Modeling and Simulation Support for ICRF Heating of Fusion Plasmas
SAIC Proposal 1-624-71-910-02
March 15, 1990
Annual Report

1990

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An Employee-Owned Company

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Other SAIC Offices: Albuquerque, Boston, Colorado Springs, Dayton, Huntsville, Las Vegas, Los Angeles, Oak Ridge, Orlando, Palo Alto, San Diego, Seattle, and Tucson
2. RECENT RESULTS AND EXPERIENCE IN ICRF ANTENNA MODELING

2.1 University of Wisconsin Collaboration

Recent experimental, theoretical and computational results have shown the need and usefulness of a combined approach to the design, analysis and evaluation of ICH antenna configurations. The work at the University of Wisconsin (UW) in particular has shown that much needed information on the vacuum operation of ICH antennas can be obtained by a modest experimental and computational effort. For example, measurements taken with a model experiment, backed up by benchmarked computational studies, have pointed out a possible source of unfavorable coupling to Ion Bernstein Waves due to incorrect geometry of the antenna sidewalls and endcaps. The codes can now be used to find new configurations which eliminate these unwanted effects in minimum time and cost before the more expensive experiments are carried out. The results of the UW antenna simulation have proven that 3-D modeling and evaluation of such complex structures are not only feasible but can be carried out successfully and yield information which is either not possible to obtain experimentally or may provide previously unknown insights and understanding of the devices. The point here is that both experiment and computation should be carried out in an iterative fashion.

These model experiments at UW and SAIC simulations have shown dramatically the potential for positive impact upon the ICRF program. For example, the ICRF antenna currently planned for the UW tokamak was experimentally investigated for its vacuum performance characteristics on a laboratory test stand. The ARGUS simulator successfully modeled the test antenna plus test stand geometry, Figures 1 and 2, including Faraday shields employing solid or slotted supports, Figure 3, and included the realistic
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SIMULATION MODEL FOR ICRF ANTENNA

- Antenna structure is enclosed in an infinite waveguide which is numerically truncated at a finite length at which boundary the outgoing radiation is expressed as the complete set of waveguide modes. A symmetry condition at the other boundary reduces the simulation by half.

- Strap is driven by potential at lead (4.5 MHz)

- 4 block problem; each block of size 6 x 53 x 93 grid pts.

Figure 1
BARE STRAP ON TEST STAND

- COMPARISON WITH "ANTENA" CODE
  - "ANTENA" USES MOCKED UP STRAP CURRENT PROFILE (35% - 30% - 33%)

- COMPARISON WITH EXPERIMENT
  - SELF CONSISTENT STRAP CURRENT

Figure 2
STRAP WITH FARADAY SHIELD
(SLOTTED SIDE SHIELDS)

Figure 3
current feed connections which are fed by oscillating voltage inputs at the feed points. Thus, instead of prescribing given current wave forms, the electric fields in the co-axial leads responsible for driving the antenna currents are prescribed. The simulation thus yields an unbiased prediction of the overall current distribution in the antenna structure. For example, the simulation results showed a curious reversal in the axial magnetic field component which was not anticipated; see Figure 4. The simulations predicted the field to reverse, as shown in the figure; and subsequent experimental measurements proved this to be so; the reason for the reversal stems from the self-consistent currents flowing in the test stand back plate. 2-D codes such as the "ANTENA" code of McVey (Ref. 16) are incapable of simulating such a phenomenon and, moreover, in order to reproduce the results of even the near-field antenna pattern the current distribution in the conductors must be given in a manner that assumes a-priori knowledge of the distribution. For example, the "ANTENA" code can be forced to reproduce some of the ARGUS and experimental results if the 2-D model is assumed to have 35%, 30%, 35% of the current flowing in the left one-third, middle one-third, and right one-third of the current strap, respectively.

For the simulated antenna structure, the dimensions, structural details including conductors and insulators and electrical connections to the central power supply were translated by the ARGUS logical geometry routines. Relatively few geometry iterations, based on recent AR experience with the UW antenna, were required to determine the conformational antenna grid.

Results of the UW-SAIC joint ICRF antenna analysis effort have been presented at several international meetings and numerous meetings in the
- We measure $\dot{B}_Z$ along the surface of the strap to indicate the current profile in the strap.

- Similar computations by Argus are in close agreement.

- Note that the location of the null in $\dot{B}_Z$ is also accurately predicted.

![Graph showing the comparison between Argus computations and test stand data](image-url)
United States. For example, Appendix A contains the presentations for the international Edge Physics Meeting in Germany, October 1989 (A-1) and the European Plasma Physics Society Meeting in Venice, May 1989 (A-2). The principle result that is contained in these two presentations is the demonstrated capability to model and simulate the global behavior of complex 3-D antenna structures and to a great extent, many of the detailed features that are a direct result of incremental changes in antenna geometry such as Faraday shield dimension and spacing. As an example of the detailed nature of the simulations, Appendix B contains a summary of the most recent results obtained from the UW antenna simulation effort. The principle result to be found in the material in Appendix B is the spatial variation of the electric and magnetic rf fields in locations where it is experimentally difficult, if not impossible, to measure.

2.2 PPPL Collaboration

The PPPL bay M antenna has been modeled using the ARGUS code. The results of this effort are shown in Appendix C. The complexity of the PPPL antenna is clearly shown in the figures representing the computational grid-structure. Comparison with the antenna blueprints also confirm that the gross features (cavity, septum, strap, feeds) and selected details (Faraday shield bars including spacing and dimensions) are captured in the computer model. The simulation results for two separate strap phasings (0-0 and 0-π) show that different antenna behavior is obtained. This behavior is associated with current accumulation leading to unwanted fringing and enhanced electric fields in regions where these fields should be weak. In addition, the simulations allow, for the first time, a prediction of the antenna power spectrum.
2.3 ORNL Collaboration

SAIC has recently begun a collaboration with the ICRF antenna design and analysis group at ORNL. At present there are two separate projects underway. The first is associated with the simulation of and determination of the effect of adding slots in the antenna septum and side walls. The slots are expected to eliminate flux linkage between adjacent current straps and to eliminate the negative "K" part of the radiated power spectrum. The negative K's act to buck out fast wave current drive.

The second project concerns the modeling and simulation of the ORNL folded waveguide (FWG) concept. This antenna is designed for high Q operation and hence should couple higher power to the plasma than is currently possible with the conventional strap antennas. The FWG modeling effort is being carried out jointly with ORNL staff.
3. **PROPOSED RESEARCH**

SAIC proposes to continue the ICRF antenna modeling and simulation effort begun earlier under DOE funding (DOE Contract DE-AC03-88ER53270) and to expand the scope of the work to include the following main areas of concentration:

i) Determination of geometry parameters governing the vacuum performance of single and multi strap antennas,

ii) Determination of geometry parameters governing the vacuum performance of advanced ICRF antennas such as the FWG concept,

iii) Determination of effects of edge and core plasmas on the performance of ICRF antennas.

### 3.1 Single and Multistrip Fast Wave and IBW Antennas

The projects underway at UW, PPPL, and ORNL will continue and will concentrate on the following issues. The effect of putting slots into the septum or sidewalls of fast wave antennas will be investigated in collaboration with UW and ORNL. Simulations of candidate slot geometry will be carried out using the UW and PPPL antenna geometry simulated with the ARGUS code and compared with experiments at UW and ORNL. The results of these studies will provide the data base required to perform trade-off studies leading to the optimization of fast wave antennas for current drive applications such as those considered for the D-III device at GA.

The CIT antenna geometry will also be simulated using the ORNL base design. The results will provide a prediction of the antenna power spectrum. In the event that the power spectrum requires modification due to unforeseen edge plasma effects, the simulation results will provide the data base required for modification studies.
3.2 Advanced Antenna Concepts

The Use of ARGUS simulations during the conceptualization and development phase of new or advanced ICRF antenna technologies will provide insight and understanding of the devices in advance of detailed costly laboratory model experiments. Such insight has already been demonstrated and documented during the joint effort with UW; considerable antenna optimization has been performed first computationally and later verified through a few experiments. The initial effort in this proposed work will be concerned with the ORNL FWG antenna. This antenna is described in Appendix D. In the Appendix it is easily seen that the proposed FWG configuration lends itself ideally to simulation and we expect to provide considerable detail in the simulation giving an extensive parametric data base which can be used to optimize FWG devices with confidence. A combined simulation and experimental verification study will be carried out jointly with ORNL.

3.3. Edge and Core Plasma Effects

The extension of the simulation efforts described in 3.1 and 3.2 to include the influence of edge and core plasma will be completed during the proposed research program. This effort consists of several distinct areas of study separated by spatial scale and level of computational complexity. For example, the edge plasma effects include the formation of sheath regions around the Faraday shield components, edge plasma heating and fast ion impact on antenna structure local to the plasma edge. Core plasma effects such as total power absorption and reflected power to and from the antenna will provide the crucial information needed to determine the antenna coupling and loading. Coupling and loading information is essential to optimize matching a given antenna design to a particular plasma column.
(The difference in performance between the TFTR bay L and M antennas illustrates this point rather strongly. At present there is no universally accepted understanding of this difference.)

SAIC has begun, under the previous contract, to couple the fluid dynamic model of the plasma (developed by E. Horowitz of SAIC) to the ARGUS code. Currently, the fluid code is being adapted to the "toroidal" plasma equilibrium used by Batchelor, et al., (Ref. 21). Also, an algorithm developed by S. Auerbach of SAIC, is being implemented to maintain the condition $E_{||} = 0$ in the bulk of plasma. The algorithm allows the full rf field pattern to be propagated outside the main plasma and matches these outside fields to the boundary of the plasma-vacuum interface. We will continue the development of the ARGUS fluid plasma code. The completed code system will provide a global simulation of the full antenna field pattern coupling to the bulk plasma and will result in a global measure of the antenna plasma loading.

The edge plasma effects an antenna performance will be concentrated initially in the development of a model and simulation of two-dimensional sheath phenomena.

Energy deposition on the plasma scrape-off layer during intense ICRH heating has deleterious consequences for the overall efficiency. It causes increased impurity flux in the plasma core by the release of carbon atoms from the limiter and chamber walls and metal atoms from the Faraday screen. The influx of impurities is caused by collisions of energetic ions with the material surrounding the plasma. It is therefore important to understand the mechanisms that accelerate ions near the antenna to sufficient energies to cause sputtering. These energies, typically of the order of 0.5 keV, are much higher than the typical ambient plasma
temperatures ~ 10 eV. In a strongly magnetized plasma strong ion acceleration requires either repeated resonant wave-particle interaction and/or high field gradients within a scale length of one Larmor radius. Resonant acceleration requires excitation of ion cyclotron frequencies below the rf frequency. This may occur via linear mode conversion in the presence of a density gradient, nonlinear parametric excitation and scattering off edge plasma modes. The above methods, in particular parametric pump decay, have been studied often in the past. Creation of high field gradients inside the plasma sheaths that form around the interface with the Faraday screen rods also seems capable of ion energization to sputtering energies. A one-dimensional theory has been developed restricting the electron motion in the y (poloidal) direction (Ref. 30). Because of the angle between the magnetic field lines and the toroidal direction, and the presence of an intense field.

\[ \vec{E} = y_E y e^{-i\omega t} . \]  

(1)

each species \( \alpha \) executes an oscillation of amplitude \( \Delta y \):

\[ \Delta y_\alpha = \frac{eE_y}{m_\alpha \omega^2} \sin \theta \]  

(2)

where \( m_\alpha \) is the species mass and \( \theta \) is the angle between the magnetic field line and the toroidal direction. Much larger excursion for electrons leads to electron depletion near the metal-plasma boundary and formation of an averaged dc component (rf rectification). The rf field is "expelled from most of the space between two grids of the screen and the induced voltage
is thus distributed over a much shorter length, namely the width of the plasma sheath $\Delta$. This results in much higher local fields, capable of accelerating ions to keV levels over distances of the order of one Larmor radius.

The one-dimensional picture, although it has produced some qualitative agreement with experimental results, is far from complete. A cross section of a Faraday screen rod in the $r-\theta$ (x-y) plane is a two-dimensional object. The plasma sheath formation can not be addressed in one dimension only but as one entity around the rod. In addition it can be shown that a new driving mechanism, ExB drift, generates a plasma sheath across the x-direction as well. To see this, consider the ExB displacement due to the rf $E_y$ component

$$\Delta x_\alpha = \frac{e/m_\alpha E_y}{\Omega_\alpha^2 \omega^2}$$  \hspace{1cm} (3)

where $\Omega_\alpha$ is the specie cyclotron frequency.

According to (3) the ion displacement is now much larger than that of the electron as $\Delta x_i/\Delta x_e \approx m_i/m_e >> 1$. A sheath in the x-direction resulting from ion depletion will form with of opposite polarity than the electron-depleted sheath across x. The interaction of these two charge layers is an intriguing question that must be addressed in two dimensions. Furthermore it seems that an alternating charge density in the x-y direction will cause a tangential electric field around the rod cross-section. If this is true a new ExB inwards influx may considerably increase the rate of impurity production. We intend to resolve the question of sheath formation in a
realistic 2-d geometry both analytically and numerically. The 2-D geometry will be obtained from a 2-D slice of the 3-D ARGUS antenna simulations retaining the computed time dependent 2-D rf fields. Addition of electron and ion dynamics via the 2-D version of ARGUS, MASK, will allow a self-consistent simulation of the sheath formation, electric field buildup and ion acceleration. This work should shed light on the controversy surrounding the validity of the so-called standard models of impurity generation (Ref. 23).
4. DELIVERABLES AND SCHEDULE

The timely completion of the proposed research will allow our results to impact the ongoing research and development of ICRF antenna configurations. To this end, SAIC has organized the research into four tasks. These tasks are described below along with a proposed schedule for task completion and delivery of results.

Task 1  Determination of single and multiple strap fast wave and IBW antenna performance with geometry modification.

Under this task we will simulate a sequence of geometry modifications and catalogue the antenna performance (field structure, K spectrum) as a function of the geometry feature. The first modification will concern the use of slots in the TFTR like antenna sidewalls and septum to determine the effect of flux linkage on the radiated power spectrum. Other proposed modifications (to be determined as the need arises according to particular design studies) include the use of resistors for disruption control, alternate Faraday geometry, to name just a few.

The first results from the slot studies will be completed after 3 months into the contract. The remaining results, depending on the exact number of modifications, will be completed in 9 months after contract start.

Task 2  Determination of performance of FWG antenna and optimized FWG geometry.

This task will provide the required data base to optimize (maximize the power coupled to the plasma by maximizing the vacuum Q) the FWG
antenna geometry. It is estimated that first results will be obtained in 3 months with final results completed in 6 months after start of contract.

Task 3  Completion of ARGUS-plasma code for global coupling determination.

Completion of this task, begun under the initial contract, will enable the ICRF designers to predict the loading characteristics of antennas in the presence of the bulk plasma core where the transmitted rf power is absorbed. We expect to finish mating the ARGUS and fluid codes during the first 6 months and to have completed the code checkout and benchmarking at the end of the first 12 months. During the second 12 months, the antenna configurations that have been analyzed for vacuum performance will be simulated using the "loading" simulator. Details of the exact geometry to be analyzed will be decided upon by mutual agreement between SAIC and the UW, PPPL, and ORNL user community.

Task 4  Edge Physics Studies

The edge physics studies will provide insight into those issues which affect the ability of ICRF antennas to withstand the intense edge region environment (heating, erosion, and sputtering) and the ultimate effect on antenna performance. The first study associated with the 2-D nature of sheath formation has been described in detail in the proposal and it is expected that initial theoretical and computational results will be ready after 6 months. These studies will continue and will be paced according to the
development of further understanding of the edge region through experimental findings and interaction with the edge physics community.
5. MANAGEMENT AND PERSONNEL

Dr. William Grossmann will serve as the principle investigator for the proposed research. Dr. Grossmann was the principle investigator for the initial SAIC antenna modeling project described in Section 2 of this proposal. Assisting him will be Drs. Adam Drobot, Spilios Riyopoulos, Eric Horowitz, and Alan Mankofsky. Each of these scientists has nationally recognized experience and capabilities in computer simulation and fusion plasma physics. In addition, the project will use the services of Drs. Kwok Ko and Michael Kress who have contributed to the development of the ARGUS code.

Collaboration with the UW, PPPL, and ORNL groups will be maintained through the key technical contacts: Drs. Noah Hershkowitz, Pat Colestock, and Dan Hoffman respectively. In addition, SAIC will make available the vax based version, VARGUS, to each of these groups and will train UW, PPPL, and ORNL staff to use this code. This local capability will allow multiple and concurrent simulation studies to be carried out.
References

15. P. Colestock and J. Hosea, personal communication.
20. M. Mayberry, et al., "Recent IBW Results on DIII-D and Their Implications for ICH in High Density Tokamaks," ibid.
27. I.S. Lehrman, "Coupling to High Density C-Mod Plasmas," ibid.


6. COSTING
**CONTRACT PRICING PROPOSAL COVER SHEET**

1. **Solicitation/Contract/Modification No.** W/A

2. **Name and address of offeror (include zip code):**
   Science Applications International Corporation
   10260 Campus Point Drive
   San Diego, CA 92121
   c/o SAIC, Technology Research Group
   1710 Goodridge Drive, P.O. 1303
   McLean, Virginia 22102
   Attn: Linda S. Spokane, M/S 2-3-1
   Code 52302

3. **Name and title of Offeror's Point of Contact:**
   Linda S. Spokane
   Contracts Representative

4. **Type of Contract Action (check):**
   - X A. New Contract
   - D. Change Order
   - E. Unpriced Order
   - C. Price Revision/Redetermination
   - B. Progress Payments
   - Guaranteed Loans
   - X CPFF Billing
   - Guaranteed Indemnity
   - Guaranteed Federal Indemnity
   - Guaranteed Cost
   - Guaranteed Billings
   - Guaranteed Indemnity Billings
   - Guaranteed Indemnity Federal Indemnity
   - Guaranteed Indemnity Federal Indemnity Billings
   - Guaranteed Indemnity Federal Indemnity Guaranteed Billings

5. **Type of Contract (check):**
   - FPI
   - Other (specify)

6. **Proposed Cost (A + B = C):**
   - A. Cost
     - $525,623
   - B. Fee
     - $52,325
   - C. Total
     - $577,948

7. **Place(s) and Period(s) of Performance:** McLean, Virginia
   15 April 1990 - 14 April 1992

8. **List and reference the identification, quantity and total price proposed for each contract line item. A line item cost breakdown supporting this recap is required unless otherwise specified by the Contracting Officer. (Continue on reverse, and then on plain paper, if necessary. Use same headings.)**

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9. **Provide Name, Address, and Telephone Number for the following (if available):**

   A. **Contract Administrative Office**
   Mr. William J. Johnson/DCAS/S-72
   10260 Campus Point Drive
   San Diego, CA 92121
   (619) 495-7484

   B. **Audit Office**
   Ms. Celia Cohan/DCA
   10260 Campus Point Drive
   San Diego, CA 92121
   (619) 535-7411

10. **Will you require the use of any government property in the performance of this work? (If "Yes", identify)**
   - Yes _X_ No

11. **Do you require government contract financing to perform this proposed contract? (If "Yes", complete Item 11B)**
   - _X_ Yes No

12. **Have you been awarded any contracts or subcontracts for the same or similar items within the past 3 years? (If "Yes", identify items(s), customer(s), and contract number(s))**
   - _X_ Yes No

13. **Is this proposal consistent with your established estimating and accounting practices and procedures and FAR Part 31 Cost Principles? (If "No", explain)**
   - _X_ Yes No

14. **Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation.**
REFERENCE A

COST ELEMENT BREAKDOWN
## Modeling and Simulation Support for ICRF Heating of Fusion Plasmas

### Cost-Element Breakdown

**Reference A**

**1-624-71-910-02**

**15 April 1990 - 14 April 1992**

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| **Labor Burden**    |       |       |        |       |       |        |
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| Overhead            | 83.6% | 77,334| 64,651 |       | 78,912| 65,970 |
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*An Employee-Owned Company*
PRICING NOTES

The cost estimate and/or pricing presented in this cost proposal was developed following the procedures outlined in SAIC's Cost Estimating System Manual (CESM). The CESM sets forth SAIC's policies, procedures and methodologies with respect to cost estimating and pricing. The CESM has been reviewed by our cognizant ACO and has been deemed to adequately describe the corporate wide estimating policies and procedures. It has also been reviewed by our cognizant DCAA and was deemed to be generally adequate and compliant with the requirements of DFAR 215.811-75 and 215.811-76.

1. COGNIZANT AGENCIES

Science Applications International Corporation and its subsidiaries, are under the audit cognizance of the Defense Contract Audit Agency, 10260 Campus Point Drive, San Diego, California 92121, and the administrative cognizance of the Defense Contract Administration Services Management Area, San Diego, 7675 Daggett Street, Suite 200/300, San Diego, California 92111-2241. The points of contact are:

DCAA - Ms. Celia Cohan (619)535-7411
ACO - Mr. William J. Johnson (619)495-7484

The direct and indirect rates used in this proposal are recognized by DCAA and DCASMA for forward pricing purposes.

2. INDIRECT RATES

The indirect rates used in this proposal are based upon detailed data supplied to SAIC's cognizant DCAA Auditor and DCAS Administrative Contracting Officer. They are applied in this manner:

<table>
<thead>
<tr>
<th>Rate</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Overhead (Onsite &amp; Offsite)</td>
<td>Direct Labor not performed in a multi-user Secured Facility</td>
</tr>
<tr>
<td>Fringe Benefits</td>
<td>Direct Labor</td>
</tr>
<tr>
<td>General and Administrative</td>
<td>All direct and indirect costs excluding Direct Material</td>
</tr>
</tbody>
</table>

3. DIRECT LABOR

The proposed Direct Labor hours are an engineering estimate.

The proposed Direct Labor bid rates are the average (arithmetic mean) of the actual salaries for those employees within each bid...
level as of May 1989. Each bid rate has been escalated 2% per annum to the mid-point of the period of performance. This escalation accounts for the anticipated annual increase of each bid level rate pool. The annual increase includes individuals entering and leaving each pool as well as salary adjustments for those who remain in each pool.

4. TRAVEL

The trips required for this effort are delineated in Reference C. The proposed airfares are the average coach fares based on historical data for roundtrip coach fares to the destination cities. The other proposed travel rates are in accordance with our established travel policy. All travel costs are escalated 4% per annum.

5. COMMUNICATIONS

Communications expense includes postage, courier services, graphics and reproduction costs. It is estimated that the Group’s historical average, one percent of Direct Labor dollars, shall be required in the performance of this effort.

6. STELLAR GRAPHICS WORKSTATION

The Plasma Technology Division’s Stellar Graphics Workstation is a category A Service Center and will be used to support this effort. The estimated rate is $24.00 per hour of usage.

7. CONSULTANTS

Michael Kress and Kwok Ko will assist in this effort as consultants. Their current agreements with SAIC stipulate rates of $41.25 and $37.50 per hour respectively. These rates may increase over the life of the contemplated contract therefore these are considered to be an estimated rate. Also this is an estimated number of hours and the actual may vary. Any changes shall be addressed as they occur.

8. FACILITIES CAPITAL COST OF MONEY (FCCM)

The FCCM factors in this proposal are based upon detailed data supplied to SAIC’s cognizant DCAA Auditor and DCAS Administrative Contracting Officer. They are applied in this manner:

<table>
<thead>
<tr>
<th>BASE</th>
<th>FACTOR</th>
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</thead>
<tbody>
<tr>
<td>Onsite Direct Labor Dollars (Onsite Overhead Pool)</td>
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<tr>
<td>All Direct and Indirect Costs Excluding Direct Material (G&amp;A Pool)</td>
<td>0.00292</td>
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</tbody>
</table>

DD Form 1861 is included as Reference D.

9. CAS NONCOMPLIANCE ISSUES/SF1411 (EXPLANATION OF BLOCK 14C)

On March 22, 1989, SAIC’s cognizant Administrative Contracting Officer (ACO) made a final determination of noncompliance with
CAS 409.50(h) and with CASB Disclosure Statement, Item 5.1.0. The determination involves two issues.

The first issue pertains to the materiality of tangible capital asset residual values when the residual values are less than ten percent of the asset acquisition cost. CAS 409.50(h) requires that "no depreciation cost shall be charged which would significantly reduce book value of a tangible capital asset below its residual value." The dispute arose because residual values are estimated to be zero for tangible capital assets other than automobiles. It is understandable that when a residual value is determined to be zero, it may appear that residual value was not considered at all. To resolve this matter we will provide information which demonstrates the immateriality of residual values associated with the asset categories in question and we will clarify disclosure of our practices. Further, to avoid potential future disagreements, we intend to seek an advance agreement specifying the amount that is mutually agreed to be insignificant.

The second issue relates to disclosure of our methods for estimating the future service lives of tangible capital assets. DCAA concluded that estimated service lives are not based on historical experience, primarily based on the lack of documentation regarding the company's periodic assessment of the actual service lives. To resolve this matter we will provide information demonstrating our estimated service lives, as adjusted for specific factors which are expected to influence future service lives, are supported by actual historical experience. Additionally, we will propose revisions to procedures and disclosures which clarify our policies and practices.

In addition, SAIC's cognizant DCAA has recommended an initial determination of noncompliance with CAS 401. SAIC's response has been provided and the matter is currently under discussion with our cognizant ACO.

Should you desire additional information regarding these issues, please do not hesitate to contact any of the following individuals:

John W. Armstrong  
Corporate Vice President  
Director, Contracts and Pricing  
(619) 535-7315

Adelaide K. Mayhew  
Vice President  
Deputy Director, Contracts and Pricing  
(619) 458-2630

Donald J. Bouma  
Director of Government Accounting  
(619) 552-4628
REFERENCE C

TRAVEL
## Reference C - Travel

**1-624-71-910-02**  
**15 April 1990 - 14 April 1992**

<table>
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<tr>
<th>YEAR</th>
<th>FROM/TO</th>
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<th>NO. OF PEOPLE</th>
<th>NO. OF DAYS</th>
<th>NO. OF CARS</th>
<th>R/T MILES</th>
<th>RATE</th>
<th>PURPOSE OF TRIP</th>
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<td>1</td>
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<th>TOTAL TOTAL TRANSPORTATION</th>
<th>TOTAL PER DIEM</th>
<th>TOTAL COMMUNICATION</th>
<th>TOTAL ESCALATION</th>
<th>TOTAL TOTAL</th>
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**TOTALS**  

$2,244 $330 $90 $84 $2,748 $2,426 $65 $2,491 $269 $5,508 $5,508

### Airline Guide Rate Date: Historical Data

**Auto Rental**: $33.00 /Day  
**Mileage**: $0.24 /Mile  
**Airport Parking**: $15.00 /Person/ Trip  
**Communication**: $5.00 /Person/ Every 2 Days

### Escalation:

- **Year 1**: 2.67%  
- **Year 2**: 6.67%

**Airfare** - Average Coach Class R/T Fare  
**Per Diem** - Includes Meals and Lodging  
Based on Federal Travel Regulations  
Maximum Per Diem Rate Effective: 09-Oct-88

---

*SAIC*  
An Employee-Owned Company
REFERENCE D

CONTRACTOR FACILITIES CAPITAL COST OF MONEY

1. CONTRACTOR NAME
   Science Applications International Corporation

2. CONTRACTOR ADDRESS
   10260 Campus Point Drive
   San Diego, CA 92121

3. BUSINESS UNIT
   Company 1

4. RFP/CONTRACT PIIN NUMBER

5. PERFORMANCE PERIOD
   15 April 1990 - 14 April 1992

6. DISTRIBUTION OF FACILITIES CAPITAL COST OF MONEY

<table>
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<tr>
<th>POOL</th>
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<th>FACTOR</th>
<th>AMOUNT</th>
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</thead>
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<td>BASE</td>
<td>(B)</td>
<td>(C)</td>
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<tr>
<td>Onsite Labor Overhead</td>
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</tr>
<tr>
<td>G&amp;A</td>
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<td>$1,389</td>
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   TOTAL $2,381

   TREASURY RATE 9.125%

   FACILITIES CAPITAL Employed (Total Divided by Treasury Rate) $26,095

7. DISTRIBUTION OF FACILITIES CAPITAL Employed

<table>
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<tr>
<th>PERCENTAGE</th>
<th>AMOUNT</th>
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<td>LAND</td>
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<td>BUILDINGS</td>
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<tr>
<td>EQUIPMENT</td>
<td>89%</td>
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</table>

   FACILITIES CAPITAL Employed 100% $26,095

Equivalent of DD Form 1861, Aug 1987

Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation.
REFERENCE E

TERMS AND CONDITIONS
TERMS, CONDITIONS AND OTHER STATEMENTS

1. GENERAL

With regard to terms and conditions other than those set forth herein and except for those provisions required by applicable Government law or statute, it is assumed that agreement as to the applicable provisions remains subject to final negotiation of any resulting contract.

2. PROPOSAL VALIDITY

This proposal is offered on a Cost Plus Fixed-Fee basis and shall remain valid for thirty (30) days.

3. AUTHORIZED NEGOTIATORS

Persons authorized to negotiate this proposal and administer any resulting contract are:

<table>
<thead>
<tr>
<th>Primary</th>
<th>Alternate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linda S. Spokane</td>
<td>Karen L. Marshall</td>
</tr>
<tr>
<td>Contracts Representative</td>
<td>Contracts Manager</td>
</tr>
<tr>
<td>(703)734-4031</td>
<td>(703)734-5889</td>
</tr>
</tbody>
</table>

4. CONTRACTOR ADDRESS

The contractor address to be used on the face of all contract documents is:

"Science Applications International Corporation
10260 Campus Point Drive
San Diego, CA 92121

c/o Science Applications International Corporation
1710 Goodridge Drive
McLean, VA 22102
Attn: Linda S. Spokane, M/S 2-3-1
Technology Research Group"

It is requested that this address be used in order to reduce mail routing delays for UNCLASSIFIED documents.

5. CONSULTANT APPROVAL

This proposal is intended to be notification to the Contracting Officer of intent to use the proposed consultants pursuant to FAR 52.244-2, Subcontracts, subparagraph a., and it is requested that

Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation.
any resulting contract contain the Contracting Officer’s approval and consent for use of these consultants pursuant to subparagraph c. thereof.

6. FEE RETENTION REDUCTION

It is requested that the fee retention (per FAR 52-216.8) of any resulting contract be reduced from fifteen percent to zero percent. Our cognizant DCAA is currently four years behind in their incurred cost audit of SAIC indirect rates. The most current negotiated indirect rates are for SAIC FY84 which ended 27 January 1984. We are therefore unable to close any contracts that have a period of performance that has ended since 28 January 1984 (the beginning of SAIC FY85). This delay prohibits SAIC from collecting the fee retention on completed contracts for unreasonably long periods of time, and diminishes the value of the retention once released. (Assuming a nominal rate of interest of nine percent per annum the discounted value of a dollar withheld for five years is approximately sixty cents.) It is not believed that granting this request will represent any added risk for the purpose of protecting the Government’s interests. As of 28 April 1989 the Government is holding $10.4 million in fee retentions due SAIC. It is requested that a special provision be included addressing this issue to read essentially:

"The amount of fee to be retained pursuant to FAR 52.216-8 shall be zero percent. The Government is currently withholding an adequate amount of fee retention to protect its interests. Withholding of zero percent of fee shall require no specific instruction from the Contracting Officer."
APPENDIX A.1
ICRF - Edge Plasma Investigations in Phaedrus B

R. Majeski, T. Tanaka, T. Intrator, and N. Hershkovitz
University of Wisconsin, Madison, Wisconsin USA

K. Ko, W. Grossman, and A. Drobot,
Science Applications International, MacLean, Virginia USA

ABSTRACT

We describe experiments which investigate the characteristics of a test ICRF coupler. The rf magnetic fields near the antenna are measured in vacuum and in plasma. Results are modelled using the code ANTENA in plasma; details of the vacuum fields are modelled with the code ARGUS. For the plasma experiments, the antenna is mounted in the central cell of the Phaedrus-B tandem mirror. ICRF modification of the edge plasma potential at the Faraday shield and coupling to electrostatic modes are also investigated.

INTRODUCTION

The interaction between an ICRF coupler and the edge plasma in tokamaks is responsible for impurity influxes, changes in the scrape-off length, and possibly edge electron heating during ICRF. These processes are still not understood. Here we present measurements, in a plasma similar to that found in the scrape-off layer of medium-sized tokamaks, of the local rf fields, electrostatic potentials, and particle currents collected by an operating low power ICRF coupler. We tentatively conclude that an electrostatic ion Bernstein wave is excited by the coupler in addition to the expected fast wave modes.
DESCRIPTION OF PHAEDRUS-B AND THE MODEL ANTENNA.

Phaedrus-B [1] is an ICRF stabilized and heated tandem mirror, with 200-400 kV of rf power coupled through two antennas operated near the ion cyclotron frequency. Only the central cell rf sources are operated. The central cell, where the model antenna is installed (75 cm from central cell midplane), is 3.2 m long (length of the uniform ~ 0.9 kG magnetic field), with limiters at 17 cm radius. The data presented here will be at peak densities of \( \leq 5 \times 10^{12} \text{cm}^{-3} \), with \( T_i, T_e = 20-40 \text{ eV} \). The density drops to \( 5 \times 10^{11} \text{cm}^{-3} \) at the limiter radius. Plasma density at the Faraday shield is \( 5 - 20 \times 10^{19} \text{cm}^{-3} \).

The data presented here were taken with two different model antenna configurations (Types A and B). Both are fast wave antennas and utilize 60° 10 cm wide current straps. The straps are fed at one end, with current return through the 20 cm wide backplane. The Faraday shield structure in the case of the Type A antenna is constructed of aluminum, with a single layer (25% transmission) of cylindrical front elements at a 17 cm radius (current strap radius 19 cm) and staggered double layers of slats for the Faraday shield sides. The Type B single-layer shield is of copper plated stainless steel, with front elements of rectangular cross section. Both shield assemblies include endplates to enclose the antenna leads, and are 20 cm wide. The Type B Faraday shield assembly is electrically isolated from the antenna backplane, and is connected via a low inductance strap to a separate electrical feedthrough. For the experiments described here the Type B Faraday shield was grounded at the feedthrough, and current driven to the Faraday shield is monitored by a current transformer. This shield was installed at a radius of 16.5 cm with the current strap at 18.5 cm.
The entire model antenna assembly is mounted on a carriage which translates 120° in azimuth. The carriage, installed in the Phaedrus-B central cell, with the Type B antenna and Faraday shield installed, is shown in Figure 1. Excitation power is ~3 kW, with antenna currents in the 100-200 A (p-p) range.

In addition to the antenna system installed in Phaedrus-B, identical Faraday shield/antenna assemblies have been constructed for test stand measurements in air.

**TEST STAND MEASUREMENTS.**

Extensive air measurements of all three components of the rf magnetic fields over the full Faraday shield have been made for the Type A shield [2]. Comparison of these measurements with field maps using the bare strap show that the component most strongly modified by the Faraday shield is the rf B₀ component. Figure 2 (a through c) shows the effect of a transition from an open, slotted frame structure to a closed frame structure on the θ component of the rf magnetic field. In the case of a closed frame, the θ component of the rf field is highly localized near the leads, and the peak value increases by 50%.

Some modelling of the vacuum field distribution has been performed with the code ARGUS. In Figure 3 we show an axial profile of the θ component of the rf magnetic field taken 2 mm above the bare strap and backplane assembly. Data and simulation are in excellent agreement. Here the field profile above the strap is proportional to the current distribution in the strap, while the position of the point at which the field reverses sign is sensitive to the return current distribution in the backplane as well.
PLASMA FIELDS.

Using the Type A coupler operated at 3.5 MHz (2.4 $\Omega_{\text{ci}}$), we have observed that the plasma fields within a few cm radius of the Faraday shield are virtually unchanged by the presence of plasma. The effects of wave propagation begin to be apparent at ~5 cm distance from the shield face, in agreement with modelling using the code ANTENA [2].

During experiments with the Type A coupler, we also observed excitation of an electrostatic mode which we have tentatively identified as an ion Bernstein wave. This mode is observed at higher frequency (7 MHz, or 4.8 $\Omega_{\text{ci}}$), in shots with high gas fueling, lowered main ICRF power (~100 kW), and low density (1-2 x $10^{12}$ cm$^{-3}$). Electron temperature for this mode of operation in Phaedrus-B is (~10-20 eV). The mode is observed with an electrostatic probe [3], and unlike the fast wave fields detected with a B-dot probe has a highly modulated envelope. Interferometric measurements near the model coupler yield a $k_{\parallel}$ of 1-3 cm$^{-1}$, with phase decreasing as the probe is moved away from the coupler, as expected for a backwards mode such as the ion Bernstein wave. $T_{\parallel} - T_{\perp}$ for this mode of operation, so that $\alpha_{\|} p_{i}$ is in the range of 0.4 - 1. We also find that the amplitude of the mode varies azimuthally, and is greatest near the ends of the coupler, at the azimuthal location of the leads. Although excitation of an IBW by a fast wave coupler via mode coupling has been previously reported [3], in Phaedrus-B the IBW is seen to coexist with fast wave excitation. Here several fast wave eigenmodes, including the m=0, are above cutoff.

We have measured the increase in the plasma floating potential with a capacitive probe in the Faraday shield gap (near the axial edge of the shield) for the Type B coupler, as a function of the strap current. The plasma
potential is found to increase linearly with strap current (Fig. 4). The Type B coupler has an isolated Faraday shield which permits monitoring of the current. Collected current scales as $I^{1.3}_{\text{antenna}}$ and therefore as $f^{1.3}_{\text{rf}}$, which is suggestive of a Child-Langmuir relationship. In Fig. 6 the floating potential of a high impedance Langmuir probe adjacent to the Faraday shield blade/gap region is plotted as a function of azimuthal position. The measurement was taken at a distance of 4 mm axially from the Faraday shield assembly, at a radius of $r_{\text{Faraday shield}} + \frac{d_{\text{blade}}}{2}$, where $d_{\text{blade}}$ is the thickness of the Faraday shield blade. The asymmetry in the potential in the gap region, which is also seen on capacitive probe measurements, appears to be due to a slight tilt of the Faraday shield blade with respect to the confining magnetic field. In the low potential region, the probe is on a field line which transits the Faraday shield gap. In the high potential region, the probe is on a field line which terminates near the midpoint of the blade, where the inductively induced voltage on the blade, and presumably the plasma self-bias, peaks. Similar effects are thought to contribute to high sputtering rates at the Faraday shield [4], [5].

CONCLUSIONS.

We have several observations on the interaction of a fast wave coupler with the edge plasma. The vacuum measurements draw attention to the effect of surrounding the antenna leads in a conducting frame on the $E_0$ rf field components. The use of solid septa to reduce inductive coupling between neighboring pairs of phased antenna straps would have a similar effect. Observation of an ion Bernstein wave excited in the edge plasma by a fast wave
coupler implies an additional heating channel for electrons. Here it should be emphasized that we have as yet made no estimates of the relative power launched in IBW vs. fast waves. We have found that a Faraday shield is a net electron collector, which should produce a positive plasma self-bias. This is confirmed by probe measurements of the plasma floating potential during excitation of the coupler. The increase in floating potential scales with the strap rf current, and is not confined to the gap region for Faraday shields of this geometry. The increase in collected electron current scales approximately with the (strap rf current)\(^{1.9}\), and therefore with the plasma (self-bias potential)\(^{1.9}\), which suggests that the evolution of the collected current and plasma self bias follow a Child-Langmuir law. This is a straightforward picture of the interaction of an ICRF coupler with the edge plasma, at least at low powers, and points to increased ion impact energy and sputtering through the rf self-bias.

This research has been supported by U.S. DOE Grant DE-FG02-88ER53264.

REFERENCES


LIST OF FIGURES

Figure 1. The carriage-mounted model antenna mounted in the Phaedrus-B central cell. Also visible is one of the two pairs of dual half-turn antennas utilized for the main ICRF. This set was not active in these experiments.

Figure 2. Contours of the $\theta$ component of the rf magnetic field in the $\theta$-z plane at constant radius (1 cm from the Faraday shield) for three Faraday shield constructions.
A. Slotted face and sides, no end plates. Peak field is 28 (relative units).
B. Slotted face and sides, solid end plates. Peak field is 31.
C. Slotted face, solid sides and end plates. Peak field is 47.

Figure 3. Axial profile of the $\theta$ component of the rf magnetic field 2 mm above the antenna strap. Stars denote measurements; the solid line is modelling by the code ARGUS. Note field reversal near $z=6$ cm.

Figure 4. Scaling of probe floating potential with model antenna strap current. The line is a linear fit to the data (stars) with intercept -2.7 V and slope 0.74 V/A rms.

Figure 5. Scaling of excess collected electron current with the 3/2 power of the strap current. The line is a linear fit to the data (stars) with intercept $-1.7 \times 10^{-3}$ A and slope $3.2 \times 10^{-3}$ A/A$^{1/2}$.

Figure 6. Probe floating potential as a function of azimuthal position, immediately adjacent to the Faraday shield gap. The stars are data; the solid bars denote the ends of the Faraday shield bars. The bars are axially slightly misaligned with the confining magnetic field; as a result, the bar ending at 2-3 cm is tilted approximately 3 mm into the gap region.
Figure 3.
Figure 4
**Figure 5.**

Excess electron current (A) vs. Antenna current (A rms) to the 3/2 power.
Figure 6.

Floating potential increase (V)

Azimuthal distance (cm)
3-D NUMERICAL MODELING OF ICRF ANTENNAS IN PHAEDRUS-B

Kwok Ko, William Grossmann, and Adam Drobot
Science Applications International Corporation
McLean, Virginia

and

Richard Majeski, T. Tanaka, and Noah Hershkowitz
University of Wisconsin
Madison, Wisconsin

* Present address:
SLAC
P.O. Box 4349
Stanford, CA 94305
Future Plans

- High-power operation with plasma in RFTF is planned to more directly demonstrate the power-handling capabilities of the folded waveguide.

- Effects on edge plasma density and temperature, and dc and rf sheath potentials will be measured in RFTF for direct comparison with similar measurements using a loop antenna.[3]

- A demonstration experiment on a large tokamak, such as TFTR or Tore Supra, is desirable.

Summary

- The folded waveguide produces an rf magnetic field pattern very similar to that of a loop antenna. Thus, we expect coupling to a plasma to be efficient.

- The electrostatic field of the folded waveguide is 2 orders of magnitude less than that of a loop antenna. This is because circulating power is in the interior of a FWG, well separated from the plasma surface. This may have a favorable effect on impurity production and allow higher coupled power flux for the FWG than for a loop antenna.

- Coupling measurements verify that the FWG behaves electrically like a simple, unfolded, resonant cavity.

- High-power operation has been demonstrated.
High-Power Tests

• Achieved 200 kW pulsed in vacuum. So far no breakdown limit has been found during vacuum tests. For expected plasma loading, this would imply multi-megawatt operation.

• Multipacting observed in the interior of the FWG for power levels between 1 and 15 watts, but disappeared after conditioning.

• At higher power (10–100 kW) a discharge in the vicinity of the top and bottom exterior surfaces of the FWG was observed. This too could be eliminated after conditioning.

• At high gas pressure (1.5 \times 10^{-4} \text{ Torr}) 100 kW pulses were sustained without breakdown.
Variation of measured reflection coefficient with vane-toucher position is consistent with intended tuning mechanism. I.e., there is cancellation of input reactance at the matching position.
Coupling Measurements

Load was varied by changing distance between FWG and plastic RF load.

Variation of vane-toucher position for optimum match (measured points) agrees well with model (solid line).
Simple Calculation of Optimum Coupler Position

The voltage applied to the central conductor is related to the input power $P$ by

$$V_{\text{coax}} = \left(\frac{2}{P} \frac{1}{Z_0}\right)$$

$Z_0$ is the characteristic impedance of the feed line.

The voltage on the central vane, at the position of the coupler (d), is related to the maximum electric field by

$$V_{\text{coupler}} = a E_{\text{max}} \sin \frac{\pi \delta}{L}$$

$L$ is the length of the vane, and $a$ is the separation between the side wall and the vane. The two voltages, $V_{\text{coax}}$ and $V_{\text{coupler}}$, must be equal.

The cavity $Q$ is the energy stored in the cavity, divided by the energy delivered per cycle

$$Q = \frac{2\pi f}{P} \int \varepsilon_0 E^2 \, d(\text{vol})$$

By carrying out the integration over the cavity volume, one finds a relationship between the optimum position for the vane toucher and the cavity $Q$.

$$\delta = \frac{L}{\pi} \sin^{-1} \left( \frac{a W L \pi \varepsilon_0 Z_0 f}{a^2 Q} \right)^{1/2}$$
Geometry for Coupling Loop
Discussion of Electric Field Comparison

- Measurements on loop antenna were made in air at low power, and then scaled for 100 kW, but measurements on FWG were made at 100 kW under vacuum (4 x 10^{-6} Torr).
- Peaking of signal near bottom edge of FWG may be related to ionization observed in that region.
- Frequencies were not the same.
- Probe was closer to Faraday shield on loop antenna than to surface of FWG, but distance from current strap on loop antenna was about the same as distance to surface of FWG.
- Nevertheless, the difference in potential is two orders of magnitude, which is quite significant.
Electric Fields
Comparison with Loop Antenna

**Graph 1:**
- **Loop Antenna**
  - $R_t \sim 50 \, \text{m} \Omega$
  - unloaded
  - 42 MHz

**Graph 2:**
- **Folded Waveguide**
  - unloaded
  - 80 MHz

*Potential (V) at 100 kW 1 cm from Faraday Shield*

*Distance from the shorted end (cm)*

*Potential (V) at 100 kW 1 cm from Faraday Shield*

**Legend:**
- Top = middle of FWG
- Bottom = 7 cm above FWG edge

*Used by permission from reference [3]*
The FWG is driven at a frequency such that the distance from front plate to back plate is one-half of a guide wavelength when front face is closed, and only slightly perturbed from this distance when openings are present. This results in current maxima and voltage minima at each end. With openings, nearly all of the current must flow along outside face as indicated because, since opening is near a voltage minimum, significant displacement current cannot flow. Thus, even the closed sections contribute to the coupled field.
Vertical and Radial Variation of RF Magnetic Field

- Variation with height is smooth.

- "Radial" profile is very similar to that of a loop antenna.
Variation of Magnetic Field Along Zig-Zag Path

With FWG closed off using solid plate, magnetic field measured just inside the front wall has this dependence and reverses direction from one fold to the next.

With polarizing plate attached, magnetic field measured just outside the plate has this dependence and does not reverse direction from one fold to the next.
## Folded Waveguide Parameters

<table>
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<th>Value</th>
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<td>Vane-to-Vane Distance</td>
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<td>Back-Plate Motion Range</td>
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<tr>
<td>Copper Coating</td>
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Folded Wave Guide Coupler

- Movable Coax Feed
- Driver Plate
- Movable Back Plate
- Folded Wave Guide Cavity
- Polarizing Plate

Side View

- Coax
- Vane Toucher

Top View

- Vane Toucher
- Center Conductor
Potential Advantages of the Folded Waveguide Structure as an ICRF Coupler

- Relatively simple structure. Should be easy to withstand disruption forces because there is no current strap to support.
- Easy to cool, because cooling channels can reach any part of the structure by passing only through metal.
- May not require a separate Faraday shield, which further simplifies the mechanical and thermal design issues.
- Insulators are not required in the vicinity of the plasma.
- Particularly attractive at higher frequency (> 80 MHz) where loop antennas begin to have difficulty.
The Folded Waveguide Concept

- The basic idea involves “folding” a simple rectangular waveguide that has a much greater width than height in order to form a more compact structure.
- This is an adaptation of a concept known as a “folded waveguide” (FWG) reported by Barrow and Schaevitz in connection with low-frequency waveguide transmission systems.\(^1\)
- T. L. Owens proposed using a resonant structure based on the FWG concept to couple ICRF power to a fusion device.\(^2\)

\(^1\) W. L. Barrow and H. Schaevitz, “Hollow pipes of relatively small dimensions,” *AIEE Trans.*, vol. 60, p. 119 (1941)


CONCLUSIONS

- VACUUM FIELDS CAN BE COMPUTED FOR REALISTIC ANTENNA CONFIGURATIONS

- FIELD CONTOURS AND PROFILES CAN BE USED TO PROVIDE INSIGHT AND UNDERSTANDING OF CURRENT ANTENNA GEOMETRY

- COMPUTATIONAL TOOLS CAN PROVIDE VALUABLE INFORMATION DURING DESIGN, ANALYSIS AND EVALUATION PHASE OF FUTURE ANTENNA EFFORTS
B_x PROFILE IN BETWEEN TWO FARADAY BARS;
LOWEST AND NEXT TO LOWEST, (0 - 0)
$B_x$ PROFILE IN FRONT OF STRAP AT MID-PLANE (0 - 0)
By CONTOURS AT MID-PLANE, z = 0, (0 - 0)
B_x CONTOURS AT MID-PLANE, z = 0 (0 - 0)

Contour Levels

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$E_z$ PROFILE IN FRONT OF FARADAY SHIELD, $z = 0$ ($0 - \pi$)
$B_x$ PROFILE IN FRONT OF FARADAY SHIELD, $z = 0$ ($0 - \pi$)
$E_z$ PROFILE IN FRONT OF STRAP IN MID-PLANE (0 - $\pi$)
Ey CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - \pi)

Contour Levels

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**B₂ CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - π)**
By Contours at 4th Faraday Bar from Top (0 - π)

Contour Levels

| A: -3.9843e+08 |
| B: -3.5696e+08 |
| C: -3.1449e+08 |
| D: -2.7251e+08 |
| E: -2.3054e+08 |
| F: -1.8857e+08 |
| G: -1.4660e+08 |
| H: -1.0463e+08 |
| I: -6.2659e+07 |
| J: -2.0680e+07 |
| K:  2.1284e+07 |
| L:  6.3255e+07 |
| M:  1.0852e+08 |
| N:  1.4720e+08 |
| O:  1.8917e+08 |
| P:  2.3114e+08 |
| Q:  2.7311e+08 |
| R:  3.1508e+08 |
| S:  3.5705e+08 |
| T:  3.9902e+08 |
**B_x CONTOURS AT 4TH FARADAY BAR FROM GOP (0 - π)**

**Contour Levels**

- A: -3.2238e+08
- B: -2.9137e+08
- C: -2.6035e+08
- D: -2.2933e+08
- E: -1.9032e+08
- F: -1.6730e+08
- G: -1.3629e+08
- H: -1.0527e+08
- I: -7.4254e+07
- J: -4.3238e+07
- K: -1.2222e+07
- L: 1.8793e+07
- M: 4.9009e+07
- N: 8.0025e+07
- O: 1.1184e+08
- P: 1.4266e+08
- Q: 1.7367e+08
- R: 2.0489e+08
- S: 2.3590e+08
- T: 2.6692e+08
MAGNETIC FIELD CONTOUR AT z = 0, (0 - π)

A: -4.2947e+08
B: -3.9993e+08
C: -3.7038e+08
D: -3.4084e+08
E: -3.1129e+08
F: -2.8174e+08
G: -2.5220e+08
H: -2.2265e+08
I: -1.9310e+08
J: -1.6356e+08
K: -1.3401e+08
L: -1.0446e+08
M: -7.4918e+07
N: -4.5372e+07
O: -1.5826e+07
P: 1.3721e+07
Q: 4.3267e+07
R: 7.2813e+07
S: 1.0236e+08
T: 1.3191e+08
TFTR SIMULATIONS

- 0 - π PHASING (75, 120 μs)
- 0 - 0 PHASING (75, 120 μs)
TFTR ANTENNA QUADRANT

ARGUS GEOMETRY
GEOMETRY MODELING

TFTR SIMULATIONS

- Antenna Backplane
- Septum
- Graphite Coated Faraday Shield
- Graphite Protection Bumper
- Antenna Current Straps
- Port Flange
- Vacuum Variable Capacitor
- Motion Guide Bearings
- Capacitor's Vacuum System
- 90° Vacuum Feedthrough

Scale: 0 cm 10 cm
APPENDIX C
ELECTRIC FIELD CONTOURS CALCULATED AT THE CENTER CROSS-SECTION OF THE ANTENNA
E$\text{Z}$ CONTOURS CALCULATED AT MID-PLANE OF THE ANTENNA

**Contour Levels**

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Contour Levels

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$E_y$ contours calculated at mid-plane of the antenna.
Ex contours calculated at mid-plane of the antenna.
ELECTRIC FIELD CONTOURS CALCULATED AT THE MID-PLANE OF THE ANTENNA
MAGNETIC FIELD CONTOURS CALCULATED JUST OUTSIDE THE FARADAY SHIELD SUPPORTS
REVIEW OF
SAIC - U. WISCONSIN PROJECT

- RECENT RESULTS
  - IMPROVED GEOMETRY FOR FARADAY SHIELD AND GAP SPACING
  - IMPROVED RESOLUTION FOR GAP - SHIELD REGION
  - ANTENNA "K" SPECTRUM DATA REDUCED FROM CALCULATIONS
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP

ARGUS ($B_z$)

EXPERIMENT ($B_z$)

CURRENT STRAP OUTLINE
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP

ARGUS ($B_X$)

EXPERIMENT ($B_R$)

CURRENT STRAP OUTLINE
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP

ARGUS ($B_y$)

EXPERIMENT ($B_0$)

CURRENT STRAP OUTLINE
$B_r$ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0^\circ$)

ARGUS

ANTENNA

CURRENT STRAP
$B_0$ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0^\circ$)
Comparison Between ARGUS and Experiment

• THE AGREEMENT IS EXCELLENT FOR THE SELF-CONSISTENT CURRENT PROFILE
• 2-D ANTENNA CODE (McVEY) USES PRESCRIBED STRAP CURRENT PROFILE TO OBTAIN AGREEMENT WITH EXPERIMENT. THREE UNIFORM CURRENT STRAPS CARRYING RESPECTIVELY 35% - 30% - 35% OF THE TOTAL CURRENT ARE SPECIFIED.

• ARGUS SIMULATION YIELDS THE SELF-CONSISTENT STRAP CURRENT PROFILE THAT CLOSELY AGREES WITH MEASURED DATA.
NEAR PLANE IS A SYMMETRY PLANE WHICH REDUCES THE SIMULATION REGION BY HALF.

STRAP IS DRIVEN BY 4.5 MHZ POTENTIAL AT LEAD.

FAR PLANE IS THE CROSS-SECTION OF AN INFINITE WAVEGUIDE SUCH THAT ANY IMPINGING RADIATION IS EXPRESSED AS THE COMPLETE SET OF WAVEGUIDE MODES. THIS MODE DECOMPOSITION ALLOWS THE RADIATION FROM THE ANTENNA TO EXIT THE SIMULATION REGION.
ANTENNA COMPONENTS

- ARGUS INPUT DECK ALLOWS COMPLEX STRUCTURES TO BE INTRODUCED, DELETED OR INTERCHANGED WITH RELATIVE EASE.
• DOMAIN DECOMPOSITION OF LARGE PROBLEM INTO 4 BLOCKS

• DIMENSION OF EACH BLOCK = 6 × 53 × 93
REVIEW OF
SAIC - UNIVERSITY WISCONSIN PROJECT

ORIGINAL GOALS

- CAPTURE U. WISCONSIN MODEL ANTENNA GEOMETRY IN AS DETAILED A MANNER AS POSSIBLE
- SIMULATE OPERATION OF ANTENNA AT GIVEN FREQUENCY IN VACUUM
- COMPARE WITH EXPERIMENTAL MEASUREMENTS
- COMPARE WITH 2-D "ANTENNA" CODE
- USE 3-D SIMULATION TO OBTAIN ANTENNA DATA WHICH IS HARD TO MEASURE EXPERIMENTALLY
EFFECT OF FARADAY SHIELD (SLOTTED SIDESHIELDS)

WITH

CONTOUR LEVELS

\[ Z \]

\[ 1.159 \times 10^{-04} \]

\[ 2.537 \times 10^{-02} \]

\[ 5.730 \times 10^{-02} \]

\[ 7.032 \times 10^{-02} \]

\[ 8.195 \times 10^{-01} \]

\[ 1.314 \times 10^{-01} \]

\[ 1.015 \times 10^{-01} \]

\[ 2.180 \times 10^{-01} \]

\[ 2.315 \times 10^{-01} \]

\[ 2.612 \times 10^{-01} \]

\[ 2.906 \times 10^{-01} \]

\[ 3.171 \times 10^{-01} \]

\[ 3.337 \times 10^{-01} \]

\[ 3.603 \times 10^{-01} \]

\[ 3.973 \times 10^{-01} \]

\[ 9.890 \times 10^{-01} \]

\[ 4.639 \times 10^{-01} \]

\[ 5.876 \times 10^{-01} \]

SHORTHING OUT OF \( E_Z \)

WITHOUT

CONTOUR LEVELS

\[ Z \]

\[ 1.836 \times 10^{-00} \]

\[ 2.615 \times 10^{-00} \]

\[ 5.112 \times 10^{-02} \]

\[ 7.760 \times 10^{-02} \]

\[ 9.890 \times 10^{-01} \]

\[ 1.185 \times 10^{-01} \]

\[ 1.570 \times 10^{-01} \]

\[ 1.835 \times 10^{-01} \]

\[ 2.100 \times 10^{-01} \]

\[ 2.395 \times 10^{-01} \]

\[ 2.629 \times 10^{-01} \]

\[ 2.894 \times 10^{-01} \]

\[ 3.159 \times 10^{-01} \]

\[ 3.429 \times 10^{-01} \]

\[ 3.680 \times 10^{-01} \]

\[ 3.853 \times 10^{-01} \]

\[ 4.116 \times 10^{-01} \]

\[ 4.382 \times 10^{-01} \]

\[ 4.601 \times 10^{-01} \]

\[ 5.012 \times 10^{-01} \]
COMPARISON BETWEEN ARGUS AND EXPERIMENT (STRAP WITH FARADAY SHIELD)

*b* Spatial profile along toroidal direction at 4cm above strap
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP

ARGUS ($B_Y$)

EXPERIMENT ($B_0$)

CURRENT STRAP OUTLINE
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP

ARGUS ($B_x$)

EXPERIMENT ($B_r$)

CURRENT STRAP OUTLINE
Comparison Between ARGUS and Experiment

- ARGUS Result
- Test Stand Data

\[ \dot{B}_z \text{ Profile} \]

HALF Strap

- THE AGREEMENT IS EXCELLENT FOR THE SELF-CONSISTENT CURRENT PROFILE
$B_\theta$ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0^\circ$)

ARGUS

ANTENNA

CURRENT STRAP
$B_R$ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0^\circ$)

ARGUS

ANTENNA

CURRENT STRAP
$B_z$ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0^\circ$)
• 2-D ANTENNA CODE (McVEY) USES PRESCRIBED STRAP CURRENT PROFILE TO OBTAIN AGREEMENT WITH EXPERIMENT. THREE UNIFORM CURRENT STRAPS CARRYING RESPECTIVELY 35% - 30% - 35% OF THE TOTAL CURRENT ARE SPECIFIED.

• ARGUS SIMULATION YIELDS THE SELF-CONSISTENT STRAP CURRENT PROFILE THAT CLOSELY AGREES WITH MEASURED DATA.
• DOMAIN DECOMPOSITION OF LARGE PROBLEM INTO 4 BLOCKS

• DIMENSION OF EACH BLOCK = 6 × 53 × 93
ARGUS MODEL

PHAEDEUS B ANTENNA CONFIGURATION
GEOMETRY AND BOUNDARY CONDITIONS

NEAR PLANE IS A SYMMETRY PLANE WHICH REDUCES THE SIMULATION REGION BY HALF.

FAR PLANE IS THE CROSS-SECTION OF AN INFINITE WAVEGUIDE SUCH THAT ANY IMPINGING RADIATION IS EXPRESSED AS THE COMPLETE SET OF WAVEGUIDE MODES. THIS MODE DECOMPOSITION ALLOWS THE RADIATION FROM THE ANTENNA TO EXIT THE SIMULATION REGION.

STRAP IS DRIVEN BY 4.5 MHZ POTENTIAL AT LEAD.
ANTENNA COMPONENTS

- ARGUS INPUT DECK ALLOWS COMPLEX STRUCTURES TO BE INTRODUCED, DELETED OR INTERCHANGED WITH RELATIVE EASE.

BACKPLANE WITH END CAPS
CURRENT STRAP
FARADAY SHIELDS
SOLID SIDE SHIELDS
SLOTTED SIDE SHIELDS
- **LARGE PROBLEMS ARE HANDLED THROUGH THE USE OF A BLOCK STRUCTURE IN LOGICAL SPACE**

"DOMAIN DECOMPOSITION"

- **ALGORITHM SELECTION HAS BEEN DONE TO DEFINE TECHNIQUES WHICH PERMIT GLOBAL SOLUTIONS IN THE PHYSICAL SPACE BY SEQUENCE INDEPENDENT OPERATIONS IN EACH BLOCK FOLLOWED BY SHARING OF DATA AT INTERFACES.**

- **COMPATABILITY WITH PARALLEL COMPUTER ARCHITECTURES**
• TIME-DOMAIN ELECTROMAGNETIC FIELD
  SOLVER

\[ \frac{\partial \vec{B}}{\partial t} = - \nabla \times \vec{E} \]

\[ \frac{\partial \vec{D}}{\partial t} = \nabla \times \vec{H} - \vec{J} - \sigma \cdot \vec{E} \]

where \( \vec{D} = \varepsilon \vec{E}, \vec{B} = \mu \vec{H} \),

and \( \nabla \cdot \vec{D} = \rho, \nabla \cdot \vec{B} = 0 \) are treated as constraint equations.

METHOD: EXPLICIT LEAPFROG INTEGRATION WITH
DISTRIBUTED POISSON CORRECTION
• THREE DIMENSIONAL SIMULATION MODEL WITH MODULAR BACKBONE ARCHITECTURE

  - SYSTEM MODULES SHARED BY ALL PHYSICS PACKAGES
    
    INPUT
    OUTPUT
    DATA MANAGEMENT
    MEMORY MANAGEMENT
    RUN TIME INTERACTION
    DIAGNOSTICS

  - PHYSICS PACKAGES
    
    ELECTROSTATIC SOLVERS
    TIME-DOMAIN ELECTROMAGNETIC SOLVER
    FREQUENCY-DOMAIN ELECTROMAGNETIC SOLVER
    ELECTROMAGNETIC PARTICLE-IN-CELL SOLVER
    HYDRODYNAMIC SOLVER
    INTEGRATED SIMULATIONS
THE ARGUS SIMULATION CODE

- RESPONSE TO NEED FOR 3-DIMENSIONAL MODELING INVOLVING ELECTROMAGNETIC FIELDS AND PARTICLE MOTION, IN COMPLEX GEOMETRICAL CONFIGURATIONS.

  - INSIGHT FOR RESEARCH ORIENTED PROBLEMS

  - DESIGN FOR DEVICE ENGINEERING

- IMPROVED PERFORMANCE OF COMPUTERS IN SPEED AND MEMORY MAKES BOTH APPLICATIONS PRACTICAL.
OBJECTIVE: TO MODEL IN 3-D THE VACUUM NEAR FIELDS OF AN ICRF ANTENNA CONFIGURATION IN USE ON CURRENT AND PLANNED FUSION EXPERIMENTS.

METHOD: ARGUS - 3-D PLASMA SIMULATION CODE.

RESULT: FOR THE UNIVERSITY OF WISCONSIN PHAEDRUS-B ANTENNA, ARGUS RESULTS AGREE CLOSELY WITH EXPERIMENTAL DATA.

CONCLUSION: WORK DEMONSTRATES THE POTENTIAL OF FULL 3-D SIMULATION AND WARRANTS FURTHER DEVELOPMENT OF THIS CAPABILITY FOR ICRF ANTENNA DESIGN (E.G., INCLUDE PLASMA EFFECTS).
Dr. William Grossmann is presently Chief Operations Scientist for the Applied Physics Operation, Science Applications International Corporation. He also holds the positions of Research Professor of Plasma Sciences at New York University's Courant Institute of Mathematical Sciences (CIMS) and Adjunct Professor of Applied Science in the Department of Applied Science. Prior to joining SAIC, Dr. Grossmann was the Associate Director, Magneto Fluid Dynamics Division, CIMS, where his duties included the direction of scientific work, initiation of new research areas, securing and managing contract and grant research. While at NYU, he was elected to the position of Chairman, Spring College on Plasma Physics, International Center for Theoretical Physics, Trieste, Italy. Significant previous positions held by Dr. Grossmann include Senior Scientist, Max-Planck-Institut fur Plasma Physik, Garching, West Germany (1969 - 1974), Assistant Professor of Applied Mathematics, Richmond College of the City University of New York (1967 - 1969), and Aerospace Technologist, National Aeronautics and Space Administration, Langley Research Center (1958 - 1965).

Dr. Grossmann received his undergraduate and graduate degrees in aeronautical and aerospace engineering from Virginia Polytechnic Institute and State University, and upon receiving a NASA award for his Ph.D. dissertation, spent a postdoctoral year in applied mathematics at NYU's Courant Institute. He also received the Sigma Xi Research Award from WI & SU in 1964.

Dr. Grossmann has been a consultant to Bell Aerosystems Company, JAYCOR, Princeton Plasma Physics Laboratory, lecturer to the University of Padua's Institute of Electronics Fusion Laboratory, visiting staff member of the Los Alamos National Laboratory, visiting senior fellow of the University of Maryland's Center for Theoretical Physics, and member of the advisory board of the University of Texas' Institute for Fusion Studies. He was twice elected to the office of secretary-treasurer for the American Physical Society Division of Plasma Physics and was named a fellow of the society in 1983.

Dr. Grossmann's work experience includes experimental and theoretical aerodynamics, plasma physics and fusion research at national and foreign laboratories, private industry and in the university. He has published widely in these fields and is presently organizing a series of books on MHD and plasma physics as a senior editor for Cambridge University Press. While at the Langley NASA Laboratory, Dr. Grossmann developed an MPD arc jet which later became the basis for research in MPD space propulsion at NASA. At the Max-Planck-Institut, he was co-discoverer and developer of the concept of electromagnetic wave energy absorption in the continuous spectrum of Alfven waves in a fusion plasma; present day rf heating experiments of fusion plasmas based on this discovery are actively being carried out. More recently, his interests have turned to large scale computing and simulation and he is leading an SAIC effort in the 3-D analysis and simulation of radio frequency heating antennas for fusion devices.

Dr. Grossmann has participated in many technology and science studies and surveys. He was chairman of the science subpanel established by DOE's Office of Program Assessment to assess the status and progress of the Office of Fusion Energy's Research and Development Program. Dr. Grossmann has also carried out a study under DARPA funding to assess the role large scale supercomputing will play in enhancing productivity and manufacturing technology in American industry.
Curriculum Vitae

WILLIAM GROSSMANN

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 556-7323

EDUCATION:

B.S., Aeronautical Engineering, Virginia Polytechnic Institute and State University, June 1958.
M.S., Aeronautical Engineering, Virginia Polytechnic Institute and State University, June 1961.
Ph.D., Aerospace Engineering, Virginia Polytechnic Institute and State University, June 1964.

PROFESSIONAL EXPERIENCE:

1983 - Present Adjunct Professor of Applied Science, Department of Applied Science New York University.
1977 - Present Research Professor of Plasma Sciences Courant Institute of Mathematical Science New York University.
1977 - 1987 Associate Director, Magneto-Fluid Dynamics Division, Courant Institute of Mathematical Sciences, New York University.
1974 - 1977 Assistant Director, Magneto-Fluid Dynamics Division, Courant Institute of Mathematical Sciences, New York University.
1967 - 1969 Assistant Professor of Applied Mathematics, Richmond College of City University of New York.
1964 - 1967 Associate Research Scientist, Magneto-Fluid Dynamics Division Courant Institute of Mathematical Sciences, New York University.
1958 - 1964 Aerospace Technologist, National Aeronautics and Space Administration Langley Research Center.
1959 Instructor in Aeronautical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
CONSULTING EXPERIENCE:

1973 - Present Visiting Staff Member, Los Alamos National Laboratory Los Alamos, New Mexico.
1971 - 1973 Consultant and Lecturer, University of Padua, Institute of Electronics, Ionized Gas Laboratory, Padua, Italy.
1974 - 1975 Visiting Senior Fellow, University of Maryland Center for Theoretical Physics.
1979 - 1987 Senior Consultant, Science Applications International Corporation (SAIC), La Jolla, California, and McLean, Virginia.
1982 - 1987 Consultant, JAYCOR, La Jolla, California.
1984 - present Director of Science and Technology, William Dunk Partners, New York, New York.
1979 - 1981 Member of DOE Energy Research Advisory Board, Sub-Panel for Research and Development, Appointed by Secretary of Energy.
1983 - 1987 Elected Chairman, Spring College on Plasma Physics, International Center for Theoretical Physics, Trieste, Italy.
1983 to 1986 Elected to Advisory Board of Institute for Fusion Studies, University of Texas Austin, Texas. Appointed Vice-Chairman (1984).

ACADEMIC AND PROFESSIONAL HONORS:

1958 Monteith Award, Virginia Polytechnic Institute and State University
1958 Sigma Gamma Tau, Honorary Aeronautical Society
1964 SIGMA XI Research Award

PROFESSIONAL SOCIETIES:

PUBLICATIONS AND PRESENTATIONS:


17. “Review of High Beta Plasma Stability,” Ibid. (Abstract only.)


27. “Spatial Landau Damping in Ideal MHD - II Laboratory Applications,” (with J. Tataronis), ibid. (Abstract only.)


34. "Stability of Reverse Field Pinch Configurations," (with S. Ortolani), Paper F8, ibid.


89. "A 2-D Transport Code for the Reversed Field Theta Pinch," (with R.N. Byrne, J. Saltzman), Annual Meeting of the Division of Plasma Physics of the APS, Boston,


120. “The Dynamo Effect in RFP’s” (with Eliezer Hameiri), ibid., 1357.

121. “Propagazione Ondosa alla Risonanza Ibrida Inferiore, Attraverso uno Sfondo di Plasma Stocastico” (with Renato Spigler), LXX Cong. SIF, Ott. 1984, Genove (Lunedì-Sezione 6, 155).


129. “Scattering di onde ibride inferiori da parte di fluttuazioni aleatorie di densita in plasmi disomogenei,” S.I.F., LXXI Congresso Nationale Trieste, 3-8 October 1986 (Abstract only, with R. Spigler.)


137. "Linear Stability of the Dense Z-Pinch," ibid, 1409 (with W. Ellis).


KWOK CHUEN KO

San Jose State University: B.A. (1972)
University of Southern California: Ph.D. (1978)

Dr. Ko is a research physicist in the Plasma Physics Division at Science Applications International Corporation. His prior experience at the MIT RF theory and computation groups includes linear and nonlinear wave propagation in nonuniform media as well as radio-frequency heating of fusion plasmas. Since joining SAIC, he has carried out theoretical and numerical studies of a variety of problems. These range from nonlinear wave excitations in space plasmas with emphasis on parametric decays to microwave breakdown of air and to particle simulation of plasma erosion opening switches. Currently, he is involved in a design study for a 100MW gyrokystron by providing key numerical and theory support.
Curriculum Vitae

KWOK CHUEN KO

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 734-4077

EDUCATION:

Ph.D., Electrical Engineering, University of Southern California, 1978
M.S., Electrical Engineering, University of Southern California, 1974
M.A., Physics, University of Southern California, 1974
B.S., Physics, San Jose State University, 1972

EXPERIENCE:

1978-1981 Postdoctoral Fellow, MIT.
1973-1978 Research Assistant, USC.
1972-1973 Teaching Assistant, USC.

PUBLICATIONS:


# CURRICULUM VITA

THE COLLEGE OF STATEN ISLAND

1. NAME: Michael E. Kress  
   COLLEGE: College of Staten Island

2. RECOMMENDATION FOR: Reappointment

   TITLE: Associate Professor  
   DEPARTMENT: Computer Science

   EFFECTIVE DATE: September 1, 1988  
   TERMINATION: August 31, 1989

   SALARY: (Subject to financial ability)

3. HIGHER EDUCATION

   A. Degrees

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<td>1/83-6/85</td>
<td>Ph.D. Computational Fluid Dynamics</td>
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<td>New York University</td>
<td>9/80-1/83</td>
<td>M.S. Mathematics and Computer Sciences</td>
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<td>Richmond College</td>
<td>9/71-6/75</td>
<td>M.A. Environmental Science</td>
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   B. ADDITIONAL HIGHER EDUCATION

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<td>9/69-6/71</td>
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   C. PROFESSIONAL COURSES


4. EXPERIENCE (OTHER THAN CUNY)

B. OTHER

<table>
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<tr>
<th>INSTITUTION</th>
<th>DATES</th>
<th>TITLE &amp; TYPE OF WORK</th>
<th>PT or PT</th>
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<tbody>
<tr>
<td>New York University Courant Institute of Mathematics</td>
<td>2/87-6/87</td>
<td>Research Associate Research Consultant Transonic Flow Project</td>
<td>PT</td>
</tr>
<tr>
<td>New York University Courant Institute of Mathematical Science</td>
<td>12/85-1/87</td>
<td>Research Associate Research Consultant Magneto Fluid Dynamics</td>
<td>PT</td>
</tr>
<tr>
<td>New York University Courant Institute of Mathematical Science</td>
<td>1981-8/85</td>
<td>Research Assistant Research, Magneto Fluid Dynamics (MFD)</td>
<td>FT</td>
</tr>
<tr>
<td>New York University Courant Institute of Mathematical Science</td>
<td>1978-1981</td>
<td>Research Associate Research, MFD</td>
<td>FT</td>
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5. ACADEMIC AND PROFESSIONAL HONORS

1. PSC-CUNY Research Grant 1988-89, Nonlinear Phase Magneto-tail Reconnection ($5,000 for student support).

3. Research Grant of Cray Supercomputer Resources from Department of Energy 1988 (52 hours for 1 year).

4. Research Please Time Grant, College of Staten Island 1987.

5. Dean's Award College of Staten Island, March, 1986.


6. REFEREEED PUBLICATIONS

B. REFEREEED ARTICLES


C. REFEREEED PROCEEDINGS


6.5 PUBLICATIONS IN PROGRESS


4. "Particle Simulation of Migma Reactor", (with Alfred Levine)


7. OTHER PUBLICATIONS:

A. NON-REFEREED ARTICLES, BOOKS, & PROCEEDINGS


8. OTHER PROFESSIONAL ACTIVITIES:

A. Technical Reports


2. Research Grant, "Plasma Simulations", DOE 1/88 for Supercomputer Resources for CSI.


5. Research Grant Proposal "Numerical Simulation of Non-Linear Phase of Magnetotail Reconnection", submitted to Office of Naval Research ($150,000), March 1987.


C. CONSULTANCIES


2. Courant Institute, N.Y.U., Dr. Kurt Riedel, (Feb. 1988 to present).


5. The Staten Island Air Pollution and Respiratory Disease Study, College of Staten Island, Environmental Science Department, (October 1986 to Present).


D. PAPERS PRESENTED


ERIC J. HOROWITZ

Yeshiva University, New York City: B.A. (1982)
University of California at Davis: M.S. (1984)
University of California at Davis: Ph.D. (1987)

Dr. Horowitz is a theoretical physicist with experience in magnetically confined plasmas and charged particle beams. In particular, he has done large-scale computational modeling of plasma and beam systems characterized by non-linear partial differential equations with disparate spacial and temporal scales. These systems required developing new algorithms which effectively used the most modern and powerful computers available.

At Science Applications International Corporation, Dr. Horowitz is currently working on simulating the neutralization and propagation of particle beams propagating in vacuum and through plasmas.

Before joining SAIC, Dr. Horowitz was a computational physicist at the National Magnetic Fusion Energy Computer Center from 1982 to 1987 where he worked on the global stability of field-reversed configuration magnetic confinement devices.

Dr. Horowitz is the author of numerous articles in scientific journals.
Curriculum Vitae

ERIC JACK HOROWITZ

Science Applications International Corporation
1710 Goodridge Drive
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EDUCATION:
B.A., Physics, Yeshiva College, Yeshiva University, 1982
M.S., Engineering/Applied Science, University of California, Davis and Livermore, 1984
Ph.D., College of Engineering, University of California, Davis and Livermore, 1987

EXPERIENCE:
1987-Present Computational Physicist with the Charged Particle Beam Group at the Laboratory for Plasma Research at the University of Maryland. Simulating high brightness charged particle beam production and propagation.
Summer 1981 Quality Assurance Engineer, Litton Industries, Control Data and Guidance Division. Collected and analyzed data on failure rates of guidance systems subjected to environmental stress.
Summer 1980 Quality Assurance Engineer, Litton Industries, Data Systems Division. Verified and recorded diagnostic tests for an integrated computer-controlled communications systems.
Summer 1979 Environmental Test Technician, Litton Industries, Data Systems Division. Tested durability of various electronic components to inertial shock, temperature shock and vibration. Also tested computer guidance systems for susceptibility to and emission of electromagnetic radiation.
INVITED TALKS:


PUBLICATIONS:


PAPERS PRESENTED:


ALAN MANKOFSKY

Cornell University: M.S. (1979)

Dr. Mankofsky is a computational plasma physicist with in-depth experience in the numerical modeling of various plasma and beam-plasma configurations and electromagnetic devices. His background also includes theoretical work and close collaboration with experimentalists. He is currently involved in the design, development, and application of multidimensional numerical simulations in the areas of particle beam and microwave propagation, plasma dynamics, diode and device physics, laser isotope separation, accelerator design, and space plasmas. He is also a member of various corporate and governmental committees and working groups involved in long-range strategic planning for scientific computer facilities and data communications networks.

Prior to joining SAIC's Plasma Technology Division, Dr. Mankofsky was a Graduate Research Assistant in the Laboratory of Plasma Studies at Cornell University, where he specialized in the development of large-scale plasma simulation codes under the direction of Professors R.N. Sudan and J. Denavit. His work at Cornell included multidimensional particle and hybrid models as applied to several problems in both magnetic and inertial confinement fusion. In 1975, he was employed by A-Division, Lawrence Livermore National Laboratory, where he participated in the development of multidimensional MHD simulation models.

Dr. Mankofsky is an author or co-author of numerous publications, reports, and presentations in the area of numerical simulation of plasmas, intense particle beams and rings, and electromagnetic devices. He is a member of Phi Beta Kappa, Sigma Pi Sigma, Pi Mu Epsilon, the Society for Industrial and Applied Mathematics, and the Divisions of Plasma Physics and Fluid Dynamics of the American Physical Society.
Curriculum Vitae
ALAN MANKOFSKY
Science Applications International Corporation
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(703) 734-5596

EDUCATION:
B.A., Physics, summa cum laude, New York University, 1976
M.S., Applied Physics, Cornell University, 1979
Ph.D., Applied Physics, Cornell University, 1982
Thesis: “Numerical Simulation of Ion Rings and Ion Beam Propagation”

PROFESSIONAL EXPERIENCE:
1982-Present Senior Scientist/Computational Physicist, Plasma Technology Division, Science Applications International Corporation, McLean, VA. Conducting numerical and theoretical investigations into various problems of current interest in plasma physics and electromagnetics, including particle beam and microwave propagation, plasma dynamics, diode and device physics, laser isotope separation, accelerator design, and space plasmas. Co-author of the ARGUS simulation code. Also participating in corporate and governmental long-range planning activities for scientific computing facilities and data communications networks.

1976-1982 Graduate Research Assistant, Laboratory of Plasma Studies, Cornell University, Ithaca, NY. Responsible for development of the RINGA particle code and the CIDER hybrid code; applied these codes to various problems in magnetic and inertial confinement fusion (R.N. Sudan, thesis advisor; J. Denavit, thesis consultant). Also managed computer facilities for the Laboratory.

1975-1976 Computer System Manager, Physics Department, New York University, New York, NY. Responsible for management, operation and maintenance of HP-3000 computer system.

1975 Computational Plasma Physicist, A-Division, Lawrence Livermore National Laboratory, Livermore, CA. Development of new physics routines and packages for the multidimensional MHD code ANIMAL.

PROFESSIONAL ORGANIZATIONS:
Division of Plasma Physics, American Physical Society
Division of Fluid Dynamics, American Physical Society
Society for Industrial and Applied Mathematics
HONORS AND AWARDS:

New York University Dean's List (1972-1976)
National Merit Scholar (1972-1976)
New York State Regents Scholar (1972-1976)
New York University Brown Scholar's Award in Physics (1975)
New York University Founder's Day Award (1976)
Phi Beta Kappa (1976)
Sigma Pi Sigma (1976)
Pi Mu Epsilon (1976)

PUBLICATIONS AND PRESENTATIONS:


PUBLICATIONS:


ADAM T. DROBOT

As manager of the Applied Physics Operation in SAIC's Technology Research Group, Dr. Drobot is responsible for supervision of approximately fifty research physicists. His main research interests are the development of advanced numerical simulation methods based on particle-in-cell techniques, and the application of these methods to complex physical systems involving the interaction of electromagnetic fields with high density energetic particles. He has contributed recently to work on collective ion acceleration, free electron lasers, and the basic theory and simulation of high power microwave sources such as gyrotrons, magnetrons and klystrons. He is currently involved in problems of power flow in high-power magnetically insulated transmission lines and in intense relativistic diodes.

Dr. Drobot is a frequent contributor to the literature and conference presentations on the above topics and is co-holder of a patent on the Converging Guide Accelerator.

Thorough cooperative efforts with the university community, he has helped supervise graduate students in their doctoral work. These include: A. Friedman with R. Sudan at Cornell, A. Palevsky with G. Bekefi at MIT, T. Hughes with E. Ott at Maryland, and R. Jackson with W.O. Doggett at North Carolina.

Dr. Drobot received the B.S. Degree in engineering physics from Cornell University, Ithaca, N.Y., in 1968 and the Ph.D. degree in physics from the University of Texas at Austin in 1974.

Dr. Drobot is a member of the American Physical Society, Sigma Phi Sigma, and Phi Kappa Phi.
Curriculum Vitae

ADAM THOMAS DROBOT

Science Applications International Corporation
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McLean, Virginia 22102
(703) 734-5595

EDUCATION:

B.S. Engineering Physics, Cornell University, Ithaca, N.Y. (1968)
Ph.D. Plasma Physics, University of Texas at Austin (1975)
Dissertation, "Theory and Experiments in the Simulation of Collisionless Plasmas"

PROFESSIONAL EXPERIENCE:


1974 - 1975 Computational Physicist, Austin Research Associates, Austin, Texas, working on problems of collective ion acceleration

1973 - 1974 Research Assistant, Fusion Research Center, Dept. of Physics, University of Texas, Austin, Texas. Analysis of turbulent plasmas, streaming instabilities and plasma heating.


1969 - 1971 Research Assistant, Center for Plasma Physics and Thermonuclear Research, University of Texas, Austin, Texas.

1968 - 1969 Teaching Assistant, Dept. of Physics, University of Texas, Austin, Texas.


PROFESSIONAL ACTIVITIES:

Member of American Physical Society and American Association for the Advancement of Science.

Member of American Physical Society Committee on Applications of Physics, 1987 - present.

Member of Sandia National Laboratory Inertial Confinement Fusion Internal Review Committee, 1980 - present.

Member of Defense Nuclear Agency Missile Flight Theory Committee, 1979 - present.


Member of SAIC Executive Science and Technology Council, 1984 - present.

Member of IEEE Committee on Computer Applications in Nuclear and Plasma Science, 1984 - 1987.

Organizer of Sessions on Computer Applications at IEEE International Plasma Science Conferences, 1980 - present.


Consultant to Hughes Aircraft Co., Microwave Tube Division, Torrance, California.
HONORS AND AWARDS:

Dean's List, Cornell University School of Engineering, 1968
New York State Regents Scholarship, Cornell University, 1964-1968
Sigma Phi Sigma
Phi Kappa Phi

PATENTS:
A Converging Guide Collective Ion Accelerator
A Gyrotron Travelling Wave Amplifier
Emittron Microwave Source

PUBLICATIONS:


Curriculum Vitae

ADAM THOMAS DROBOT
Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 734-5595

EDUCATION:

B.S. Engineering Physics, Cornell University, Ithaca, N.Y. (1968)
Ph.D. Plasma Physics, University of Texas at Austin (1975)
Dissertation, "Theory and Experiments in the Simulation of Collisionless Plasmas"

PROFESSIONAL EXPERIENCE:


1973 - 1974  Research Assistant, Fusion Research Center, Dept. of Physics, University of Texas, Austin, Texas. Analysis of turbulent plasmas, streaming instabilities and plasma heating.


1969 - 1971  Research Assistant, Center for Plasma Physics and Thermonuclear Research, University of Texas, Austin, Texas.

1968 - 1969  Teaching Assistant, Dept. of Physics, University of Texas, Austin, Texas.


PROFESSIONAL ACTIVITIES:

Member of American Physical Society and American Association for the Advancement of Science. Served as consultant to Hughes Aircraft Co., Microwave Tube Division, Torrance, California.

HONORS AND AWARDS:

Dean's List, Cornell University School of Engineering, 1968
New York State Regents Scholarship, Cornell University, 1964-1968
Sigma Phi SigmaPhi Kappa Phi

PATENTS:


RECENT ACTIVITY AND PRESENT DUTIES:

Manager of Applied Physics Operation in SAIC's Technology Research Group. Responsible for supervision of approximately forty research physicists. Actively pursuing research on the modeling of pulsed power diodes for applications to inertial confinement fusion with light ion beams. Involved in numerical simulation and analysis of gyrotron and free electron laser devices. Frequent contributor to the literature and conference presentations on the above topics. He is responsible for the modeling of high power ion beam sources in the NRL Light Ion Beam program and has developed fluid and particle-in-cell codes for this purpose.

Principal Investigator on the dynamics of High Temperature Plasmas contract with the Naval Research Laboratory. As a numerical physicist actively pursuing research in several areas that include, collective acceleration, millimeter and submillimeter sources of microwave radiation, pulsed power devices, and nonlinear plasma phenomena. He has been involved in the development of codes for and in the analysis of free-electron lasers, gyrotron device and high power microwave sources based on relativistic beams. He has a continued involvement in collective acceleration and is co-holder of a patent on the Converging Guide Accelerator. At present he is developing fluid and particle in cell codes for modeling of intense light ion sources to be used as inertial confinement fusion drivers. He has thorough cooperative efforts with the University community and has helped to supervise graduate students in their doctoral work. These include: A. Friedman with R. Sudan at Cornell, A. Palevsky with G. Bekefi at MIT, T. Hughes with E. Ott at Maryland, and R. Jackson with W.O. Doggett at North Carolina. His main interest is the development of advanced numerical simulation methods with particle in all techniques for millimeter and submillimeter devices and relativistic power flow in diodes.
PUBLICATIONS:


