Technical Quarterly Progress Report

**Quarterly Report
July 1 - September 30, 1997**

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Technical Quarterly Progress Report
Advanced Gas Turbine Systems Research
Cooperative Agreement DE-FC21-92MC29061

July 1, 1997 - September 30, 1997

SUMMARY

Major Accomplishments by AGTSR during this reporting period are highlighted below and amplified in later sections of this report:

Administrative

- AGTSR submitted FY98 program continuation request to DOE-FETC for \$4M
- AGTSR distributed 52 proposals to IRB subarea technical contacts for review and evaluation for the 1997 RFP
- AGTSR hosted IRB proposal review meeting at SCERDC on September 4-5, 1997
- AGTSR submitted minutes of the IRB meeting to DOE-FETC along with a list of the top ten proposals short-listed by the IRB
- AGTSR provided no-cost extensions to Purdue (FY94) and Penn State (FY95) until February 1998 and April 1998, respectively
- AGTSR presented annual program review briefing to DOE-FETC on August 29, 1997 at Morgantown, WV

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AGTSR SERVICES

- AGTSR prepared overview slide presentation and update paper and abstract for the ATS Annual Review Meeting
- AGTSR submitted information to DOE-FETC on the NIST Advanced Technology Program (ATP) related to sensors R&D in the power generation industry
- AGTSR submitted consortium update information for the IGTI 1998 technology report booklet
- AGTSR submitted information and points of contacts to DOE-FETC on the German industry-university R&D collaboration
- AGTSR submitted programmatic information to DOE-FETC on university and industrial members currently active in the consortium
- AGTSR submitted information and material to the American Council of Energy Efficient Economy (ACEEE) on the AGTSR consortium

Research

- AGTSR coordinated the review, rank-ordering, and deliberations of all the research proposals from the 1997 RFP
- AGTSR coordinated the distribution of BYU's experimental research database and user's manual for BYU's new computational combustion code
- AGTSR distributed final research project reports from UC Berkeley and VPI to the IRB and DOE-FETC
- AGTSR reviewed UC Irvine's research project and facilities on August 19, 1997 in Irvine, CA
- AGTSR toured Solar Turbines combustion research facilities on August 20, 1997 in San Diego, CA
- AGTSR's PI at Syracuse University conducted turbine blade simulations for GEPS using a 3-D inverse design code

- AGTSR assembled a 27 poster research session and a 5 member industry panel interactions session for DOE-FETC's Annual Review Meeting
- AGTSR provided 4 research success stories to DOE-FETC in materials, aerodynamics, and combustion
- AGTSR organized a land-based gas turbine university research session for the ASME Energy Conference, Houston, TX, in February 1998

Workshops/Education

- AGTSR organized and co-hosted a short course on film-cooling fundamentals and applications on August 6-7, 1997
- AGTSR participated in the NIST sensors workshop on August 25-26, 1997
- AGTSR distributed Combustion Workshop IV proceedings (Volumes I and II) to workshop participants, IRB, and DOE-FETC
- AGTSR began coordination of Combustion Workshop V with UCBerkeley for March 25-27, 1998
- AGTSR began coordination of a specialty TBC Workshop with Stevens Institute of Technology for April-May 1998
- AGTSR had 17 interns finish their industrial internship program with ATS companies at the end of August 1997
- AGTSR was invited to participate in the active combustion control seminar on November 12, 1997 at NASA-Lewis

Membership

- Two new universities expressed interest in becoming AGTSR performing members: Stevens Institute of Technology and the University of North Dakota
  - AlliedSignal Engine Company were invited to renew their membership in AGTSR for 1998
  - Southern Company Services became a trial associate member of AGTSR for the period July 1, 1997 to December 31, 1997
  - Two companies expressed interest in becoming associate members of the AGTSR consortium in 1998: Fluent and Southern Company Services
  - AGTSR through SCERDC was accepted as a member of the Council of Consortia (COC) within the United States
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Membership

During this reporting period, the following institutions became AGTSR Performing Members: Stevens Institute of Technology and the University of North Dakota. AGTSR membership is currently at 92 schools, representing 37 states.

Fluent, Inc. again expressed interest in possibly becoming an associate member of the AGTSR Consortium in 1998. Fluent markets advanced computational software that may be used to analyze problems in gas turbine heat transfer, combustion, and materials processing. AGTSR sent a formal invitation to Fluent during the last reporting period, but they decided to postpone membership consideration until the new cycle in 1998. The point-of-contact for Fluent is Dr. Tom Norton who indicated to AGTSR that they now have enough material and information on AGTSR to make a decision on membership in 1998, which should take place by the late fall of 1997.

On a trial basis until the end of December 1997, Southern Company Services (SCS) in Birmingham, AL. became an associate member of AGTSR from July 1, 1997 through December 31, 1997 for a pro-rated fee of \$3K. The point-of-contact there is Charles Boohaker of the Power Technology Division. Charles indicated to AGTSR that membership in 1998 would have to be reconsidered based on potentially other funding priorities. Sy Ali of Allison (an AGTSR focal point) recommended contacting the vice president of SCS about renewing their membership in 1998. The VP's name is Charles Goodman. AGTSR will follow up with SCS during the next reporting period.

AGTSR also reinvited AlliedSignal Engine Company to become either a full member or an associate member of AGTSR in 1998. In 1997, due to corporate budget cuts, AlliedSignal withdrew their membership. The new points-of-contact are Vinod Nangia of Advanced Technology and Len Myer of Industrial Engines. AGTSR anticipates a decision by the late fall of 1997.

In 1993 through 1996, AGTSR received cost-sharing contributions of \$25,000 from each of the IRB members. The IRB now consists of seven U.S. turbine engine/component manufacturers with EPRI and GRI continuing to act as utility and industrial gas turbine advisors for AGTSR. As of this date, all the IRB members have paid their annual contributions for 1997. Invoices for their 1998 contribution to AGTSR should be released in December 1997.

1993-through-1997 Subcontract Progress

Brigham Young University (BYU), which is a four year combustion effort started in FY93, received a no-cost extension until December 31, 1997. Their final report is due to AGTSR on February 28, 1997. All other FY93 final reports have been received with the exception of LSU (heat transfer), who promised to deliver their report by the end of October 1997. During this reporting period, AGTSR received final reports from VPI and UC Berkeley (UCB) - both FY93 combustion projects. The IRB has approved UCB for a \$32K add-on until December 31, 1997 to continue the testing of their optical probe for measuring air/fuel mixing.

Out of the thirteen FY94 AGTSR research projects, five are still active. The five active FY94 projects are: Purdue and Minnesota (aero-heat transfer), Maryland and UC Irvine (combustion), and Georgia Tech (materials). For the other FY94 projects, final reports have now been received from MIT (heat transfer), Cornell (combustion), Central Florida (materials), and Wyoming and Michigan State (both in heat transfer). By October 31, 1997, final reports are due from: Clemson University (heat transfer - Leylek), Carnegie Mellon (heat transfer - Chyu), and Oklahoma (aerodynamics - Agrawal).

The FY95 Annual Progress Reports are due to AGTSR by the end of October, 1997. The FY96 projects that were selected by the IRB started in June 1997 with their first semi-annual report due on January 31, 1998. Ten FY97 research projects were short-listed by the IRB from the proposals submitted in response to the FY97 RFP. The distribution for the short-listed proposals is: 3 in combustion (UC Irvine, CalTech, VPI), 4 in heat transfer (2 from Purdue, UMinnesota, Carnegie Mellon University), and 3 in TBC's (Georgia Tech, Central Florida, UCSantaBarbara). AGTSR anticipates that all 10 FY97 projects will be supported starting in early 1998, provided full funding is secured from DOE-FETC.

At the request of the IRB, AGTSR is working on a succinct evaluation form for AGTSR progress reports. The purpose of this form is to better assess the value added to industry from the AGTSR university research results, and to improve R&D interactions between the PI's in funded AGTSR projects and the industry subarea contacts in the various technical disciplines. This form is being drafted with the help of a few industrial partners and will accompany the next round of AGTSR progress reports.

FY97 Budget and AGTSR's Continuation Request

AGTSR's 5-year renewal request to continue the AGTSR consortium until the Year 2001 was approved last quarter by both DOE-HQ and DOE-FETC. The balance of the FY97 funds were received on June 13, 1997, bringing the total to \$4M to carry out the consortium until December 31, 1997. The AGTSR FY98 continuation request for \$4M was submitted to DOE-FETC on September 30, 1997. The 1998 request included sections on FY97 accomplishments, financial status of the consortium, and an outline of FY98 goals for AGTSR. A budget-cut impact statement was also submitted to the DOE-ATS team to explain the effects on AGTSR if a potential budget cut was experienced in 1998.

Status of the 1997 RFP Proposals

On May 30, 1997, AGTSR received 52 proposals in response to the 1997 RFP solicitation: 22 in combustion, 20 in heat transfer, and 10 in materials (thermal barrier coatings). The 1997 RFP represents AGTSR's fifth announcement. Proposals were reviewed by the IRB subarea contacts during July and August 1997 and the IRB proposal review meeting was held at SCERDC on September 4-5, 1997. The IRB meeting went very smoothly this year. Prior to the meeting, AGTSR consolidated all the scoring sheets from the IRB members, GRI, and EPRI. This provided a convenient starting point for the proposal deliberations which seemed to expedite the ranking and voting process by the IRB. In fact, the IRB recommended that the meeting at SCERDC be reduced to one full day next year. The IRB short-listed 10 proposals: three projects in combustion, four in heat transfer, and three in thermal barrier coatings. AGTSR anticipates enough funding in FY98 to initiate all ten FY97 awards with a probable start-date of January or February 1998.

AGTSR through SCERDC Becomes a Member of the COC

The Council of Consortia (COC) is an organization of senior executives and managers from the nation's leading research and development and applied technology development consortia. The council's mission is to sustain the vitality of collaborative R&D and technology development, transfer, and application as a means of maintaining and advancing North America competitiveness in key industries. Some of its current members include: EPRI, Ohio Aerospace Institute, GRI, and Sematech to name a few.

In July 1997, SCERDC requested membership into COC after reading about it in an EPRI article written by Ric Rudman - the COO of EPRI and also the current chairman of the COC. In August 1997, SCERDC was accepted into the COC and were invited to their next board meeting on October 7, 1997. Dr. Bob Gilliland, Clemson's Special Assistant to the President, represented AGTSR at this meeting and minutes from the meeting will be forthcoming next quarter. The COC offers SCERDC/AGTSR a unique opportunity to interact with other consortia on a national basis and discuss ways to improve the management of consortia and the effectiveness and focus of university-based research in support of a U.S. gas turbine power industry. Membership in COC is at no cost to AGTSR.

AGTSR Plans to Attend ACC Seminar

The JANNAF (Joint Army-Navy-NASA-Air Force) Interagency Propulsion Committee has organized a technology awareness seminar on Active Combustion Control (ACC) for November 12, 1997 at NASA-Lewis. The POC for this JANNAF meeting is Klaus Schadow of the Navy in China Lake, CA. The purpose of the meeting is to: discuss recent successes in suppressing combustion instabilities and reducing emissions, identify R&D barriers in ACC, and explore ways of improving coordination of future combustion R&D activities funded by the government. DOE representation has been requested by Klaus Schadow and both AGTSR and Geo Richards of DOE-FETC are planning to participate in the meeting as this research area is of extreme interest to the ATS program.

AGTSR Gets Ready for the ATS Annual Review

The ATS Annual Review Meeting will be at DOE-FETC in Morgantown, WV this year. The AGTSR program will be reviewed during the morning of October 29, 1997. AGTSR has a three-part review planned: part 1 is the AGTSR poster session displaying 27 university research projects and their major accomplishments during FY97; part 2 will present an overview on the AGTSR consortium summarizing its research and educational impact over the past five years; and part 3 will be an industry panel consisting of the 5 IRB voting members to discuss specific research successes with AGTSR and highlight any novel AGTSR research results that may have application to post-ATS concepts and advanced gas turbine product development. AGTSR also submitted a paper on the consortium to be published in the ATS Annual Review Proceedings.

AGTSR Submits Four Research Successes to DOE

In September 1997, AGTSR submitted four research successes from the university projects that DOE-FETC would like to expand into "success" viewgraphs. The four projects are: Syracuse University - 3D inverse viscous method used for advanced compressor design; UC Berkeley - novel fiber optic probe with high frequency response for unsteady in-situ measurements of fuel/ air mixedness; Georgia Tech (materials) - cost effective combustion chemical vapor deposition (CVD) process for producing thermal barrier coatings; and Georgia Tech (combustion) - closed loop active control strategy for extending the lean limit and eliminating combustion instability in gas turbine combustors. A possible fifth "success" story is also in the works with UConn (materials), related to their stress measurement techniques in thermal barrier coatings that may have spinoff application for use as an NDI technique to determine initial coating quality and life remaining for service parts.

AGTSR Conducts Their First Short Course

AGTSR's first short course on film-cooling fundamentals and applications took place on August 6-7, 1997 at Clemson's Madren Conference Center. The philosophy of the course was to provide an intensive, two-day foray into film-cooling issues from the fundamental understanding and analysis to the realistic application and incorporation into gas turbine systems. Both experimental and computational approaches were emphasized. Twenty-four people attended the course with the majority being from the ATS companies, and three were from an overseas turbine blade manufacturer in the Netherlands (ELDIM). The instructors for the short course were: Ed Hall/ Allison, Forrest Ames/ Allison, Ron Bunker/ GE, and Terrence Simon/ UMinnesota. Professor Ting Wang of Clemson University also provided a laboratory tour of Clemson's heat transfer research facilities pertaining to advanced gas turbine development. In FY98/ FY99, AGTSR is considering the organization of another short course in the area of thermal barrier coatings with industry and university instructors from the ATS and AGTSR programs. The IRB have already approved AGTSR to pursue the organization of this new short course, time permitting. Additional copies of the film-cooling course notes are also available. If interested, please contact Ms. Donna Kelly at 864-656-2267.

AGTSR Organizes Gas Turbine Session for DOE

At the request of DOE-FETC, AGTSR has organized a gas turbine session for the ASME Energy Sources Technology Conference, February 2-4, 1998, Houston, TX. The session is entitled "Land-Based Gas Turbine Research." The session includes four university research presentations which are representative of the core technologies being pursued by the AGTSR program. The papers are: (1) Central Florida/ Desai/ Performance of Industrial Gas Turbine Materials at High Temperature, (2) Syracuse University/ Dang/ Design of Turbomachine Blades using a 3D Inverse Method, (3) University of Minnesota/ Simon/ Flow and Heat Transfer Measurements in Gas Turbine Film-Cooling, and (4) Penn State University/ Lee and Santavicca/ Fiber Optic Probe for Primary Zone Fuel Distribution Measurements in Actual Turbine Combustors. AGTSR will also chair this session and will handle the review process for all four papers.

AGTSR Conducts Program Review at DOE-FETC

On August 29, 1997, AGTSR presented a four-hour program review to the ATS Product Team at DOE-FETC in Morgantown, WV. The AGTSR presentation consisted of four parts: (1) AGTSR implementation and status update, (2) description of the 41 research projects supported by AGTSR, (3) discussion of select research successes and spinoffs, and (4) the exploitation of AGTSR to meet the R&D needs of other DOE technology-base programs. The ATS Team recommended that AGTSR should probably conduct these detailed reviews on an annual basis, in addition to the programmatic ATS reviews conducted in the fall of each year. If interested in obtaining a copy of the AGTSR presentation, please contact Ms. Donna Kelly, 864-656-2267.

AGTSR Interns Finish-Up at ATS Company Sites

During the summer, starting in June 1997, AGTSR placed 17 interns at ATS company sites to gain hands-on, practical experience in an industrial setting.. To date, AGTSR has placed 37 interns at ATS industrial sites. Of the 17 interns placed this summer, 6 were in the combustion area, 7 in heat transfer, and 4 in CFD/ materials. Most of the 1997 interns have now finished their 10-week program with industry, and AGTSR is currently reviewing the final reports on their projects and the value of the internship experience. Two of the interns will finish-up in November 1997 – one from UCIrvine and the other from UC Berkeley. Professor Wang of Clemson's ME

department will be summarizing each of the intern reports with respect to the pros and cons of their internship experience and a brief description of their technical accomplishments and the projects they worked on during the summer. Professor Wang is assisting AGTSR on a part-time basis on various technical-administrative tasks in support of the consortium. For next year, AGTSR is planning to extend the industrial internship program to 12 weeks and will also consider more expedient ways to pay the interns throughout the summer since several interns had problems in receiving their weekly stipend from the "home" university in a timely manner.

Miscellaneous Activities

AGTSR plans to release their 8th newsletter in November 1997. This newsletter will highlight AGTSR's participation in the ATS Annual Review Meeting, present some of AGTSR's recent research successes, and will summarize the results of the 1997 RFP selection as well as the 1997 Industrial Internship Program that placed 17 interns at company sites during the summer.

Also in November 1997, AGTSR plans to release their first announcement for the fifth combustion workshop co-hosted with UC Berkeley in California. Combustion Workshop V is scheduled for March 25-27, 1998.

During the fall of 1997, AGTSR will be planning a TBC specialty workshop with Professor Woo Lee of Stevens Institute of Technology. This workshop is tentatively planned for the late spring of 1998 but may have to be postponed until the fall of 1998 due to potential conflicts with other materials conferences occurring next spring.

AGTSR will begin coordinating RFP research topics in December 1997 and plans to release the 98RFP in March 1998. Again, the research issues will be solicited from the IRB subarea contacts in each of the AGTSR companies.

AGTSR plans to participate in the Active Combustion Control seminar at NASA-Lewis on November 12, 1998. AGTSR will also visit the P&W/ West Palm Beach combustion R&D group to discuss the AGTSR mission and research projects currently being supported by AGTSR in the combustion instability area – this meeting is tentatively planned for November 18, 1997.

AGTSR is working on a draft white paper with the University of North Dakota with potential collaboration with Allison Engine Company. AGTSR plans to submit the white paper to DOE-FETC and DOE-HQ in the fall of 1997 seeking possible funding support for the post-ATS project in 1998. The white paper deals with a timely research effort on the characterization of

catalytic combustor exit-turbulence and its effect on vane heat transfer with and without film-cooling.

AGTSR attended Clemson's Energy Forum on October 7, 1997 and assisted in coordinating some of the gas turbine industry speakers who talked about their research and education expectations from universities. AGTSR will also be available to assist Clemson's Central Energy Facility (CEF) if it turns out that they select gas turbines as their next power/co-generation capability for the university.