ions needed to propel a spacecraft during a round trip to Mars is trivial compared to the mass of fuel and oxidizer required by a rocket engine. The power for accelerating the ions can be supplied from direct or concentrated sunlight converted to electric power with solar cells. Currently, solar cells for space power cost more than $300 per watt in a solar array that weighs more than one kg per square meter. This array delivers around 65 watts per kg. R. Raffaiele reported at IECEC an achievable power density of 1000 watts per kilogram of solar array on which are mounted flexible thin-film triple-junction copper-indium-gallium-diselenide solar cells [14]. For converting sunlight into electric power, efficiencies up to 40% have been measured.

These developments open new opportunities for human missions to other planets; one author showed how frequently-moving explorers on Mars' surface could be supplied night-time power generated on their orbiting spacecraft. This power would be transmitted through a microwave beam!

REFERENCES

The references identified by an IECEC number are published in the “Proceedings of the 2nd International Energy Conversion Engineering Conference.” This conference was held August 16-19, 2004, at the Rhode Island Convention Center, Providence, Rhode Island, USA. These Proceedings can be purchased from the American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, USA.

Radar Imaging and its Operational Use in the Military Field was held at the Istituto per le Tele comunicazioni e l'Eletronica, by G. Vallauri, Mariteleradar, Livorno (Italy), on 24-25 November 2004.

Requirements for Non Co-operative Target Recognition (NCTR) are rapidly emerging for applications in military surveillance and defense systems. In particular, target imaging by means of radar is absolutely essential to minimize: fratricide, attacking neutrals or civilian targets, and hostile targets penetrating defenses. Other developments are: asymmetric warfare, unconventional adversarial approaches, stealthy platforms, and disinformation. Target recognition is needed to improve: threat assessment, identification of friend or foe, optimal weapon use, reaction time, evasive action, control of battle area, situational awareness, provision of local air picture, information superiority, and kill assessment or debris characterisation. Thus, radar is key sensor to achieve NCTR because: of its long range capability, it does not depend on target emissions, it has all weather capability, it is technology rapidly developing.

Mariteleradar (mariteleradar@marina.difesa.it), a research institute of Italian Navy, has recently organised and held an unclassified workshop on "Radar Imaging and Its Operational Use in the Military Field," 24-25 November 2004. Over 140 attended the workshop; 30% from military institutions, 50% from national industries, and the remaining 20% from universities. After an introduction on Mariteleradar is a short summary of the workshop.

MARITELERADAR

Mariteleradar is a Naval Institute established in 1916 by the founder and first Director G. Vallauri; the first projects were related to radiotelegraphy and long distance communications. During the 1930s work was carried out on radiotelemetry and microwaves, culminating in 1936, when for the first time in Italy experiments involving radar in the real operative scenario were performed. During the Second World War, the Institute worked on communications and radars to support the requirements of the Italian Navy fleet. In the late 1940s, after the Second World War, the Institute was reorganised and during the 1950s activity dealing with electronic warfare started. In the 1960s, the activity was focused on testing satellite telecommunications. In the middle 1970s, the Institute worked on infrared technology, EMC (Electro Magnetic Compatibility), and HERO (Hazard of Electromagnetic Radiation to Ordnance). Nowadays, as a Naval Research Institute, Mariteleradar seeks to increase the effectiveness of electronic systems (radar, telecommunications, etc.) installed on naval vessels. mainly via:

- Technical and scientific studies on new technologies for possible ship-board application.
- Compilation of technical requirements and/or specifications for installation and certification of new equipment.
- Assessment of studies and projects for new equipments.
- Research in cooperation with inter-service organizations or industry for the development of new equipment and systems in areas of mutual interest. Today, the Institute has 80 employees and it is based on seven departments: antenna, radar, electronic and electromagnetic, optoelectronic, telecommunications, radar cross section diagnosis and electronic warfare. A photo of the naval institute is on the next page.

WORKSHOP, NOVEMBER 24-25, 2004

A number of Italian MoD departments (Marista, Segredifesa, Navispelog, Telefide) cooperated with Mariteleradar in the organization of the workshop.

The workshop aimed to study the strategic, technical, and operational aspects of radar images in the naval, air, and land fields.

After the welcome introduction by the Italian Navy representative and the Director of Mariteleradar, twenty-five presentations were given by authors of Italian Navy Departments (Telefide, Mariteleradar), industry (AMS, Agilent Technologies, Eleltronica, Fincantieri, Galileo Avionica, IDS, Oto Melara), and universities (Rome “La Sapienza” and Rome “Tor Vergata,” Pisa, Florence).

During the workshop the following topics were illustrated:

- Imaging radars and experimental results,
- Radar images of targets,
- Radar imaging for battlefield applications,
- NCTR technology in tracking and naval radar,
- Data acquisition techniques,
- Modelling & simulation,
- Waveform coding,
- Real-time and adaptive processing techniques,
Mariteleradar site in Livorno, Italy

- Time-frequency signal analysis for JEM (Jet Engine Modulation) and HERM (Helicopter Rotor Modulation),
- Feature extraction,
- Exploitation of radar images to improve target tracking in airport surface movement application,
- Multi-frequency and multi-pulse polarimetric radars,
- Dynamic 1D, 2D, 3D radar images,
- SAR (Synthetic Aperture Radar),
- Radar images as diagnostic tools,
- Naval, air, and land (low RCS Cross Section),
- Use of radar imaging to estimate and control the reflectivity of ship components during the ship design,
- Use of RAM (Radar Absorbing Materials): synthesis techniques, and application in RCS control,
- ECM to radar imaging,

The workshop audience

- EMC (Electro Magnetic Compatibility): numerical simulation tools.

The workshop was successfully attended and attracted a number of interactions with the audience. A photo of the audience is above.

G. Abbatangelo (Mariteleradar),
A. Farina (AMS SpA)
1st International Waveform Diversity & Design Conference

A huge milestone in the ever-budding field of Waveform Diversity took place November 8 - 10, 2004. Although the development of Waveform Diversity concepts began well over 20 years ago, it wasn’t until 2004 that engineers and scientists from all over the globe gathered to share their innovative ideas and concepts in Waveform Diversity.

The idea of choosing the Caledonian Hilton in Edinburgh, UK was born two years prior when several participants attended a Ground Penetrating Radar Conference in that city. Up until that point in time, we had been looking for the perfect venue to foster the greatest participation from the widest variety of countries, thus bringing together the best collection of engineering talent to learn, share, and experience the beginning of growth and recognition for an exciting technology field, namely Waveform Diversity.

The 1st International Conference was a huge success with more than 125 participants from 17 countries around the world. We are also proud to announce that there were several excellent student papers, representing new young talent, who participated in this historic event. We strongly encourage future student involvement.

Dr. Vincent Amuso, Rochester Institute of Technology, and Dr. Chris Baker, University College London, were the Co-Chairs of this 1st International Waveform Diversity & Design Conference. The 3-day program began with a day of tutorials. In the morning, Dr. Tapan Sarkar, Syracuse University, delivered a riveting lecture on A Maxwellian Approach to Adaptive Antennas, while down the hall, Dr. Byron Keel, Georgia Tech, discussed Introduction to Radar Pulse Compression Waveforms with Applications. The two afternoon sessions were Dr. Clive Alabaster and Evan Hughes teaching on Radar Waveforms, and Lajos Hanzo, who presented an in-depth lecture on Interference-Free Wireless communications: The myth and potential of spreading codes exhibiting an interference-free window.

The evening of Day 1 held a poster session and a social event held in the Castle Suite Lounge.

The formal presentations began on Day 2 with a keynote presentation, Knowledge-Aided Adaptive Waveform Design: The Next Wave in Adaptive Radar from Dr. Joe Guerci, DARPA, (who recently received the honor of IEEE Fellow for his pioneering work in adaptive radar). Day 3 began with Purdue University’s Dr. Michael Zoltowski who presented Waveform Diversity Aspects Pertaining to Communications. The last two days of the program were filled with 24 oral paper presentations and 40 poster presentations in the session areas of: Waveform (General), Radar, Communications, Phenomenology, and Other Sensors.

Day 2 ended with a Banquet in the Castle Suite Ballroom of the Caledonian Hilton. Dr. Amuso presented an award to Mrs. Patty Woodard acknowledging her efforts in coordinating this 1st International Waveform Diversity & Design Conference. Dr. Lars Falk, Swedish Defence Research Agency – FOI, rounded out the evening with an interesting talk on P.M. Woodard’s life, complete with personal photographs and anecdotes. Dr. Woodard is the author of the 1953 text entitled: Probability and Information Theory with Application to Radar, the first reference in this important technology area.

The entire selection of papers was disseminated on CD-ROM to all attendees. In addition to the CD-Rom, a book of select and invited papers is currently being developed. The completed book will be sent to all attendees. Work is also being accomplished on a photograph collection from the conference and areas toured during the trip to Scotland. We thank all who submitted photographs and we expect the finished product to be a wonderful memento of this conference.

Plans are currently underway for the 2nd International Waveform Diversity & Design Conference to be held 22 - 27 January 2006 at the Radisson Resort in Kauai, Hawaii. Dr. Vincent Amuso will be the Chair with Dr. Ravi Adve, Toronto University, as the Co-Chair. The technical program will be co-chaired by Dr. Eric Mokole, Naval Research Laboratory, and Dr. Chris Baker.

We would like to thank the organizing committee, the staff of the Caledonian Hilton, and the attendees for making the 1st International Waveform Diversity & Design Conference such a huge success.

Patty Woodard
Mike Wickes
Second International Workshop on
Ultrawideband and Ultrashort Impulse Signals (UWBUSIS’04)

The Second International Workshop on Ultrawideband and Ultrashort Impulse Signals (UWBUSIS’04) was held September 19-22, 2004 in Sevastopol, Ukraine.

Sevastopol is the largest non-freezing commercial and fishing Black Sea port of Ukraine and one of the major industrial, scientific, and cultural centers of the country and Eastern Europe in general. Located on the site of the ancient Greek colony, Chersonesos, the city itself and the Black Sea Fleet, based in Sevastopol, have occupied a prominent place in Russian and Soviet history. Advantageous geographical situation of the city, its favorable natural climatic conditions, as well as the availability of highly developed industrial, scientific, and human resources make the Sevastopol region one of the most promising international tourist, commercial, and industrial centers of Europe.

The place of carrying out of the Workshop had been chose sanatorium “Builder” which is located at coast near to ancient city Chersonesos. The schedule of the Workshop gave enough time for scientific discussions, for acquaintance to city, and rest at fresh sea air. Now Chersonesos is museum – reserve in territory of city, which had been founded in 422 B.C. by the ancient Greeks and during 18 centuries had a great importance in the history of Greece, Rome, Byzantium, Rus.

The 2004 Second UWBUSIS Workshop was dedicated to 200th Anniversary of V.N. Karazin Kharkov National University (one of the oldest and most recognized universities of the Eastern Europe). The Workshop provides the international forum for discussing recent advances in the theory investigations, computer modeling, experiments, technology, and applications of the ultrawideband and ultrashort impulse signals.

The V.N. Karazin Kharkov National University, IEEE AP/C/EMC/SP Kharkiv Joint Chapter of Ukraine Section, Ukrainian URSI Committee, Radio Astronomy Institute of NASU, Institute of Radio Physics and Electronics of NASU, Sevastopol National Technical University, and Kharkiv National University of Radio Electronics were the main organizers of the Workshop. The Workshop Chairman was Prof. Nicolay Kolchigin, the Head of Theoretical Radio Physics Department of the Kharkov National University. UWBUSIS’04 Honorary Chairman was Prof. Yakov Shifrin, Kharkiv National University of Radio Electronics. The European Office of Aerospace Research and Development of the USAF, AP-S IEEE, the State Scientific Research Institute of Radar Systems, “Kvant-radars” (Kiev), Radio Astronomy Institute of NASU, Ukrainian Science Academy SMF “Institute of automatic system” were sponsors of the Workshop.

Three plenary sessions, sessions of six sections, and also poster session were held at the Workshop. The scientific committee selected 97 papers, which were divided into several technical sections:

Section 1: Theoretical Investigations, Numerical Simulations;
Section 2: Generation, Radiation, Receiving;
Section 3: Applications (Communication, Radar, GPR, Medicine);
Section 4: Electromagnetic Compatibility;
Section 5: Electromagnetic Metrology Propagation and Scattering in Natural and Artificial Materials

Several invited review papers on the most significant achievements and scientific problems in the field of application of UWB signals in radars, communications, and acoustics have been presented at plenary sessions. Invited lecturers reviewed at these areas: Prof. Carl E. Baum (USA), Prof. Ali R. Baghaji-Wadji (Austria), David V. Giri (USA), Prof. A.L. Gutman (USA), Prof. Igor J. Imoreev (Russia), Prof. A.S. Illinski (Russia), Prof. A.F. Kardo-Sysoev (Russia), Prof. Victor F. Kravchenko (Russia), Dr. Genadiy P. Pochanin (Ukraine), Prof. Yakov D. Shirman (Ukraine), Prof. Felix J. Yanovsky (Ukraine).

The Workshop attracted more than 100 participants from USA, Austria, the Netherlands, Turkey, Ireland, Lithuania, China, Denmark, Mexico, Russia, and Ukraine, from which practically half are young scientists.

THE MOST INTERESTING SESSION PAPERS

Levitas, B. and Matuzas, J.,
UWB Radar High Resolution ISAR Imaging

Butrym, A. and Pivnenko, S.,
CPW To CPS Transition for Feeding UWB Antennas
Sevastopol, Monument to Admiral Nakhimov

The opening of the UWBUSIS’04 Workshop: (l to r) C.E. Baum, A. Yu Butrym, N.N. Kolchigin, Ya. S. Shifrin

Demonstration of the VTY-2 ground penetrating radar (V.P. Prokhorenko, V.E. Ivashchuk and S.V. Korsun, Ukraine) at the Applications Section

UWBUSIS’04 Participants

Presentation by Professor Carl E. Baum

Poster Session at the Beach
Immure equal, I.J.,
Ultra-Wideband Systems, Features, and Ways of Development

Kravchenko, V.F. and Smirnov, D.V.,
Wideband Signals Processing with Atomic Functions in Antenna Systems

Giri, D.V.,
Radiation of Impulse-Like Waveforms with Illustrative Applications

Immure, I.J. and Ziganshin, E.G.,
Ultra-Wideband Radar

Prokhorenko, V.P., Ivashchuk, V.E. and Korsun, S.V.,
The VIY-2 Ground Penetrating Radar

Immure, I.J. and Samkov, S.V.,
Ultra-Wideband Radar for Remote Detection and Measurement of Parameters of the Moving Objects on Small Range

Kipke, M.V., Okhten, N.A., Nikolayev, V.A., and Badeykin, A.V.,
Application of the Audio Interface for Ground Penetrating Radar Data Representation and Interpretation

Pavlov, S.N. and Samkov, S.V.,
Algorithm of Signal Processing in Ultra-Wideband Radar Designed for Remote Measuring Parameters of Patient’s Cardiac Activity

Immure, I.J. and Zaitsev, A.V.,
The Scope of Application of Reciprocity Principle in the Theory of Antennas at Radiation and Reception of Ultra-Wideband Signals

Samkov, S.V.,
Signal Processing in UWB Radars of Small Distance

CULTURAL PROGRAM AND BANQUET

At the Workshop there was also a cultural program. The schedule of the Workshop left a free time after dinner. At this time, participants have taken part in a tour in museum – reserve Chersonese, have visited diorama “Storm of Sapun Mountain on May 7, 1944,” have made a water trip on bays of Sevastopol, and also had a rest on the Solar Beach of the city of Sevastopol. Remarkable weather has allowed leading also the poster session on fresh air near the sea, which has considerably brightened up discussions and has positively affected mood of participants.

To strengthening of contacts, continuation of scientific discussions, and also opportunities of “relaxation” of participants appreciably promoted Welcome Party and Banquet organized in the evening on September 19 and 21.

The Workshop has shown that interest to ultra-wideband systems as in the countries of the former Union, and in abroad very great. Similar Workshops allow not only to get acquainted and expand scientific communications, but also to discuss already received results, to determine a circle of problems on the future, and to make possible introduction of scientific ideas in the industry.

Igor J. Immure

Nikolay, N. Kolchigin
FROM THE EDITOR-IN-CHIEF

What's Coming? . . . Based on Past Actions . . . Now it is Your Turn to Ask

The responses to Tutorial I, sent to all members, subscribers, and IEEE Student Branches with our January 2004 issue was so very well-received that Tutorial II is already in its final stages. It will be in your hands in the next month or two; the tutorials in this issue will be: Distributed Power Systems, Energy Constrained Network Systems, Probabilistic Data Association Techniques, Nonlinear Filters, and Cross-Track SAR Interferometry. We will distribute copies of Tutorial II to each and every IEEE Student Branch (as we did with Tutorial I) to make them aware of this new “lode” of easily (well, readily) understood essays on various technical topics, and of the type of publications and areas that are of interest to this Society.

Additional copies of Tutorial II will be available to our Lecturers, Chapter Chairs, Conferences, and our Educational Activities area, as are (still) copies of Tutorial I. All you have to do is tell us: How many, where, and when. (Contact Dave Dobson, data inside rear cover.) Preliminary plans have already been prepared for Tutorial III. to appear in early 2006. Your thoughts and comments on this series are welcomed; send them to Peter Willett at: willett@engr.uconn.edu.

– Evelyn Hirt

Congratulations!

We extend our congratulations to these new Senior Members (as of January 2005).

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<td>Graham W. Pulford</td>
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IEEE Dennis J. Picard Medal for Radar Technologies & Applications

Sponsored by the 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. Recipient selection is administered by the IEEE Awards Board through its Medals Council. A Picard Medal Evaluation Committee, consisting of representatives from the Aerospace and Electronics Systems Society, 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 Ultrasonics, 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/sums/picard.htm.

Nomination Deadline: 1 July 2005
# Distinguished Lecturers Program

James R. Huddle, Chairman

All AESS Chapters and IEEE Sections are encouraged to take advantage of the AESS Distinguished Lecturers Program for their regular or special meetings. We have selected an outstanding list of speakers who are experts in their fields. The AES Society will cover up to $500 of the speaker’s expenses for travel in North America, with any remaining amount normally covered by the 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 AES, 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.

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<th>Title</th>
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<td>(261) 4693 F</td>
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<td>(310) 393-1261 F</td>
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<td><a href="mailto:ybi@engr.ucconn.edu">ybi@engr.ucconn.edu</a></td>
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<td><a href="mailto:itzbar@technion.ac.il">itzbar@technion.ac.il</a></td>
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2006 IEEE Radar Conference

Radar – Our Sight into a Spectrum of Information

April 24-27, 2006
Turning Stone Resort and Casino
Verona, NY, USA

Sponsored by:
Aerospace & Electronics Systems Society of the IEEE
Mohawk Valley Section of the IEEE
Syracuse Section of the IEEE

Our conference theme: Radar – Our Sight into a Spectrum of Information, describes radio detection and ranging as a succinct functional description of the first radar systems, which extended our sense of awareness by informing us “a target is out there and here is its location” – Information

Radar – Our Sight into a Spectrum of Information highlights the connection between radar and information. This theme provides an interesting perspective to consider the increasingly wider spectrum of target and environmental information that has evolved, far beyond the original capability to detect the target and determine its range, from innovative radar research, technology, and component development, for both military and civilian applications.

This innovation is evident today in the development of foliage penetration (FOPEN) radars to provide MTI and SAR capabilities against targets obscured by vegetation or camouflage, in development of ground penetrating radars, in improvements to high range resolution and SAR systems, in development of advanced airborne surveillance systems for denser civilian and military environments, and in ongoing research into many areas, including automatic target recognition, radar data exploitation and fusion, sensor management, space-time adaptive processing (STAP), knowledge-aided sensor signal processing and expert reasoning (KASSPER) architecture, multi-static radars and radar networks, phenomenology, and much more.

For additional information, contact:
Scott Stumpf
Publicity Chair, Radar Conference 2006
Institute of Electrical and Electronic Engineers
Onondaga County Government
srstumpf@ieee.org
(315) 637-5567
IEEE AEROSPACE & ELECTRONIC SYSTEMS SOCIETY ORGANIZATION

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USUIRCA 2005
First International Conference on
Ultrawideband Signals and Ultrashort Impulses in Radar, Communications, and Acoustics
September 27-29, 2005, Suzdal, RUSSIA

CALL FOR PAPERS

Technical Program
The Technical Program Committee (TPC) “Ultrawideband Signals and Ultrashort Impulses in Radar, Communications, and Acoustics” (USUIRCA 2005) announces the first USUIRCA conference to be held in September 2005 on the base of the Vladimir State University in Suzdal (this ancient city is a part of the famous “Golden Ring of Russia”). The TPC invites the international community to present and discuss state-of-the-art developments, advances, and innovations in the areas of generation, radiation, propagation, and processing of ultrawideband signals and ultrashort impulses in natural media.

Paper Submissions
Authors are invited to submit contributions in the following areas:
- Generation and radiation of ultrawideband signals and ultrashort impulses;
- Radiation, acceptance, and processing of ultrawideband signals and ultrashort impulses;
- Propagation of ultrawideband signals and ultrashort impulses in nature media;
- Remote sensing of nature media with ultrawideband signals and ultrashort impulses;
- Mathematical modeling of physical processes of ultrawideband signals and ultrashort impulses.

Working language of the Conference is English. Prospective authors must submit to the TPC no more than 5-page Full paper manuscript for reviewing (via E-mail). The accepted papers will be published in the Conference Proceedings and will be available at the Conference. Upon a decision of the TPC, selected presented papers will be published in English in the special issues of the International Journals of Electromagnetic Waves and Electronic Systems and Achievements in Modern Radio Electronics published by Publishing House “Radiotehnika”, Moscow.

Organizers: IEEE Russia Section, A.S. Popov Society (RNTORES), Institute of Radio Engineering and Electronics RAS, Bauman Moscow State Technical University, Moscow Institute of Physics and Technology (State University), Moscow Aviation Institute (State Technical University), Joint-Stock Company of Radio Building “Vega”.

Instructions for Electronic Submissions of the 5-page Papers
Paper size: A4 (210x297 mm). pages are not numbered. Font type: Times Roman. Title: 14 pt size uppercase bold centered. Authors’ names: 12 pt size lowercase centered 2 lines below the title. Affiliations: 10 pt size lowercase centered 1 line below the authors’ names. Headings: 12 pt size, uppercase, centered. Text: formatted one-column, single-spaced, 11 pt size, double line space between paragraphs. Margins: Top, Right, and Left – 25 mm, Bottom – 30 mm. Figures and tables: centered. References: listed 2 lines below the text; format:

REFERENCES
[1] Author, N.N., Title of Book, Place: Publisher, year.

Address for electronic submissions: nto.popov@mtu-net.ru
Acceptable file formats: MS_Word.doc (7.0 or higher) only

Payment Information
We draw your attention to the fact that some banks take a special fee for money transaction. That is why you should pay in such a way that the amount of money that would arrive in our Organizing Committee should be equal to either US$250 (before June 15, 2005) or US$300 (after June 15, 2005).

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