PPSA

Propulsion and Power Systems Alliance

Annual Report
Fiscal Years 2009-2010

DOD-DOE-FAA-NASA

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EXECUTIVE SUMMARY

Traditionally, the Department of Defense (DoD), Department of Energy (DOE), Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA) have separately developed and demonstrated new technologies for enhancing the operating safety, performance, affordability, and environmental compatibility of propulsion and power generation systems. A Memorandum of Understanding was signed in 2004 where the agencies agreed to improve coordination and collaboration in the areas related to propulsion and power systems, in anticipation that this would lead to greater national cooperation among the participants and stakeholders and more effective leveraging of program funding. This provided the framework for the Propulsion and Power Systems Alliance (PPSA). The efforts of this alliance have led to more coordinated and integrated DoD/DOE/FAA/NASA program plans that achieve individual organizational goals and objectives while maximizing investment synergy in areas of common need or interest. It will also lead to the broader application and more rapid transition of advanced propulsion and power generation technologies.

Intellectual collaboration is the basis upon which PPSA is formed and managed. The Leadership Team (LT) is comprised of senior managers from the member government agencies. The roles and responsibilities of the LT include providing the necessary senior leadership and direction to ensure that PPSA achieves its vision. PPSA, through its twelve Technology Area Teams (TATs), which are comprised of technologists and project managers from the member organizations, provides opportunities for government researchers in common areas of interest to regularly meet and exchange information on current research efforts. These interchanges form the basis to explore and plan more formal collaborations, designated as partnerships, where common objectives are defined, available resources from each partner are committed, and roles and responsibilities are delineated along with appropriate intellectual property agreements.

The impact of PPSA, in terms of adding value to the technology development and insertion processes, is measured and assessed using activity metrics (which count PPSA sponsored and supported activities that foster opportunities for collaboration) and accomplishment metrics (which measure the critical efforts that contribute to the prime outcomes or products of the various activities sponsored by PPSA). During this reporting period, all agencies benefited as shown by the key accomplishments in this report.

Turbine engine based propulsion and power systems play a critical role in our country's health, both commercially and militarily. If required technologies are to be developed and transitioned to the US user community in a timely fashion, collaboration between and among government agencies and with external organizations must become an even more important part of the technology development process. As this report demonstrates, PPSA clearly plays a leadership role in identifying, forming, and executing collaborative activities that will contribute to a strengthened technology portfolio.

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INTRODUCTION/OVERVIEW

Vision

The primary goal of the Department of Defense (DoD), Department of Energy (DOE), Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), and Propulsion and Power Systems Alliance (PPSA) is to:

"Improve propulsion and power systems technology program coordination and collaboration among government agencies, e.g., DoD, DOE, FAA, and NASA – leading to a greater national alliance/reliance among the program participants and, therefore, stakeholders resulting in more effective leveraging of existing federal investments in aerospace propulsion and power research and technology."

As the vision statement indicates, PPSA is a Federal government agency centered activity. However, PPSA does openly encourage industry and university participation on a case-by-case basis where the non-government partner's contribution would be critical to the success of a specific collaborative effort.

Collaboration Model

The collaboration model being utilized by PPSA is shown in Figure 1.

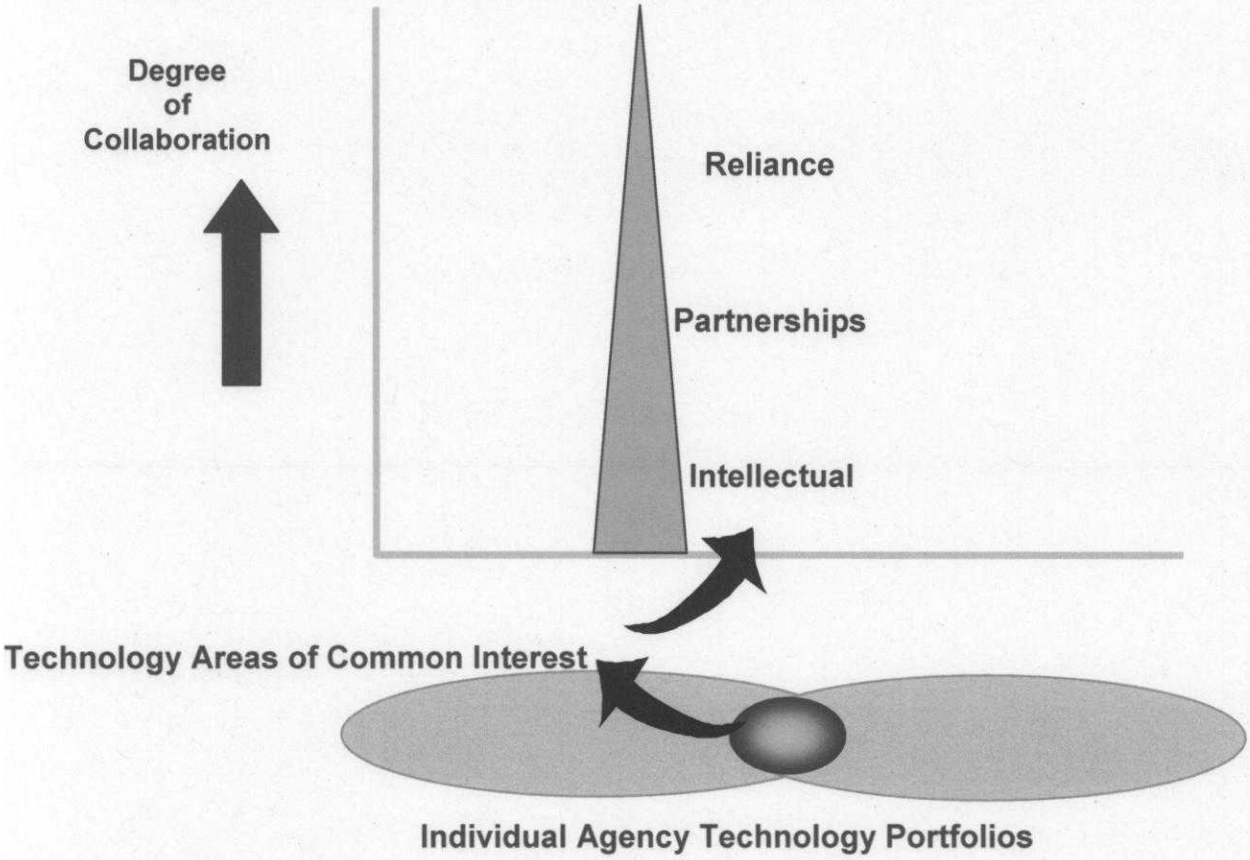

Figure 1. PPSA Collaboration Model

Intellectual collaboration is the basis upon which PPSA is formed and managed. PPSA provides opportunities for government researchers in common areas of interest to regularly meet and exchange information on current research efforts. These interchanges form the basis to explore and plan more formal collaborations designated, as partnerships where common objectives are defined, available resources from each partner are committed, and roles and responsibilities are defined along with appropriate intellectual property agreements.

Partnerships are a shared risk, shared reward effort. Opportunities will occasionally be determined where one agency could choose not to pursue a required technology area as it is being developed by another agency (or agencies). These relationships are defined to be dependencies. Obviously, the higher up one goes in the collaboration triangle, the greater degree of trust which must exist.

Organizational Structure of PPSA

The current organizational structure of PPSA is shown in Figure 2.

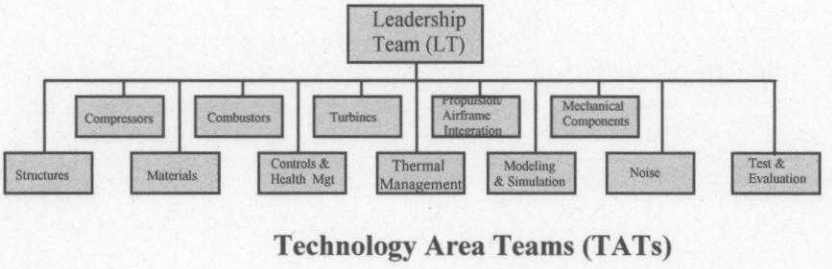

Figure 2. Current PPSA Structure

The Leadership Team (LT) is comprised of senior managers from the member government agencies. The roles and responsibilities of the LT include providing the necessary senior leadership and direction to ensure that PPSA achieves its vision. The LT is led by a chairperson selected from the current LT membership. The chairperson normally serves a two-year term.

The PPSA currently has twelve Technology Area Teams (TATs), which are comprised of technologists and project managers from the member organizations. The TATs are critical to the success of PPSA as they identify, plan, and execute specific collaborative efforts. Currently, PPSA TATs are:

- Combustors
- Compressors
- Controls and Health Management
- Materials
- Mechanical Components
- Modeling and Simulation
- Noise
- Propulsion/Airframe Integration
- Structures
- Test and Evaluation
- Thermal Management
- Turbines

As the listing of TATs indicates, the current emphasis in PPSA is on technologies that are required for future turbine based propulsion systems across the speed range (subsonic through hypersonic) as well as for future ground power systems which incorporate turbine systems.

The number of TATs can change from time to time as new areas are identified that seem opportune for collaborative opportunities or areas are de-emphasized and no longer appropriate for collaboration.

Each TAT has developed its vision in the following statements:

Combustors

The Combustors TAT vision is to be the recognized source of technological knowledge and research for combustion issues of mutual interest to DoD/NASA/DOE/FAA programs.

Compressors

The Compressors TAT investigates technologies that will improve the operability, durability, and efficiency of gas turbine engine compression systems. Advances are also pursued to increase the per-stage loading capability of compression systems without negatively impacting efficiency or operability. The members of the Compressors TAT are interested in a wide range of different technologies that are driven by the vehicle requirements of the various organizations. The Compressors TAT seeks to identify areas in which multiple agencies share interest in developing a particular technology, and then works collaboratively to advance the state of the art in that area.

Controls and Health Management

In collaboration with industries, the Controls and Health Management TAT develops and validates advanced intelligent control system, health monitoring technologies, and accessories that are vital to enhancing the safety, reliability, and operability of aircraft propulsion systems. The overall technical approach of controls and engine health management consists of developing the capability to identify problems and failures before they occur, reconfiguring an engine's control system so that it automatically compensates for problems or failures when they occur, and developing these capabilities in a generic sense so they can be applied to different classes of aircraft. Advanced technologies include both hardware and software. The research interest includes advanced health monitoring technologies using smart sensors located in harsh environments to provide direct measurements of the quantities of interest. When integrated with intelligent controls algorithms, this will allow the aircraft to operate safely in the presence of engine subcomponent failures. *The Controls & Health Management TAT in collaboration with industries will develop, demonstrate, and transition advanced distributed intelligent Engine Control Systems concepts in combination with emerging active control, health management, aircraft subsystem integration, and information technologies to bring new levels of capability, survivability, and affordability to legacy, current, and new engines for expendable, unmanned, and manned weapons systems as well as commercial applications.*

Materials

To effectively coordinate and collaborate on the development of advanced material systems used in the design and manufacture of engine components and power systems.

The focus of the Materials TAT's efforts is development of advanced ceramics, ceramic matrix composites (CMC), alloys, polymers, polymer matrix composites, and thermal and environmental barrier coating systems. Components being addressed include turbine system blades, vanes, disks, combustors, nozzles as well as shape memory alloy actuator components, and solid oxide fuel cells. The team's efforts address advanced component architectures, multi-

functional materials and structures, advanced material processing and manufacturing issues, and performance and durability for use in challenging application environments.

Mechanical Components

The Mechanical Components TAT focuses on coordination of technologies and programs that enable improvements in mechanical components for turbine engines and drive systems. Areas of mutual interest include turbine engine mainshaft bearings, lube system, sump seals, secondary air seals, and engine and rotorcraft gear and drive systems. The Mechanical Components TAT seeks to identify potential collaborative opportunities amongst PPSA agencies with the end goal of meeting increased propulsion performance demands without compromising mechanical system reliability and safety.

Modeling and Simulation

The Modeling and Simulation TAT focuses on technologies that enable improvements in the design, development, and operation of advanced systems. These improvements result in lower development time and cost and in lower risk for infusion of advanced technology. Specific technologies of interest include but are not limited to multi-fidelity system simulation (e.g., zooming), capability based analysis, advanced scientific visualization, cost modeling, collaborative engineering environments, and high performance computing platforms for engineering analysis. It is assumed that modeling and design tools specific to components and subsystems are considered by those respective TATs. Due to the breadth of the topic, the TAT will also identify technologies that will impact future propulsion and power systems but are outside the scope of the other TATs.

Noise

The Noise TAT started in 2005 and is focused primarily on coordinating engine noise research across government agencies and advocating for future work. Members include NASA, Air Force, Navy, and the FAA. One of the objectives is to leverage resources across government organizations to identify noise reduction technologies that can benefit military high performance and transport aircraft. The TAT provides a mechanism to raise awareness of work across a wide range of government sponsors. Solutions for noise reduction are sought that include source noise reduction from the propulsion system and flight operational procedures that can minimize community noise impact. Since most of the noise reduction research supported in the past has been aimed at commercial aviation, applying the technologies to military aircraft are met with limited success due to different requirements. The major noise source for high performance aircraft is the jet noise radiating from the high velocity hot exhaust. Jet reduction remains a challenge for this application due to the need to maintain high performance. For transport aircraft, solutions for commercial engines are easier to implement and in many cases have common engine components.

Propulsion/Airframe Integration

The Propulsion Airframe Integration TAT focuses on coordination and cooperation in technology areas of inlet-airframe, nozzle-airframe, inlet-engine and nozzle-engine integration that are of mutual benefit to the participating organizations. Current areas of common interest include advanced inlet flow control technologies, inlet design tools, inlet-fan integration technologies and performance prediction tools, structurally-integrated exhaust systems with fluidics technology (including incorporation of third stream available from advanced variable

cycle engine concepts) for area and vector control, and large-eddy simulation methods for improved prediction of turbulent quantities in exhaust system flows.

Structures

The Structures TAT focuses on coordination of technologies and programs that enable improvements in structural components across all turbine engine systems. Since Structures is an integral part of the engine system it has maintained close coordination with the other TAT (Materials, Modeling & Simulation, Testing & Evaluation, Compressors, Turbine, & Mechanical Systems). The Structures TAT seeks to identify potential collaborative opportunities amongst PPSA agencies with the end goal of meeting increased propulsion performance demands without compromising engine system reliability and safety. At the end of FY2010 the Structures TAT will be disbanded and integrated into the other TAT teams to best utilize the PPSA time for transfer of information between the various services and agencies.

Test and Evaluation

The Test and Evaluation TAT will improve propulsion and power systems testing technology development through coordination and collaboration. The technology area includes hardware, software, and techniques used to acquire, condition, reduce, and validate data in support of ground/flight developmental and operational testing of turbine engines and components. Topics include but are not limited to instrumentation and control, information technology, computer aided modeling and simulation, test facilities and hardware, test planning, and operator training. Toward this end, the team will leverage existing federal investments in aerospace propulsion and power research and testing. This team will operate in cooperation with other technology area teams who share interests.

Thermal

The Thermal Management TAT utilizes a multidisciplinary systems approach to assess and manage the heat loads of the aircraft, aircraft subsystems, propulsion system and additional heat generated by the payload and/or environment. Creates awareness to base components (compressors, turbines, combustors, nozzles, etc.) and subsystems (fuels, ECS, avionics, electronics, actuators, etc.) to minimize heat loads and increase temperature capabilities. Acquires and manages knowledge/ awareness of thermal management activities across participating organizations (i.e., IAPG, et al) to identify effective collaborative opportunities.

Turbines

The Turbine TAT investigates technologies that will improve the operability, durability, and efficiency of turbine systems. Investigations into increasing stage loading and decreasing required cooling flows for the turbine system without adversely affecting efficiency or operability are of interest. Experimental and computational research methods are used to further the turbine component state of the art. The Turbine TAT seeks to identify potential multi-agency collaborations, which would advance turbine technologies toward transition into future engine systems.

Business Practices

The current business practices of the PPSA are as follows:

Annual Meeting: Each year the PPSA LT plans and executes a multiple day meeting that provides an opportunity for the individual TATs to meet and conduct business as well as meet with other TATs where cross functional collaboration opportunities can be explored. Each TAT is also asked to report out to the LT emphasizing the topics of status, opportunities, and issues for that particular TAT. At these meetings, the LT invites external organizations, which might have collaboration opportunities, to present appropriate overviews in a plenary session. In addition, the LT invites speakers to give featured presentations on various aspects of the collaboration process. This annual meeting also provides an opportunity for the LT to have closed sessions to devote to overall PPSA business.

Monthly telecons: Each month the LT has a one- to two-hour telecon to discuss appropriate PPSA business as well as hear an update from selected TATs. A schedule for these telecons is developed by the Executive Secretary such that each of the TATs has one session with the LT each quarter. It is believed that these brief but regular interactions have improved communication between the LT and TATs and improved the collaborative activities being conducted by PPSA.

LT mid-year meeting: Each February, the LT conducts a one half-day closed session to conduct appropriate business. Typically this meeting is planned to occur the day before the DoD VAATE Steering Committee meeting typically in Washington DC.

Web site: PPSA has an operational publicly available web site: **https://ppsa.grc.nasa.gov**. The web site is used to communicate the PPSA story to external individuals and organizations as well as provide opportunities for organizations to recommend collaboration opportunities to PPSA.

Reports: Every other year the PPSA writes an overview report on status and accomplishments of PPSA. This is a publicly available report but is primarily intended for key stakeholders.

Metrics: The impact of PPSA (in terms of adding value to the technology development and insertion processes) should be measured and assessed using appropriate metrics. The metrics being employed are of two types - activity and accomplishment. As the title suggests, *activity metrics* are those which count PPSA sponsored and supported activities which should foster opportunities for collaboration. *Accomplishment metrics* measure the critical efforts that contribute to the prime outcomes or products of the various activities sponsored by PPSA. Currently, the PPSA metrics are:

Activity Metrics

Technology exchange meetings/telecons held since annual meeting
Invited technology exchange presentations since annual meeting

Accomplishment Metrics

Collaboration working groups established since annual meeting
Formal/informal collaboration agreements established since annual meeting
Partnership efforts initiated since annual meeting
Reliance agreements (formal/informal) established since annual meeting
Collaboration efforts successfully completed since annual meeting
Collaboration efforts terminated since annual meeting.

OVERVIEW OF RECENT ACCOMPLISHMENTS

This report covers the period of FY 2009-2010.

Combustors TAT, Peter Strakey, DOE, National Energy Technology Lab, Lead

1. NETL and NASA jointly looking at pressure-gain combustion for enhanced performance for propulsion and power generation turbines.
2. Active combustion control – Air Force continuing to provide data to NASA from the ACC program.
3. MACCCR – National Academies study on Cyber Infrastructure (CI) for combustion research tapping broad range of govt./academic people for input (AFOSR, DOE, AFRL, NASA). Final report due in November 2010.
4. AFRL, Army and NETL participated in the third NASA Fundamental Aeronautics Combustion Technical Working Group Meeting (held in conjunction with AIAA ASM Meeting, Jan 06, 2010).
5. Third Fuels Summit meeting held Sep. 20-23 2010 at Princeton University. Participation from AFRL, NASA, DOE, NETL, NIST, NSF and Army.
6. Joint NASA / AFOSR combined cycle propulsion center established for hypersonics.
7. AFRL, NASA and ARL are active participants in alternative fuels and are interacting regularly.

Compressors TAT, Anastasia Kozup, Army AATD, Ft. Eustis, VA, Lead
Gregory Bloch, AFRL, WPAFB, 2009 Lead

1. Joint (Air Force, Army, NASA, Navy) support of ADVENT program to include weekly Government IPT telecons, rig test PDRs and DDRs, overall program DDRs, Phase I Final Reviews, Weapon System Contractor Vision Systems reviews, Phase II Authorization-to-proceed deliberations, Phase II IBRs, monthly in person IPT meetings
2. Joint (Air Force, Army, NASA, Navy) support of HEETE program to include PDRs, Mobility/ISR workshops, DDRs, TRRs, periodic TIMs
3. Joint (Army, Air Force, Navy, NASA) support AATE program to include bi-weekly telecons, PDRs, DDRs, TRRs, periodic TIMs
4. Joint (Army, Air Force, NASA) support of FATE Compressor program to include the kickoff, monthly telecons, and PDR
5. Joint (NASA, Army, Air Force, Navy) support of NASA Subsonic Rotary Wing NRA for the Highly Efficient Centrifugal Compressor program to include the PDR, DDR, laser vibrometry, and periodic TIMs
6. Joint (Air Force, Army, Navy, NASA) review of turbine engine OEM Advanced Technology Program Plans
7. Joint (Air Force, Army, NASA, Navy) support of SAE S-16 Committee meetings
8. Joint (Army, Navy) erosion coating working group meeting
9. Joint (Army, Air Force, NASA) support of SHFE program to include periodic TIMs and final program brief
10. Joint (Air Force, Army) Hybrid Disk Workshop

11. Joint (Air Force, Navy, NASA) support of RATTLRS XTE89 to include monthly meetings, the PDR, and DDR
12. Joint (Air Force, NASA) support of STF compressor rig
13. Joint (NASA, Air Force, Army, Navy) support of engine component improvement programs

Controls and Health Management TAT, Al Behbahani, AFRL, WPAFB, Lead

1. Joint (all government and industries) collaboration on Advanced Intelligent Adaptive Affordable Distributed Modular Propulsion Controls for the future (**Distributed Engine Control Working Group (DECWG)** / Aeronautics Sensors Working Group (ASWG): Collaboration between AFRL and NASA
    i. Distributed Intelligent Control (All)

2. Smart Sensors and Open Systems Sensor Suite
3. Universal / Distributed FADEC System Components/Platform
4. Generic Electronic Module
5. High Temperature Capability
6. Smart Actuation Systems
7. 2010 Honeywell High Temperature Electronics Hosted the DECWG in Plymouth, MN . Only Steering Committee Members were invited to attend. Key activities were agreed on Phase I for High Temperature Electronics by the OEM and the FADEC manufacturers with the government.
8. 2010 AFRL Hosted the DECWG in Dayton, April 27-28, 2010. Only Steering Committee Members were invited to attend. Strategic Plan approved establishing goals, objectives and path forward.
9. DECWG Strategic Plan has served as a road map for next year and cited by the working group as the model for all DECWG.
10. Implementation underway with several accomplishments and more planned for the AFRL funded effort on Distributed High Temperature Control systems.
11. Individual studies have revealed that Distributed Engine Controls make a business case.
12. Definitions, objectives, document structure, Functional Architectural Framework for the Distributed Controls of the future.
13. 2010 Honeywell Hosted the DECWG in Phoenix, Feb 17-18, 2010. Only Steering Committee Members were invited to attend.
14. Serious collaborative efforts by DECWG - Continue making progress in distributed control and transfer of the main FADEC to a safer environment. Need to develop a "smart node" that can operate at high temperature. High temp electronics is lynch-pin to realizing distributed controls.
15. 2009 NASA GRC Propulsion Control and Diagnostics Workshop was held in Cleveland, OH Dec 8-10 2009. All Government, OEM, and OEM participated and presented their status. The workshop will help us identify new venues for collaboration and provide opportunities to leverage our efforts
16. SBIR efforts continue to solve building blocks for advanced distributed intelligent sensors, actuators, pumps, accessories. The DECWG shared ideas on the topic of interest. NASA-GRC provided evaluation support for SBIR proposals.
17. DECWG to form consortium for extensive collaborative efforts initially funded by the AFRL.

18. Joint Collaboration (AFRL/NAVAIR) on Adaptive Versatile Engine Technology (ADVENT)/ Highly Efficient Embedded Turbine Engine (HEETE). Collaboration on **ADVENT Program** continues. Joint (AF, Army, Navy, NASA, DARPA) evaluation of ADVENT technology demonstrator engine proposals; 2 contracts awarded for combined values of $524M, including cost share. Integrated Baseline Review (IBR) for Phase II.
    a. Weekly reviews with the entire ADVENT Team
    b. Risk assessment & contractor authorization to proceed for Phase II
    c. Reviewed action items and design requirements for GE and LW and participated at MPR, Bi-weekly meeting on Operability & Supportability, design reviews
19. **Turbine Engine Technology Symposium (TETS)** - Collaborative effort for Distributed Engine Controls
20. **FADEC Working Group** (AFRL/DOD/ Commerce /OEM/FADEC Manufacturers)
    a. Industry Members of the Working Group participated in the WA Intercessional Meeting
    b. "FADEC systems", software, hardware, common goals, proprietary information, etc
21. **Modeling and Simulation** for Gas turbine engine and Controls
    a. Joint Collaboration (TSU, OSU, UC, AVETEC, AFRL, NASA, original equipment manufacturer or original engine manufacturer (OEM) and Airframers)
    b. Integration with TMS and Power (AFRL(Propulsion and Power with collaboration from AVETC and NASA)
22. Joint **SBIR Coordination and Collaboration** (AFRL/NASA/NAVAIR)
23. Distributed Controls smart sensors (NAVAIR/AFRL/GE)
24. Fiber Optic Research (AFRL / NAVAIR/ P&W)
25. **PHM Algorithm Development** – GE/Stanford/ Goodrich (F110) Collaboration between OEM and small business.
26. AFRL Coordination with NASA on actuation concepts / development on a active combustion.
27. AFRL coordination with universities on **Active Combustion Control**, control algorithms (University of Cincinnati, OSU, Georgia Tech, Stanford) Joint Collaboration (AFRL/NASA) on Active Combustion Control System (ACCS) . AFRL/ Goodrich/Parker/OSU/Stanford/GIT/Spectral Sciences on ACCS
28. Mide Technology and GE Aviation
29. Goodrich and GE Aviation
30. Parker and Pratt & Whitney
    a. High Temperature Combustion Measurement (Purdue, AFRL, SSI, Parker, Goodrich, Advanced Fuel Research)
31. Joint Collaboration (AFRL/ GE/ Stanford) on PHM **Algorithm Development**
32. Joint Collaboration (Intelligent Automation Corporation now is part of Honeywell (IAC)/Honeywell /AFRL/NASA/Hamilton-Sundstrand, P&W, Boeing) PHM Generic Propulsion Health Management for vibration and integrate oil debris monitor with vibration for Joint Strike Fighter (JSF) engine bearing health monitoring
33. Joint Collaboration (AFRL/P&W/SBIR) on PHM Hardware Development
34. Joint Collaboration (Notre Dame /NAVAIR/AFRL) on Advanced Sensors
35. Joint Collaboration (AF, Army, Navy, NASA, Defense Advanced Research Projects Agency (DARPA)) on Fuel Pump Development: evaluation of ADVENT technology demonstrator engine proposals; 2 contracts awarded
36. **Small Engine Development (NASA/Army/Navy/AFRL)**
    a. Fuel Components for UAV Engines (AFRL/Army/Navy) – SBIR –Phase II

b. Power Generation Technology for UAVs – SBIR –Phase II
c. SBIR work on small FADEC for IC Engine

37. Joint (USAF/ NAVAIR /ARMY) collaboration on Safety and Affordable Readiness (**P-SAR**) Program Formulation
    a. Proactively Ensure Propulsion Safety and Affordable Readiness Through Emerging Sustainment Technologies by: (1) Safety – Reduce propulsion related Class A mishaps by 75%, (2) Affordability – reduce maintenance costs by $420M (10%), and (3)Readiness – Increase Average Time on Wing (ATOW) by a factor of two (2X).
    b. Respond to Integration, Transition & Implementation team
38. Joint (NAVAIR / USAF/ UK Ministry of Defence **(MOD) collaboration on US/UK Program** Agreement on the following: Military Engines Reliability & Safety (MERS)
    a. Focused on PHM System Demo for Short Takeoff And Vertical Landing Aircraft (STOVL) F-35 LiftFan and LiftFan drive
39. Joint (NAVAIR and AFRL) collaboration on controls and Prognostics & Health Management (PHM) for F-35 Reconstruction for VAATE and SBIR programs
40. Joint SBIR Coordination and Collaboration (AFRL/NASA/NAVAIR)
41. Stability / Distributed Controls smart sensors (NAVAIR/AFRL/GE)
42. Fiber Optic Research (AFRL / NAVAIR/ P&W)
43. Joint Collaboration (Intelligent Automation Corporation now is part of Honeywell (IAC)/Honeywell /AFRL/NASA/Hamilton-Sundstrand, P&W, Boeing) PHM Generic Propulsion Health Management for vibration and integrate oil debris monitor with vibration for C-17 and Joint Strike Fighter (JSF) engine bearing health monitoring
44. Joint Collaboration (AFRL/P&W/SBIR) on PHM Hardware Development
45. Joint Collaboration (Notre Dame /NAVAIR/AFRL) on Advanced Sensors
46. Joint Collaboration (AF, Army, Navy, NASA, Defense Advanced Research Projects Agency (DARPA)) on Fuel Pump Development: evaluation of ADVENT technology demonstrator engine proposals; 2 contracts awarded

Materials TAT, Mary Anne Alvin, DOE NETL, Lead

1. A collaborative program was initiated between DOE NETL and NASA GRC to address the potential use of extreme temperature land-based engine thermal barrier coatings using NETL's bond coat system and diffusion barrier coatings, and NASA's overlayer coatings. High temperature thermal flux testing of composite architectures was funded by NETL for testing conducted in NASA's laser flux test facility.
2. In addition to extreme temperature coatings, DOE NETL and NASA GRC established collaborative efforts with respect to aerothermal and pulsed detonation combustion testing. This is directly the result of DOE NETL's September 2009 Green Forum presentation and subsequent discussions at NASA GRC.
3. DOE NETL hosted NASA GRC in March 2009 to explore potential collaboration in the areas of turbine materials, life prediction, clean combustors, combustion modeling, emissions control, measuring and monitoring, and advanced turbine engine designs.
4. Discussions in February 2009 between DOE NETL and AFRL focused on advantages and limitations of Nb and Mo as substrate materials for advanced land-based engines.

5. DOE NETL presented research efforts on advanced materials, aerothermal focus, and NDE at NASA GRC in February 2009, and advanced turbine life prediction modeling in August 2009.
6. Through a 60-day detail at NASA GRC in July-September 2009, DOE NETL identified a potential partnering collaboration plan with NASA in the areas with respect to clean coal technologies, smart grid, and analysis of advanced energy systems.
7. NASA GRC and AFRL completed development of a joint SiC/SiC ceramic matrix composite roadmap to identify materials and components that can operate at 2700°F or greater. Transfer of technology has occurred between the organizations. Major technical interchange meetings were held in April 2009 and October 2010.
8. NASA GRC and AFRL collaborated with COIC to evaluate current Sylramic fiber manufacturing issues and its impact on SiC/SiC CMC technology advancement. NASA conducted fundamental high temperature chemistry experiments to understand processing chemistry. Both NASA and AFRL used in-house resources to assist in finding the root cause of the SiC/SiC fiber quality issues.
9. NASA and AFRL completed SiC/SiC CMC creep testing. A paper reporting the results was issued.
10. AFRL funded NASA GRC to conduct environmental testing on SiC/SiC in support of AFRL's behavior and life prediction efforts.
11. NASA GRC provided technical support to Goodrich's VAATE contract by transferring GRC-developed processing technologies and property models for high temperature SiC/SiC composites, and by performing key tests to verify technology transfer and demonstrate Goodrich-developed advanced materials and processes for turbine airfoils.
12. AFRL and NASA hosted a fiber forum with industry to address high temperature fibers. Current and future fiber availability was addressed in preparation of AFRL's solicitation for 2700°F SiC/SiC proposals.
13. NASA GRC collaboration with DemVal was initiated for coating support of AFRL's F100 engine augmentor project.
14. NASA GRC and AFRL collaborated on STTR with DVTI on environmental coatings.
15. All agencies participated in the April 2010 Hybrid Disk Workshop that was organized by AFRL which was held in Dayton, OH.
16. In awarding the Hybrid Disk contracts, AFRL decided to rely on NASA and Navy to continue to provide technology related environmental coating for nickel-based superalloys.
17. NASA GRC entered into discussions with Sandia National Laboratories with respect to a potential joint workshop on shape memory alloys.
18. Air Force and NASA worked collaboratively to conduct ultra high temperature ceramic research for hypsersonic propulsion.
19. AFRL and ONR initiated collaboration on Ni-based turbine disks.
20. Erosion resistant coating and UAV coating efforts between NASA/DOD/DOE ORNL continued.
21. Interactions continued between NASA GRC and Army to support advanced TBC development for Army Demonstrator Engine Programs.
22. Army worked to extend Air Force's hybrid disk technology to impeller disk applications.
23. Collaboration continued between Air Force and Navy with respect to flight testing of Snecma CMC exhaust nozzle divergent seals on F414 vehicle.
24. Army, Navy regularly supported technical interchange meetings of AFRL ManTech Advanced Manufacturing Propulsion Initiative

25. NASA GRC Coatings and DOE Sandia National Labs collaborated on thin film coating processing.

Proposal and Program Reviews

1. AFRL participated in technical reviews of ONR programs.
2. NASA provided support to evaluate MURI topics by AFOSR for the solicitation on Gas Surface Interactions for Hypersonic Environment.
3. NASA GRC participated in DOE NETL's *Materials and Component Development for Advanced Turbine Systems* project in June 2009.
4. A joint Annual Review was held for the AFOSR/NASA National Hypersonics Science Center (NHSC) and the NASA Hypersonics Materials and Structures NRA projects. The review was held August 31 – Sept. 1, 2010 in Cleveland, OH.
5. NASA GRC sought a Peer Review of its CMC technology areas which was conducted Aug. 31-Sept. 1, 2010. Representatives from industry, universities, DOD and DOE served on the review panel.
6. The GRC Ceramics Branch hosted a kick-off meeting on July 8 and 9 for a Space Act Agreement (SAA) with DOE/INL on *Solid Oxide Fuel Cell Development for High Temperature Electrolysis*. This 9-month agreement was intended to accelerate small stack development for the NASA patented BSC-SOFC.
7. AFRL and NASA personnel participated in each other's reviews of multiple contracted efforts, including AFRL Thermal Protection Systems BAA and SBIRs.

MOU Established

1. *Materials for Green Propulsion* MOU was established between NASA and AFRL. This included efforts for the 2700°C SiC/SiC development and hybrid disk development.

Mechanical Components TAT, James Hopkins, Navy, NAVAIR, Lead

1. Power Dense Helicopter Transmission program: **Army-AFRL**
   - Army congressional add effort awarded to Timken via AFRL VAATE ID/IQ
   - Developing corrosion resistant gear steel – benefits across all agencies
2. Laser shock Peening of Gears Congressional add: **Army-NASA**
   - Bending fatigue tests completed on laser peened gears at NASA
3. Rotorcraft Drive Systems Health Management: **NASA-Army**
   - Condition indicator (CI) data collected & analyzed from fielded U.S Army UH-60 helicopters
   - Assessed vibration response using current CIs on Apache hanger bearings with seeded faults
4. Foil bearing coating screening & full-scale rig tests in support of HiSTED & RATTLRS: **AFRL-NASA-Navy**
   - Successful coating down selection & results transitioned to contractor; LW
5. Joint Enhanced Ester oil development program: **AFRL-Navy**
   - TRL 6 Demo Engine Test Complete
6. ADVENT Program: **AFRL-Navy-Army-NASA**
   - Completed PDRs, DDRs, & Phase I Final Reviews
7. New Collaborative Initiative for Rotor Dynamics Consortium: **DoD-NASA**
   - Need identified for multi-agency collaboration in rotor dynamics

8. ADVENT Phase II: **DoD-NASA**
9. Enhanced Pyrowear® 675 Phase II SBIR: **DoD-NASA**
    - Develop a technology to process P675 with enhanced corrosion resistance
10. Navy TRR Standard Work Package (SWP): **DoD-NASA**
    - Navy developed a SWP to provide guide for Mechanical Systems during acquisition programs' Test Readiness Review (TRR) milestone
    - ARFL and Army providing lessons learned to be incorporated into the Work Package
11. AFRL Hosted 3RD Bearing Modeling Symposium: **DoD-NASA-Industry**
12. UH-60 Tail Rotor Drive Train Overload Testing: **Army-Navy**
    - Tested at PAX River Facility
    - Testing completed Sep 2010
13. OH-58C Planetary Fault Detection: **Army-NASA**
    - Determine fault, location and size for a blind seeded fault
14. Williams International HiSTED Root Cause Analysis: **AFRL-Navy**
    - Demonstrator program returned to test upon successful determination of failure cause

Modeling and Simulation TAT, Tom Lavelle, NASA Glenn, Lead

1. Finalized legal agreement between US Government and NPSS Consortium. The agreement ensures all of US Government will have access to latest consortium version of NPSS for non-commercial work.
2. NASA evaluated AFRL SRHEAT analysis package for the analysis of thermal management of hypersonic vehicles. Provided feedback on issues found.
3. NASA obtained copy of AFLR developed Model Engineer for analysis of fuel delivery systems. NASA is currently using the system for the evaluation of hypersonic feed systems.
4. AFRL worked with NASA and the Navy on modeling of pressure gain combustion device
5. NASA and AFRL worked together on a hardware in the loop transient simulation in support of INVENT.
6. NASA and AFRL held a joint meeting on future hypersonic modeling methods development.
7. Collaboration on fretting fatigue of blade/disks between NAVAIR and AFRL using CAPRI/DARWIN codes.
8. 3D crack initiation and propagation software, FRANC3D/NG, developed under NAVAIR/USAF SBIR.
9. NAVAIR initiated multiple CFD spray atomization SBIR's for elevated pressures and temperature conditions.

Noise TAT, Brenda Henderson, NASA Glenn, Lead
Dennis Huff, NASA Glenn, 2009 Lead

1. Noise group first attended PPSA Annual Meeting – September, 2010
2. Navy, Air Force, FAA, NASA participated in quarterly research portfolio reviews for DoN Jet Noise Research Science and Technology Panel – 2009 and 2010
3. Navy, Air Force, NASA participated in NAVAIR exhaust noise workshops – December, 2009 and January 2010
4. Air Force, Navy, NASA reviewed results from JSF noise test – April, 2009

5. Navy, NASA participated in F404 engine test – July, 2009
6. Team members collaborated with Propulsion/Airframe Integration TAT to coordinate 1st Annual Workshop on Large-Eddy Simulations for Jet Flows – June, 2010
7. Navy, NASA conducted joint SBIR and STTR reviews – 2009 and 2010
8. Navy, Air Force, FAA, NASA participated in tactical aircraft measurement protocols workshop funded by ONR – May, 2010
9. Completed noise metric for VAATE – August, 2010
10. Formed separate noise pervasive panel for VAATE – August, 2010
11. Navy, Air Force, NASA participated in TETS Exhaust Noise Reduction Workshop – September, 2010

Propulsion/Airframe Integration TAT, Mary Jo Long-Davis, NASA Glenn, Lead

1. Space Act Agreement signed between NASA Glenn and AFRL to test Aerojet's Advanced Combined Cycle Integrated Inlet (ACCII) in GRC 8'x6' wind tunnel
    a. Supported by NASA's Fundamental Aeronautics- Hypersonics Project
    b. Objective was to perform transonic testing to expand experimental database previously acquired at LaRC unitary tunnel (M2.3 to M4.6)

2. 2nd Annual Shock Wave/Boundary Layer Interaction Workshop conducted at the Ohio Aerospace Institute co-sponsored by NASA and AFRL (Apr 2009)
3. NASA Glenn provided dynamic data acquisition/analysis support to AFRL COSMIC inlet test
4. NASA Glenn and AFRL collaborated (i.e. both parties provided funding on a contract to Boeing) on experiments involving the TRICS supersonic inlet test rig at Boeing
5. AFRL and NASA collaborated to conduct Shock wave Boundary Layer Interaction Workshop
    a. Government, industry and university experts performed CFD simulations of 4 benchmark experiments (2 open cases and 2 blind cases) to assess SOA in computational tools
    b. Results presented during workshop help in conjunction with AIAA ASM in Orlando, FL in Jan 2010
6. 3rd Annual Shock Wave/Boundary Layer Interaction Workshop Workshop conducted at the Ohio Aerospace Institute co-sponsored by NASA and AFRL (Apr2010)
7. 1st Annual Large-Eddy Simulation for Jet Flows Workshop conducted at NASA Glenn Guerin Management Center supported by Navy, NASA, and Air Force
    a. PAI TAT collaborated with Noise TAT to host
    b. 60+ participants representing government, industry, and academia
    c. Participants agreed to collaborate on defining benchmark problems to analyze with LES codes and compare results at the next Annual LES workshop
8. NASA participated in Air Force's Interim and Final Reviews of ASPIR Phase 1 effort with Northrop Grumman and Lockheed Martin

Structures TAT, Ken Barlow, Navy Lead
Bill Stange, AFRL, WPAFB, 2009 Lead

1. Fretting fatigue and crack initiation simulation discussions were conducted between AFRL and NAVAIR at the 8th Fatigue Damage of Structural Materials (FDSM-VIII) conference in Hyannis, MA, 19 - 24 Sept 2010.
2. Collaboration between the NAVAIR & AFRL on fretting fatigue assessment of disks has issued a technical paper in the July 2010 issue of the Journal of Engineering for Gas Turbines and Power. This work was also presented at the 8th Fatigue Damage of Structural Materials (FDSM-VIII) conference.
3. Supported action teams at the PSAR 2010 conference 16-18 March 2010.
4. 3D Crack Initiation and Propagation software , Franc3D/NG developed under Navy & USAF SBIRs with Fracture Analysis Consultants is being evaluated by P&W on disk and blade dovetails.
5. Collaboration between NASA and AFRL on Superconducting Motors and Generators
6. GUIDE IV Consortium – On-Going Collaboration.
7. NASA/AFRL coordinated evaluation of aeroelastic harmonic balance code.
8. NASA/AFRL coordinated further development of the TURBO-AE Navier Stokes Aeroelastic Code.
9. NASA/AFRL coordinated on piezoelectric work.

Test and Evaluation TAT, Todd Morrison, AFRL, WPAFB, Lead
Mike Barga, AFRL, WPAFB, 2009 Lead

1. Received funding to create a custom turbine engine and rotorcraft rotor dynamics class through the ROMAC (University of Virginia - Rotating Machinery Consortium) for in-house training of Propulsion and Power Engineers. Training will be "hands on" using spin facility balance machines, helicopter drive stands, and small engine test stands.
2. Completed DARPA funded FOD detection program using NSMS based systems to detect ice and FOD events.
3. Conducted long term planning review with AEDC to recognize the Air Force test facility strategic plans to meet the future long term test challenges.
4. Established coordination meetings with AEDC to assess the test facility upgrade measures and to minimize the test and evaluation impacts of these activities.
5. VAATE, XTE78/LF1 completed testing successfully. Demonstrating several key technologies for the JSF, F136, engine.
6. Several internal combustion (IC) engine SBIR test have completed. These tests are in direct support of several UAV mission activities.

Thermal Management TAT, Jeff Brown, AFRL, WPAFB, Lead

1. Continued collaboration with M&S Technology Area Team in development of improved system-level thermal models – Focus of 2010 Turbine Engine Technology Symposium Thermal Management Workshop is on modeling & simulation
2. Using NPSS Simulink Capability (NASA worked consortium licensing issues for Air Force use) as critical part of integrated adaptive turbine engine and thermal management architectures for system-level analyses (NASA/AF)
3. System-level tools in use by AFRL made available to NASA – Model Engineer, PCKA, and SRHEAT (NASA/AF)
4. Joint (AF, Navy, NASA) participation in ADVENT Detailed Design Reviews related to thermal management (June/July 2009)
5. Joint (AF, Army, Navy, NASA) review of turbine engine OEMs and weapon system contractor's Advanced Technology Program Plans (ATPPs) related to thermal management (fall/winter 09-10)
6. Potential for ADVENT thermal benefits presented as part of AFRL/RZP Industry Day in support of INVENT research/planning (May 2010)
7. Joint (AF, Navy) evaluation of TMS and engine integration related to INVENT Spiral II subsystem integration and technology development proposals; selection to occur Sept-Oct 2010
8. Coordination with controls technology area team on FADEC thermal management Phase I SBIR efforts and evaluation of Phase II proposals (AF, Navy, NASA)
9. Coordination of Phase II heat exchanger M&S SBIR effort (AF, Navy, NASA)
10. Additional Support of PPSA Thermal TAT – Larry Byrd (AFRL/RZP) and Chris Georgiou and Mike McGonigle (NavAir); improved opportunities for TMS and HX development information exchange

Turbines TAT, Kat Lyons, AFRL, WPAFB, Lead
Jim Heidmann, NASA Glenn, 2009 Lead

1. Accomplished multiple Technical Interchange Meetings (TIMs) with Pratt & Whitney to address XTE68-LF1 1st turbine blade casting setbacks (AF, Navy)
2. AFRL hosted Army, Navy for overview of GE ceramic turbine technologies
3. Army helicopter re-engine program AATE concluded Power Turbine TRR for ATEC (Honeywell/Pratt & Whitney joint venture) with help of AF and Navy
4. Advanced Gas Generator Turbine program replans completed for both GE and Honeywell (AF, Navy participation)
5. NASA-conducted Low Pressure Turbine Workshop attended by AF, Army, Navy
6. Thermal Wave Imaging SBIR integrated into JSF program
7. Multitude of turbine technical discussions at June 2009 IGTI meeting (Orlando) – Marc Polanka (AFRL) and Jim Heidmann (NASA) worked together on heat transfer session planning as POC and Vanguard chairs, respectively.
8. Minking Chyu from Pitt/NETL visited NASA turbine group to discuss NASA input to NETL aerothermodynamics facility development

9. Mary-Anne Alvin (DoE) visited NASA-GRC summer 2009 to discuss turbine/materials needs and tour GRC turbine facilities
10. NASA turbomachinery visits to P&W, GE, Rolls Royce & Honeywell in August 2009 resulted in plans for additional collaboration
11. NASA, Navy personnel attended AFRL HEETE Concept Exploration Workshop

CONCLUDING REMARKS

Turbine engine based propulsion and power systems play a critical role in our country's health both economically and militarily. If required technologies are to be developed and transitioned to the US user community in a timely fashion, collaboration between government agencies and with external organizations must become an even more important part of the technology development process. PPSA has an opportunity to play a leadership role in identifying, forming, and executing collaborative activities that will contribute to a strengthened technology portfolio.

The most recent accomplishments of the organization as described in this report suggest progress is being made towards the PPSA vision.

PPSA welcomes any/all feedback on this report. Responses should be sent to the outgoing chairperson of the Leadership Team William Koop (william.koop@wpafb.af.mil) or the incoming chairperson, Gary Seng (gary.t.seng@nasa.gov). PPSA also encourages interested persons to utilize our website (https://ppsa.grc.nasa.gov) for additional information on our organization.

DEFINITION OF TERMS/ACRONYMS

AATE: Advanced Affordable Turbine Engine

ADVENT: Adaptive Versatile Engine Technology

AFRL: Air Force Research Laboratory

ASME: American Society of Mechanical Engineers

CLEEN: Continuous Lower Energy, Emissions and Noise

CMC: Ceramic Matrix Composite

DoD: Department of Defense

DOE: Department of Energy

DDR: Detailed Design Review

FAA: Federal Aviation Administration

FATE: Future Affordable Turbine Engine

GE: General Electric

HEETE: Highly Effective Embedded Turbine Engine

IAPG: Interagency Advanced Power Group

LT: Leadership Team

LPT: Low Pressure Turbine

NASA: National Aeronautics and Space Administration

NETL: National Energy Technology Laboratory

NPSS: Numerical Propulsion System Simulation

NRA: NASA Research Announcement

OEM: Original Equipment Manufacturer (a turbine engine manufacturer)

P&W: Pratt & Whitney

PDR: Preliminary Design Review

PPSA: Propulsion and Power Systems Alliance

RAMGEN is the name of a company.

SBIR: Small Business Innovative Research

STF: Small Turbo Fan

STTR: Small Business Technology Transfer

TAT: Technology Area Team

TIM: Technical Interchange Meeting

TRR: Test Readiness Review