

The National Institute for Rocket Propulsion Systems: A Status Report

L. Dale Thomas, Ph.D., P.E.¹ and Emma K. Fry²
NASA Marshall Space Flight Center Huntsville, AL 35812

The National Institute for Rocket Propulsion Systems (NIRPS) serves to maintain and advance U.S. leadership in all aspects of rocket propulsion for defense, civil, and commercial uses. The Institute's creation in 2011 was in response to widely acknowledged concerns dating back more than a decade over the health of the U.S. rocket propulsion base. U.S. leadership in rocket and missile propulsion is threatened by long-term industry downsizing, a shortage of new solid and liquid propulsion development programs, limited ability to attract and retain fresh talent, and pressure on discretionary federal budgets. NIRPS serves as policy steward, technology integrator, and solutions facilitator to reverse this erosion and strengthen the global competitiveness of the U.S. propulsion base. As a multi-agency organization, NIRPS provides comprehensive factual information to policymakers about all issues affecting the propulsion industry to make the most efficient use of taxpayer dollars while keeping the U.S. in the forefront of space exploration, national defense, and commercial competitiveness. This paper provides a status report of NIRPS membership, accomplishments, current goals, and continuing challenges in the Institute's second full year of operations.

I. Introduction

THE National Institute for Rocket Propulsion Systems (NIRPS) is dedicated to the support of a vibrant US rocket propulsion community that provides reliable and affordable propulsion systems in support of the nation's defense, civil and commercial needs. The Institute's creation is in response to widely acknowledged concerns dating back more than a decade about the U.S. rocket propulsion industrial base (USRPIB). U.S. leadership in rocket and missile propulsion is threatened by long-term industry downsizing, a shortage of new solid and liquid propulsion development programs, limited ability to attract and retain fresh talent, and pressure on discretionary federal budgets. Erosion of this capability has been cited in numerous trade and independent studies as a threat to both national security and the U.S. economy. The end result of these conditions and concerns is an overall lack of global competitiveness of the US propulsion industry.

NASA Administrator Charles Bolden authorized the creation of NIRPS in a letter dated September 16, 2011 (See Appendix). The letter recommended three focus areas for the Institute, including monitoring and analyzing the state of the USRPIB, identifying technology needs and recommending technology insertions, and maintaining relationships and awareness across the industry. The letter directed Marshall Space Flight Center (MSFC) to lead the effort to establish NIRPS in cooperation with the Department of the Air Force and the National Reconnaissance Office (NRO).

As a multi-agency organization, NIRPS provides comprehensive factual information to policymakers about all issues affecting the propulsion industry to make the most efficient use of taxpayer dollars while keeping the U.S. in the forefront of space exploration, national defense, and commercial competitiveness. This paper will provide a status report of NIRPS as the Institute has completed its second full year of operations. Recent challenges facing the USRPIB, current NIRPS membership, and a highlight of recent NIRPS accomplishments will be covered in this paper.

¹ Associate Director of NASA Marshall Space Flight Center and Director, National Institute for Rocket Propulsion System, DA01, NASA/MSFC, AIAA Senior Member.

² Management Analyst, Office of Strategic Analysis and Communications, CS10, NASA/MSFC, AIAA Member.

II. NIRPS Membership

Operating as a collaborative organization, NIRPS leverages the knowledge and capabilities of government agencies, including DoD, NRO, and the FAA, that require rocket propulsion and support research, the industrial base that provides the development and manufacturing capabilities, and academia, which ensures a continuous supply of skilled workers. NIRPS is a multi-agency, multi-sector organization that is government-led and includes participation from industry and academia. The Institute is operating primarily as a virtual organization, drawing on the resources and capabilities of the nation's rocket propulsion industrial base.¹

NIRPS is committed to supporting a healthy and strong USRPIB and the Institute incorporates membership from all aspects of the industrial base. This collaborative approach allows NIRPS to act in a stewardship role representative of the USRPIB when providing information to policymakers.

The NIRPS Planning Team meets monthly and consists of representation from industry, academia and other government agencies. The main purpose of the Planning Team is to ensure awareness and collaboration of NIRPS planning, strategies and activities. The Planning Team also provides opportunities for feedback on NIRPS and its activities, from a broader audience with a collaborative interest in the sustainment of the USRPIB. Figure 2 shows NIRPS membership as of August 2013.

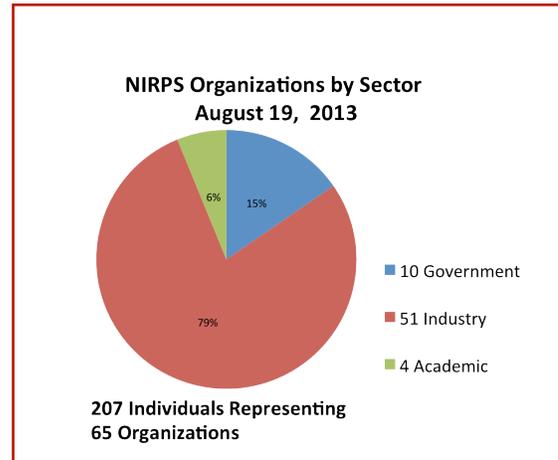


Figure 1. NIRPS Membership 2013

III. Recent Challenges Facing the USRPIB

Immediately following the creation of NIRPS, the team collaborated with leaders in the three key sectors of the propulsion ecosystem: government (civil and national security space), industry (prime contractor, supplier, and new commercial space entrants) and academia. The initial task of this collaborative group was to identify the common challenges facing the USRPIB and identify inter-related themes to distinguish the Grand Challenges to the industrial base. The team reviewed numerous reports, survey results, and over 40 previous publications to identify common challenges. These Grand Challenges were used from the Institute's strategy going forward and to measure success in the future. Figure 1 shows the common challenges to the USRPIB, with the six Grand Challenges highlighted in the center of the figure.

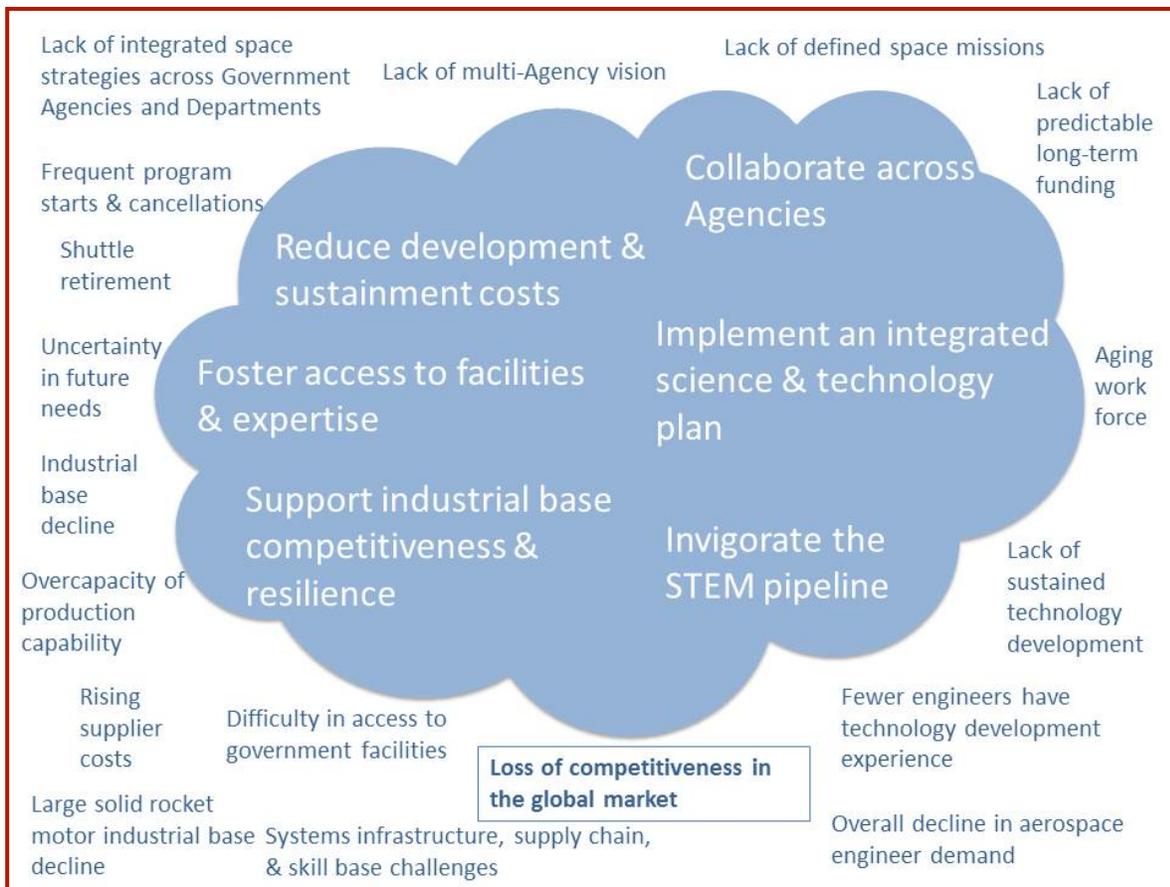


Figure 2. Grand Challenges facing the USRPIB.

The Grand Challenges are identified as:

- A. Support the competitiveness and resilience of the industrial base
- B. Invigorate the Science, Technology, Engineering and Mathematics (STEM) pipeline
- C. Develop and implement an integrated science and technology plan for propulsion systems
- D. Reduce development and sustainment costs for missile and rocket systems
- E. Foster access to facilities and expertise across government, industry, and academia
- F. Collaborate across agencies for missile and rocket propulsion system development

These Grand Challenges serve as the guiding principles for NIRPS efforts to support a vibrant USRPIB. The following section of this paper will describe several recent accomplishments in the Institute’s efforts to mitigate these challenges.

IV. Recent NIRPS Accomplishments

The first two years of operations for NIRPS are defined by the outstanding teamwork that was demonstrated every step of the way. The commitment and dedication of the NIRPS team is evident, particularly in the following recent accomplishments that begin addressing the Grand Challenges facing the USRPIB. While these accomplishments highlight the collaborative efforts of the NIRPS team, they are by no means an exhaustive list of the extensive work the Institute has initiated in its first two years.

A. Support the Competitiveness and Resilience of the Industrial Base

1. Industrial Base Health Metrics

A key first step in addressing all of the Grand Challenges, and in particular the first, is to determine the current state of the propulsion industrial base in the United States and to develop metrics to track the USRPIB health. A

defined set of USRPIB health metrics will allow decision and policy makers to measure the effectiveness of their actions over time. To this end, the NIRPS team recently conducted an Industrial Base Health Metrics Survey to track the health of the US propulsion industrial base over time. The data collected will allow NIRPS to develop “critical indicators” that will be used to predict the possible effects of policy decisions made by the Government. Additionally, the data will be used to inform senior leadership within the Government regarding decisions on policy, propulsion technology development and acquisitions.

The NIRPS team distributed the survey on October 22, 2012, and as of September 2013 has received inputs from a variety of industry organizations including integrators, propulsion suppliers, component and material suppliers and U.S. Government organizations. The NIRPS team will present a paper with comprehensive preliminary results of the survey and initial analysis in a technical Session SSEE-05 on September 10, 2013, at this AIAA Space 2013 Conference.² While the data show that more analysis remains to be completed, the NIRPS team found some correlation in the responses. Figure 3 depicts a sample of some of the results regarding employee age distribution from the survey responses that are of particular concern for the health of the USRPIB. This graph depicts the employee age distribution of the responding organizations. Over the past decade, the number of employees in the 51-60 years group has risen substantially. This is of particular concern, because the younger age groups have not increased in kind. As older employees reach retirement age, it is vital to the health of the USRPIB that new scientists and engineers enter the field at a sustainable rate.

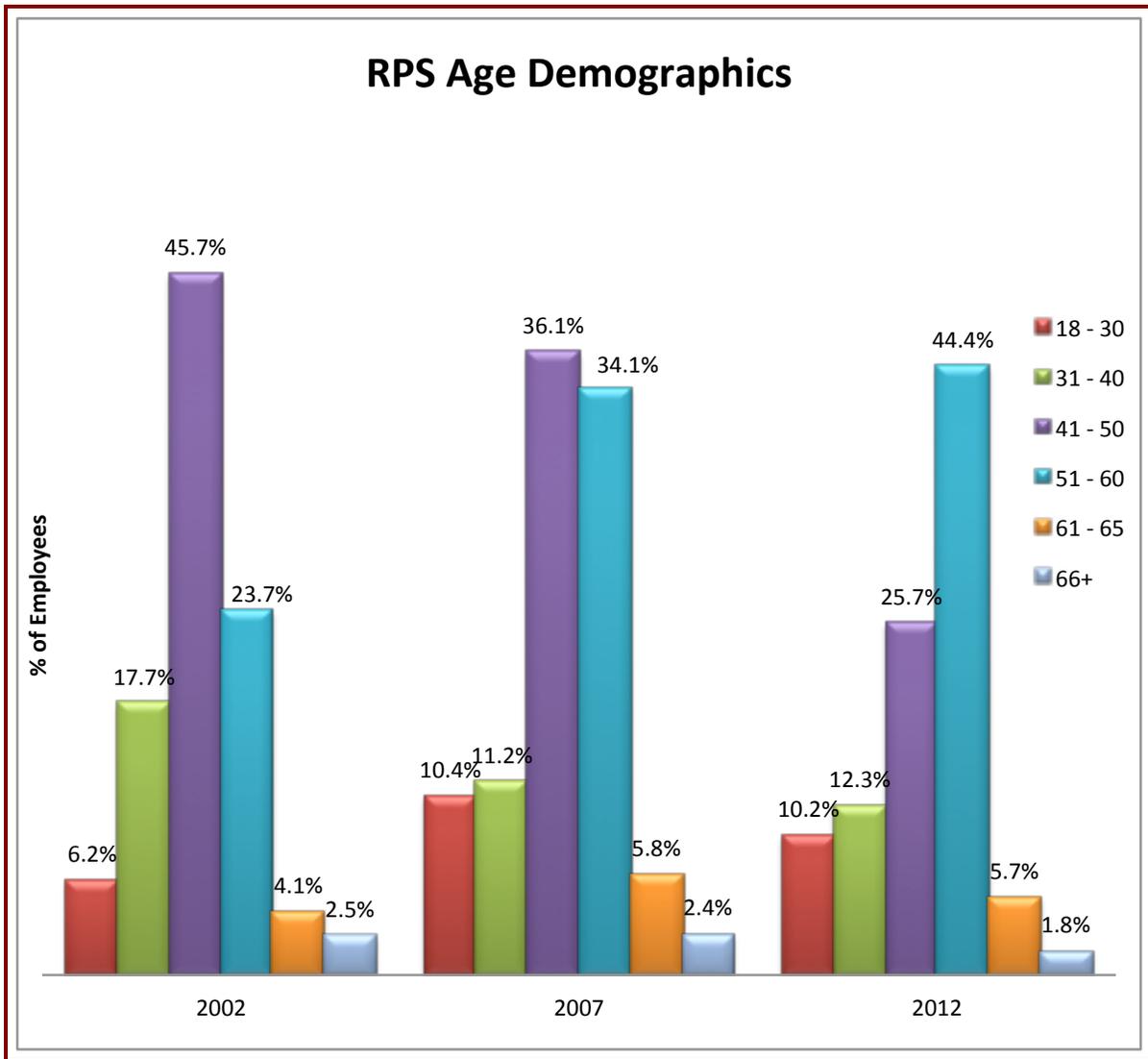


Figure 3. USRPIB Health Survey Preliminary results of Rocket Propulsion Systems employee age distribution.

Going forward, the NIRPS team will continue to collect results from industry partners to fill gaps and resolve inconsistencies, and will work to compare and validate the results with data from previous Department of Commerce surveys to provide an accurate assessment of the health of the USRPB.

2. SLS Supply Chain Analysis

In another effort to support the competitiveness and resilience of the USRPB, the NIRPS team is developing supply chain analysis methods for the Space Launch System (SLS). The objective of this task is to inform Agency decision and policy makers of the potential impacts of SLS architecture decisions on the USRPB.

The NIRPS team, working with Aerospace Corporation in conjunction with HEOMD and the SLS Engines and Booster Office has begun work on Phase 1 of this SLS supply chain analysis effort. Phase 1 is expected to take approximately 20 weeks and is anticipated to be completed this fall.

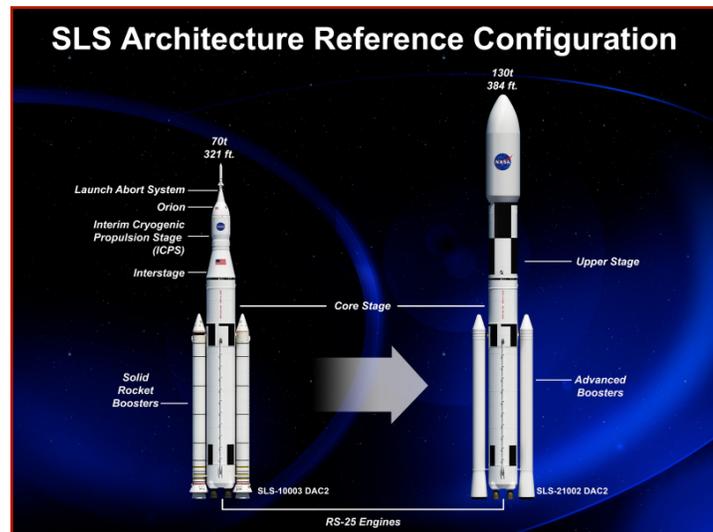


Figure 4. Space Launch System Configuration.

The primary tasks of Phase 1 are to:

- 1) Evaluate the current and planned U.S. Government investments in U.S. launch vehicle propulsion systems
- 2) Provide subject matter expertise to deliver an estimate of the affect of SLS funding on the USRPB. In particular, what these funding decisions would mean to NASA and the DoD in terms of future costs and technology development.
- 3) Develop an approach to produce and analyze multi-layer supply chain maps for SLS rocket engines. This effort will use the supply chain and industrial base, which supported RS-25D (Space Shuttle Main Engine) as pathfinder for this study.

To date, the NIRPS team has developed the taxonomy and visualization methods for this SLS supply chain analysis effort and has begun performing initial analysis using test data. Additionally, the NIRPS team is utilizing data from the Department of Commerce’s Space Systems Deep Dive Survey to provide further inputs to the effort. Additional phases of this work will examine at other Liquid Rocket Engines (LRE), Solid Rocket Motors (SRM) and tactical/strategic applications.

B. Invigorate the STEM Pipeline

1. Generalized Fluid System Simulation Program (GFSSP)

NIRPS recognizes the importance of strong a STEM pipeline to ensure a healthy USRPB. In one effort to invigorate the STEM fields, NIRPS team supported the continued development and university utilization of the MSFC Generalized Fluid System Simulation Program (GFSSP). This student version is available to students and instructors and is being utilized in support of fluid dynamics education and student design projects. This program allows STEM students to gain hands on experience solving problems and working through projects using a simulation program they would encounter in their career.

2. Fall 2013 Academic Workshop

In another effort to invigorate the STEM pipeline, the NIRPS team is planning an academic workshop to solicit inputs from academic community on NIRPS activities and strategic plan. This workshop, to be hosted by the University of Alabama in Huntsville, in October 2013, will be the beginning of an enhanced dialogue with the academic community. Academia has a clear and vested interest in a healthy USRPB, although the perspective of academic institutions is often different than that of industry. This workshop will allow participants from numerous universities to provide the NIRPS team with a “vector check” on the concerns, capabilities, and needs of the academic community in relation to the health of the USRPB. In particular, the Academic Workshop objectives include re-validation of the Grand Challenges from an Academic perspective, and development of a candidate set of

rocket propulsion academic base health metrics, analogous to the industrial base health metrics described in section A previously.

C. Develop an Integrated Science and Technology Plan

3. NDAA Section 1095 Action

Section 1095 of the National Defense Authorization Act (NDAA) of 2012, signed by the President on December 31, 2011 required development of a National Rocket Propulsion Strategy. In March of 2012, the Office of Science and Technology (OSTP) tasked NIRPS to lead in the development of the strategy. The study addressed the previously mentioned challenges to the USRPB, and required an intra-agency task team (IATT) to ensure each government stakeholder was represented in the study.

NIRPS formed the Interagency Task Team (IATT) with representatives of NASA, US Army, US Air Force, US Navy, Missile Defense Agency (MDA), the Office of The Secretary of Defense (OSD), the National Reconnaissance Office (NRO), and the Federal Aviation Administration (FAA). Under NIRPS leadership, a Senior Steering Group (SSG), consisting of executive and flag-level leadership, was formed to review the draft reports and provide high-level guidance to the IATT. The final draft of the Rocket Propulsion Strategy was submitted to OSTP in January 2013. OSTP then developed draft National Rocket Propulsion Strategy in May 2013, which is currently in review and coordination cycle with Agencies. The IATT continues to work to identify figures of merit and selection criteria to assist in developing the implementation plan.

4. IHRPT Steering Committee Meeting

Members of the NIRPS team supported the Integrated High Payoff Rocket Propulsion Technology (IHRPT), Steering Committee Meeting held April 23-24, 2013, at Edwards AFB. This successful meeting resulted in several potential areas for collaboration in areas of interest to the USRPB.

MSFC is currently supporting the USAF Risk Reduction work on the Hydrocarbon Boost Demonstration Program. This support includes materials work, turbo machinery risk reduction, and completed water flow testing. Radial pump inlet testing at MSFC is scheduled to begin in late FY13.

Several informal discussions took place regarding potential areas for collaboration in propulsion activities. The participants are planning a meeting to discuss mapping the NASA and IHRPT Roadmaps collaboratively. MSFC will also be inputting some of its technology through the IHRPT GOTChA process (Goals, Objectives, Technical Challenges and Approaches).

NIRPS is also working with other NASA centers with equities in propulsion—Johnson Space Center (JSC) and Glenn Research Center (GRC) to begin the process of integrating NASA technology roadmaps. This is a necessary precursor to developing integrated Government-wide propulsion technology plans.

D. Reduce Development and Sustainment Costs

1. Coordinated AP Buy Strategy

The reduction of development and sustainment costs incurred by the USRPB is of vital importance in the current challenging budget climate. The recent coordinated ammonium perchlorate (AP) buy strategy is a great example of the collaboration NIRPS has worked to facilitate to reduce costs to the US government and sustain a healthy USRPB.

Ammonium perchlorate is an important oxidizer used in the production of SRMs. In the past, NASA has accounted for about half of the government's AP purchases, although every branch of the U.S. military and commercial launch firms all use AP. Substantial decline in the demand for large SRMs since the 1990s, has contributed to increased costs of SRMs overall. The SRM industry decline in demand has also impacted second and lower tier suppliers such as those that produce AP. Further, AP price per pound is very sensitive to quantity procured, particularly at lower production rates.

Through the collaborative efforts of NIRPS team members from multiple agencies, NASA and the U.S. Army have coordinated on the issues associated with the cost increases for AP. Along with consultation with the Office of the Secretary of Defense, and with the entities in the AP supply chain, the NIRPS team determined that if NASA spread its purchase of AP over several years, it



Figure 5. NIRPS AP Team Members awarded the ASMDA Technical Achievement Award. Pictured L-R: Army Lt. Gen. Richard Formica, commander USSMDC, NASA's Alex Priskos, Army's Jamie Neidert, and Alabama 5th District Rep. Mo

would provide a more stable business forecast for the AP supply chain, and thus would stabilize the price for all U.S. government customers.

This NIRPS AP Team was awarded the Air, Space and Missile Defense Association Technical Achievement Award in early 2013 for their coordinated effort to reduce cost to the U.S. government and support a viable purchase forecast to sustain a healthy USRPIB.

2. 3-D Printed Rocket Engine Injector

The NIRPS team recently worked in collaboration with MSFC engineers to reduce development costs for rocket engine components. Engineers have known for some time that 3-D printed rocket parts have the potential to reduce development costs for NASA, the U.S. government, and the USRPIB. These 3-D printed components open up new affordable design possibilities for rockets and spacecraft. However until recently, no one had tested 3-D printed rocket parts critical to engine combustion in a hot-fire environment. NIRPS team members participated in project to 3-D print a Selective Laser Melting (SLM) engine injector and hot-fire test the part for durability and performance.

Traditional manufacturing processes for an Space Shuttle Main Engine/RS-25 injector consist of creating 4 components that must be assembled with 5 welds; a process that typically takes 6 months to complete. However, in June of 2013, the team at MSFC was able to 3-D print the injector in one continuous piece (no welds required), and the whole process was completed in just 3 weeks from printer to test stand. The team then installed the injector in a subscale RS-25 engine model and performed a hot fire test. During this test, the 3-D printed injector was exposed to temperatures near 6,000 degrees Fahrenheit. Post-engine inspections indicated that the injector remained in excellent condition, and engineers saw no difference in performance of the 3-D printed injectors when compared to the traditionally manufactured components. This recent project is just one of many efforts to fabricate 3-D printed rocket components to reduce development time and cost, and to continue to advance technological innovation to ensure U.S. leadership in rocket propulsion. These efforts are critical to the sustainment of a strong and vibrant USRPIB.



Figure 6. Hot-fire test of 3-D printed SLM engine injector at NASA-MSFC on June 11, 2013.

E. Foster Access to Facilities and Expertise

1. Cross-Community Skills and Capabilities Directory/Database

One barrier in the USRPIB to accessing government skills, facilities, and capabilities is having limited or no knowledge of what is available for use, or how to pursue gaining access. Therefore, in order to mitigate these difficulties, and ease access to government assets, the NIRPS team teamed with the Chemical Propulsion Information Analysis Center (CPIAC) to develop the *Cross-Community Skills and Capabilities Directory/Database*, leveraging the CPIACs work in administering the Joint Army Navy NASA Air Force (JANNAF) Propulsion Committee. The static storyboard for this database was presented at the 2012 December JANNAF/NIRPS workshop, and comments were solicited from workshop attendees. This storyboard allowed potential users to view how the data is categorized, accessed, and the type of information available. This directory, will require a secure login and will be part of a broader online collaborative portal available through the NIRPS website. The NIRPS and CPIAC recently team completed the following milestones in support of this goal:

- 1) Identified key organizations and points of contact (POC's) who will be responsible for maintaining their organizations information in the database
- 2) Solicited initial data from government, academia, and industry POCs to begin populating the skills & capabilities database
- 3) Defined web management requirements
- 4) Developed a static representation of the skills and capabilities architecture
- 5) Debuted the initial version of the database at the AIAA Joint Propulsion Conference in San Jose, CA, in July 2013.

The NIRPS and CPIAC team is continuing to develop this important database and the release of the fully functional version of the web portal tool is anticipated in early 2014.

2. Partnership with Defense Acquisition University

The NIRPS team has initiated a task with the Defense Acquisition University (DAU) through an Interagency Space Act Agreement to perform a streamlined mechanisms study. In July 2013, the team developed the questionnaire for the survey, and is continuing work to flowchart the Space Act Agreement process as a baseline for comparison. The surveying will target propulsion experts within U.S. Naval Air Warfare Center (NAVAIR), Missile Defense Agency (MDA), U.S. Air Force Arnold Engineering Development Center (AEDC), US Army White Sands Missile Range (WSMR), Stennis Space Center (SSC), U.S. Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC), U.S. Army Program Executive Office for Missiles and Space.

The NIRPS and DAU team plan to compile and analyze survey results beginning in September 2013. The team will then identify a representative sample of binding mechanisms used for industry access to government resources. From this sample, the team will propose concepts of improved mechanisms and develop an execution strategy to bring these binding mechanisms to reality. Finally the coordinated team will create a roadmap and a path ahead at the end of 2013.

F. Collaborate Across Agencies

3. Supported negotiations with USAF on AUSEP & AKE collaboration

NIRPS recently facilitated discussions between NASA and the U.S. Air Force with respect to Upper Stage LOX/LH2 Engines in support of the Affordable Upper Stage Engine Program (AUESP). Specifically, MSFC is executing 4 requirements studies to support Advanced Upper Stage Engine development. Additionally, NASA is communicating with the Air Force as it considers options for the SLS Upper Stage Engine.

MSFC is also leading 3 requirements studies with respect to the American Kerosene Engine (AKE) as a replacement for the Russian-made RD180 Engine currently in use. MSFC and AFRL have also formulated collaborative effort for Oxygen Rich Staged Combustion booster engine technology development. This coordinated effort includes funding collaboration between the USAF Program Executive Office for Space Launch, NASA, and AFRL. This collaborative effort will test hardware produced with one of the NASA Advanced Booster studies. Comprehensive and strategic government collaboration across agencies is essential for the sustainment of a vibrant USRPB. The NIRPS team continues to seek additional programs where facilitated collaboration would benefit all interested parties.

V. Conclusion

NIRPS is a unique responsive solution to the current needs of government, industry, and academia. It leverages the capabilities of the entire industry and makes the most efficient use of taxpayer dollars while keeping the United States in the forefront of space exploration, national defense, and commercial competitiveness. To this end, 2013 has been a very successful year at NIRPS. The team has accomplished numerous efforts to continue to support a vibrant USRPIB and to reverse this erosion and strengthen the global competitiveness of the U.S. propulsion base. These successes are due in large part to the collaborative work of, not only the NIRPS team members, but participants from many other government agencies, as well as active involvement from academia and industry.

As NIRPS moves into the future, the Institute will continue work in several areas. The following specific tasks are of high priority for the Institute going forward:

- 1) Respond to and implement the outcomes of NDAA Section 1095 and the National Rocket Propulsion Strategy
- 2) Develop a coordinated STEM strategy and execution plan to incorporate inputs from the October 2013 NIRPS Academic Workshop
- 3) Effectively communicate the value and accomplishments of these recent collaborative efforts across the Agency, Government and USRPIB
- 4) Utilize the NIRPS USRPIB Health Survey Metrics and DoC data to develop a “State of the Propulsion Industry” report/dashboard
- 5) Continue the development of the SLS Supply Chain Analysis to inform major architecture decisions
- 6) Complete the initial Integrated Propulsion Science and Technology Roadmap in conjunction with IHRPT
- 7) Launch the fully functional collaborative Web Portal Tool across the propulsion ecosystem and ease access to NASA facilities, skills, and personnel

NIRPS and the USRPIB will continue to face challenges in coordinating across government agencies and effectively engaging industry and academia as the Institute works to build an efficient and responsive government system to ensure U.S. leadership in rocket propulsion. Although these challenges remain to building a sustainable Institute, the NIRPS team is committed to addressing the concerns of the rocket propulsion community. The Institute will continue this work throughout 2013 and beyond as the operational model and strategic direction become more defined.

Appendix

National Aeronautics and Space Administration
Office of the Administrator
Washington, DC 20546-0001

SEP 16 2011



TO: Officials-in-Charge of Headquarters Offices
Directors, NASA Centers

FROM: Administrator

SUBJECT: Intent to Establish a National Institute for Rocket Propulsion System

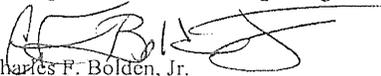
Last October, the Secretary of the Air Force, the Director of the National Reconnaissance Office, and I jointly signed a Letter of Intent that signified our commitment to collaborate in multiple areas including the development of a coherent Government strategy aimed at preserving our Nation's rocket propulsion industrial base. Over the past several months, representatives from each of these organizations have had the opportunity to discuss areas of mutual interest as outlined in the Letter of Intent. While still ongoing, these discussions have identified the need for a recognized entity to serve as the Nation's integration point for matters pertaining to rocket propulsion systems.

Fundamentally, it is envisioned that the mission of this organization will be to help preserve and align Government and private rocket propulsion capabilities to meet present and future U.S. commercial, civil, and defense space needs, while providing authoritative insight and recommendations to national decisional authorities. To accomplish this mission, specific efforts of the proposed organization may include the following:

1. Monitoring and analyzing the state of the industry in order to inform policy leaders on options and strategies that promote a healthy industrial base and ensure best-value for the American taxpayer.
2. Identifying technology needs and recommending technology insertions by leading roadmap assessments and actively participating in program formulation activities.
3. Maintaining relationships and awareness across the industry to match requirement holders with the most relevant solution approach.

In order to support this need, I have asked the Marshall Space Flight Center Director, Mr. Robert Lightfoot, to lead this Agency's efforts in the joint definition and establishment of a National Institute for Rocket Propulsion Systems in cooperation with the Department of the Air Force and the National Reconnaissance Office.

It is my belief that this institute will be a strategic asset that better prepares NASA and other Government agencies to plan and nurture future national propulsion needs and ensures that commercial industry is ready to fulfill those needs. Your support and cooperation with Mr. Lightfoot and his staff regarding this matter are greatly appreciated.


Charles F. Bolden, Jr.

Acknowledgments

The National Institute for Rocket Propulsion Systems would like to thank all of the NIRPS partners in Government, Academia and Industry for their contributions, collaboration and thoughts. NIRPS is a partnership that could not be successful without the engaging and dedicated participation of all of its partners.

References

¹ “2012 NIRPS Annual Report,” National Institute for Rocket Propulsion Systems, NASA, Marshall Space Flight Center, February 25, 2013.

² Doreswamy, R., and Fry, E., “2013 U.S. Propulsion Industrial Base Health Metrics Survey Preliminary Results,” 48th AIAA Space 2013 Conference and Exhibition, The American Institute of Aeronautics and Astronautics, San Diego, CA, 2013.