

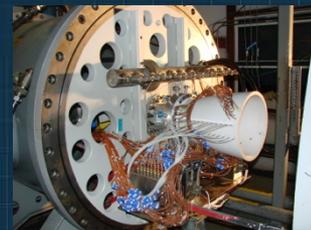


NATIONAL INSTITUTE FOR ROCKET PROPULSION SYSTEMS

# NIRPS/UAHuntsville Academic Workshop

December 16-17, 2013

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Associate Director, Technical  
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# NIRPS: Where we started

- Widespread recognition of the problem
- September 16, 2011 NIRPS authorization letter signed by NASA Administrator Bolden
- Established MSFC as NASA lead, in cooperation with USAF, NRO
- Briefed TRIBE on December 14, 2011



# Derivation of the Grand Challenges



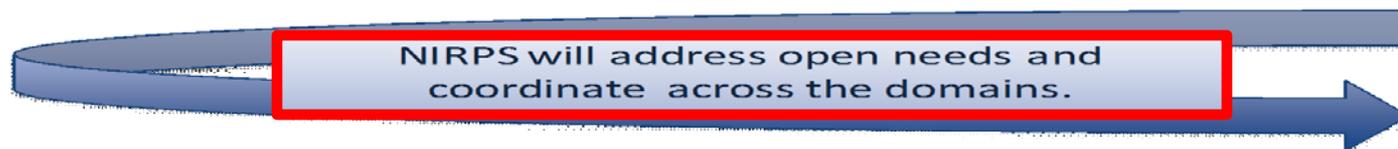
**Loss of competitiveness in the global market**

# Grand Challenges Trace to Propulsion Forums & Needs Assessment

Grand Challenges	Collaborate across Agencies for missile & rocket propulsion system dev.	Invigorate the STEM pipeline	Develop & implement an integrated science & technology plan for Prop. Systems	Support the competitiveness and resilience of the industrial base	Foster access to facilities & expertise across gov't, industry & academia	Reduce development & sustainment costs for missiles and rocket systems	Reduce development & sustainment costs for missiles and rocket systems	Support the competitiveness and resilience of the industrial base
National Needs	Forum for Collaboration (Technical Exchange/ Teaming/ Partnership)	STEM	Technology Roadmap Assessments	Recurring Industrial Base Assessments (Corporations, Facilities, Infrastructure, Obsolescence)	Access to Engineering Resources to Address Problems	Coordination and Synchronization of Government Investments	Scenario Analysis (in Support of Acquisition Strategy)	Policy Analysis and Recommendation
Forums								
<b>Associations/Councils</b>								
JANNAF	Primary	Contributing	Contributing	Not Addressed	Not Addressed	Not Addressed	Not Addressed	Not Addressed
AIAA	Primary	Contributing	Not Addressed	Not Addressed	Not Addressed	Not Addressed	Not Addressed	Contributing
AIA	Contributing	Not Addressed	Not Addressed	Contributing	Not Addressed	Not Addressed	Not Addressed	Primary
NDIA	Contributing	Contributing	Not Addressed	Not Addressed	Not Addressed	Not Addressed	Not Addressed	Contributing
SIBC	Not Addressed	Not Addressed	Not Addressed	Primary	Not Addressed	Not Addressed	Not Addressed	Primary
<b>Sponsored Programs</b>								
RP21 (IHPRPT)	Contributing	Contributing	Primary	Not Addressed	Not Addressed	Primary	Not Addressed	Not Addressed
NRPTA	Primary	Not Addressed	Not Addressed	Not Addressed	Primary	Primary	Contributing	Not Addressed
XUIP (CUIP)	Not Addressed	Primary	Not Addressed	Not Addressed	Contributing	Not Addressed	Not Addressed	Not Addressed

## Needs Assessment

	Forum for Collaboration (Technical Exchange/ Teaming/ Partnership)	STEM	Technology Roadmap Assessments	Recurring Industrial Base Assessments (Corporations, Facilities, Infrastructure, Obsolescence)	Access to Engineering Resources to Address Problems	Coordination and Synchronization of Government Investments	Scenario Analysis (in Support of Acquisition Strategy)	Policy Analysis and Recommendation
<b>Aggregate Assessment</b>	<b>Well Addressed</b>	<b>Moderately Addressed</b>	<b>Moderately Addressed</b>	<b>Slightly Addressed</b>	<b>Slightly Addressed</b>	<b>Slightly Addressed</b>	<b>Slightly Addressed</b>	<b>Moderately Addressed</b>



### Legend

Primary	A key activity or organization that supports the national need in this area.
Contributing	An activity or organization that offers opportunities to help support the national need in this area.

-  **Addresses Entire Sector**
-  **Addresses Multiple Sectors**
-  **Addresses Small Sector**

# Collaborative Activities Status

**Objective: Develop capability to perform propulsion supply chain analysis to inform decision makers**

**Grand Challenge: Support the Competitiveness and Resilience of the Industrial Base**

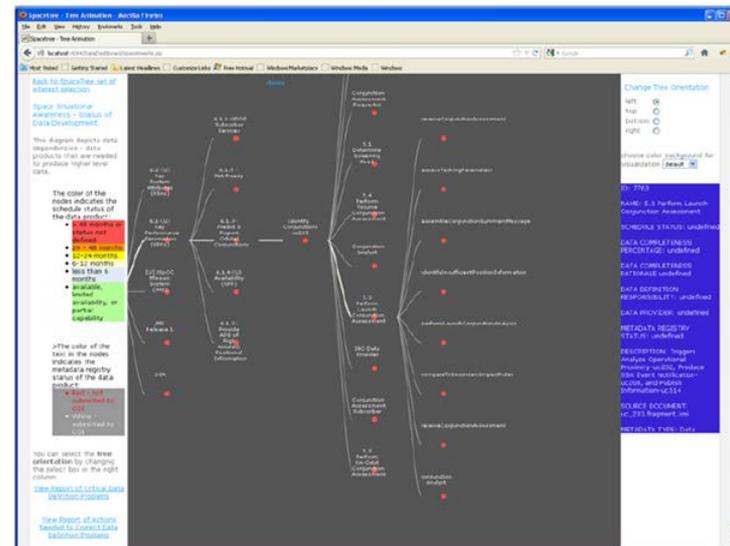
## Status:

- Initiated Aerospace Corp. task to:
  - Address HEOMD near-term questions concerning impact of DoD and SLS current/planned expenditures on propulsion industrial base
  - Generate RS-25D multi-layer supply chain maps for SLS and develop methodology to identify connectivity between suppliers and identify risks/obsolescence issues
- Addresses early HEOMD/SLS needs while developing this capability (complete August 2013)
- Integrating Department of Commerce (DoC) data

## Plans:

- Future work will expand supply chain mapping and analysis beyond SLS RS-25D
  - RL10, RD180, RS68 LREs, SRMs & tactical/strategic applications
  - Invited to join Joint Industrial Base Working Group (JIBWG) by OSD, present early results at next JIBWG in Fall 2013

**Participants:** NASA, Aerospace Corp, Aerojet Rocketdyne, ATK



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# Collaborative Activities Status

**Objective: Develop an interactive web-based collaborative tool for use across the propulsion community**

**Grand Challenge: Collaborate across Agencies**

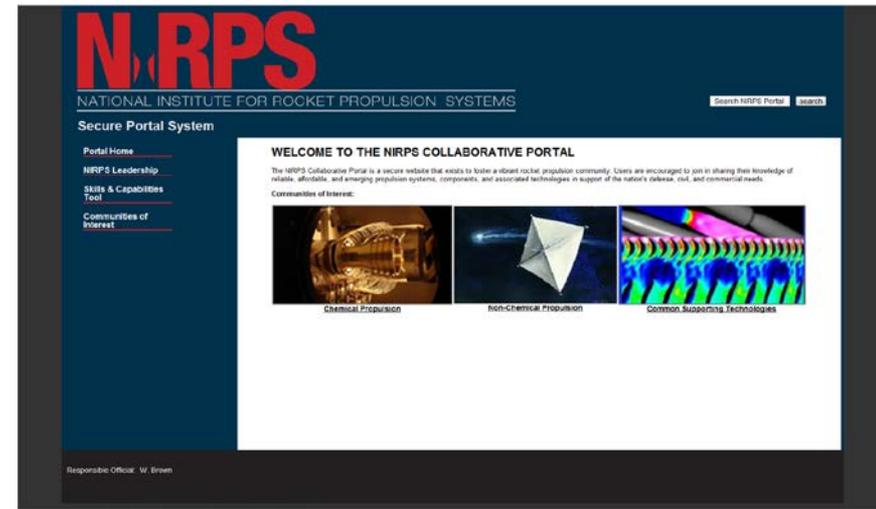
**Status:**

- Contracted with Johns Hopkins University via the Chemical Propulsion Information Analysis Center (CPIAC) mechanism for:
  - Propulsion Skills and Capabilities Tool
    - Demonstrated during NIRPS Workshop at JANNAF (May 2013)
    - Implemented interim at AIAA JPC (July 2013)
  - Small Team Collaboration Portal
  - Communities of Interest Portal

**Plans:**

- Implementation of Collaboration Portal and Communities of Interest Portal targeted for September 2013 and December 2013 respectively

**Participants:** CPIAC, Aerospace Corp, MSFC, GRC, ATK, Redstone Test Center, Georgia Tech, RPT, NRPTA



# Collaborative Activities Status

**Objective:** Assume responsibility for executing the JANNAF/Data Management & Logistics effort currently managed by the DoD Defense Technical Information Center (DTIC), due to DTIC information analysis center changes and significant budget reduction

**Grand Challenge: Collaborate across Agencies**

## Status:

- Potential issues with restructuring of DTIC IAC contracts identified at the JANNAF Executive Committee Meeting during the 2012 JANNAF Propulsion Meeting – April 2012
- As a member of the JANNAF EC, NIRPS & NASA-MSFC volunteered to assume responsibility for execution and management of new procurement, continuing JANNAF support activities as part of NIRPS – October 2012
- RFI – *Propulsion Technical Expertise, Technical Information Management, and Logistical Support of the National Institute for Rocket Propulsion Systems and the Joint Army Navy NASA Air Force Subcommittees*
  - Posted Date - August 19, 2013
  - Response Date – September 6, 2013

## Plans:

- Finalize Statement of Work for the new JANNAF/NIRPS contract
- Release RFP & award contract FY14

**Participants:** JANNAF Executive Committee, Army, Navy, NASA, Air Force



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# Collaborative Activities Status

**Objective: Perform streamlined facilitation mechanisms study to identify possible strategies for easier access to US government facilities & expertise**

**Grand Challenge: Foster access across Industrial Base**

## **Status:**

- Executed Interagency Space Act Agreement with the Defense Acquisition University (DAU) to perform streamlined mechanisms study (July 2013)
  - Developed questionnaire for survey (July 2013)
  - Flowcharting Space Act Agreement process as a baseline for comparison (on-going)
  - Surveying propulsion experts within US Naval Air Warfare Center (NAVAIR), Missile Defense Agency (MDA), US Air Force – Arnold Engineering Dev. Center, US Army White Sands Missile Range (WSMR), Stennis Space Center, US Army Aviation and Missile Research Dev. And Engineering Center (AMRDEC), US Army PEO Missiles and Space (On-going)

## **Plans:**

- Compile survey results (September 2013)
- Identify representative sample of binding mechanisms used for industry access to government resources (October-November 2013)
- Propose concepts of improved mechanisms (October-November 2013)
- Develop execution strategy to bring binding mechanism to reality (December 2013)
- Create a roadmap and path ahead (December 2013)

**Participants:** Defense Acquisition University



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# Collaborative Activities Status

**Objective:** Facilitate the development of a near-term plan to enable a more stable demand and better predictability of pricing for Ammonium Perchlorate

**Grand Challenge:** Reduce development and sustainment costs

**Status:**

- On February 28, 2012 a meeting was held between Alex Priskos (representing the NASA SLS solid rocket projects) and AMRDEC/Kevin Blacklock (Missile Industrial Base Team Lead for US Army AMRDEC) and PEO MS/David Tritt
  - Discussions centered on current and future demands for AP as well as the potential impacts to pricing
  - Current AP demand was primarily driven by the following programs: SLS Booster, EELV Strap-on and GMLRS
  - Agreed that total demand could not be altered, but timing and predictability of our known future demands could be levers

**Plans:**

- Booster element of the SLS program agreed to attempt to level load SLS AP requirement to the maximum extent possible

**Participants:** AMRDEC, AMPAC, NASA, PEO MS



**NIRPS AP Team presented**  
Technical Achievement Award from  
the Air, Space and Missile Defense  
Association Jan. 25, 2012

# Collaborative Activities Status

**Objective:** Develop synergistic collaborations across USG for new National propulsion needs

**Grand Challenge:** Collaborate across agencies

**Status:**

- NIRPS has helped facilitate discussions between NASA and the Air Force with respect to Upper Stage LOX/LH2 Engines
  - MSFC is executing four requirements studies to support Advanced Upper Stage Engine - \$9.9M MIPR from Air Force to MSFC received March 2012
  - NASA keeping Air Force informed as it trades RL-10 vs. J2-X Advanced Upper Stage Engine vs. JAXA/Rocketdyne MB60 for SLS Upper Stage
- MSFC is leading three requirements studies with respect to American Kerosene Engine as a replacement for the RD180 - \$9.5M MIPR from Air Force to MSFC received December 2012
- MSFC and AFRL formulated collaborative effort for Oxygen Rich Staged Combustion booster engine technology development.
  - AF PEO/SL has agreed to augment NASA and AFRL funding by \$25M and \$10M, respectively, but execution delayed due to Sequestration
  - This funding is needed in order to test hardware produced with one of the NASA Advanced Booster studies

**Plans:** Exploration Upper Stage will be discussed at Dec. JANNAF

**Participants:** Air Force, NASA, Aerospace Corp, Industry



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# Collaborative Activities Status

**Objective: Facilitation of targeted Propulsion Training/Technical Interchange in conjunction with CPIAC**

**Grand Challenge: Collaborate across Agencies**

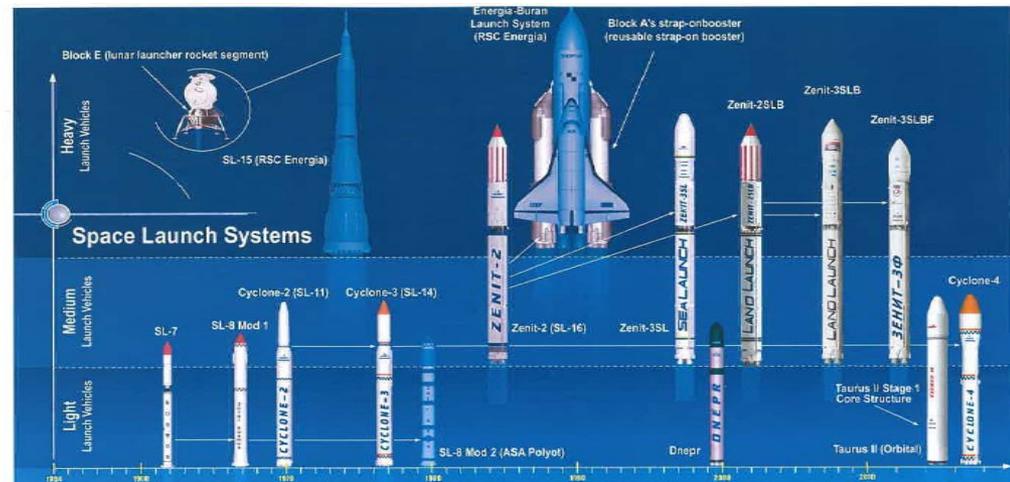
**Status:**

- Experts from the Yuzhnoye Design Office presented Ukrainian designs and experience
- Topics included Liquid Rocket Engines, Hypergolic Launch Systems, LOX/Kerosene Launch Systems, Liquid Strap-on Boosters and Human-rated Launch Systems

**Plans:**

- Continue fostering new Propulsion-related Technical Interchange opportunities using CPIAC as the facilitator

**Participants: CPIAC, Yuzhnoye DO, NASA, SAS**



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# Collaborative Activities Status

**Objective: Integrate NASA Propulsion Technology Efforts with similar USG Products and Roadmaps (IHDRPT/RP21)**

**Grand Challenge: Develop Integrated S & T Plan**

## Status:

- IHDRPT/RP21 efforts focus on long-te view of technology development resulting in propulsion technology that can be used by the USG and RPIB
- NASA efforts tend to be more product-oriented focused on near-term technology solutions of specific problems
- Integration of Government S & T portfolios is underway

## Plans:

- Continue discussions for synergistic collaborations across government agencies

**Participants:** IHDRPT/RP21, NASA MSFC, JSC, GRC

TRL 1-3  
Fundamental/Basic Research R&D



Conducting Fundamental Science & Basic Technology Research for NASA's Missions

TRL 4-6  
Component & Prototype Testing



Maturing Technologies



TRL 7-9  
Demonstration, Qualification, & Operations



Testing & Applying Technologies

# Collaborative Activities Status

**Objective:** Supported continued development and university utilization of the MSFC Generalized Fluid System Simulation Program (GFSSP)

**Grand Challenges:** Invigorate STEM Pipeline

**Status:**

- In FY13, NIRPS enabled the continued development of the student version of the Generalized Fluid Systems Simulation Program (GFSSP) which has been used in senior design classes at several universities
- The University of Central Florida used GFSSP for a Senior Design Project on “Humidity Control in Space Craft”
- GFSSP Version 6 was released to Vanderbilt University, MIT and University of Houston
- At UAHuntsville, GFSSP has been used for designing an Air-conditioned system in a multi-storied building
- GFSSP is an MSFC developed, general-purpose computer program for analyzing complex internal flow in rocket engine turbo pumps and main propulsion systems

**Plan:** Continue the support of Student version development and expansion, including the insight and guidance for applications to future student curriculum and design project activities

**Participants:** University of Central Florida, Vanderbilt, MIT, University of Houston, UAHuntsville, NASA

# Collaborative Activities Status

**Objective: Develop a common combustion stability scaling methodology for use across the propulsion community**

**Grand Challenge: Collaborate across Agencies**

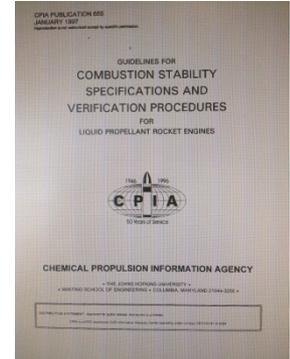
## Status:

- Participated in a combustion stability working group discussion between NASA, Georgia Tech, and Aerojet Rocketdyne (February 2013)
- Presented the formal CPIA 655 combustion stability standards update task to the CPIA Combustion Stability Panel at the JANNAF (April 2013)
- Assembled Combustion Stability Panel CPIA 655 committees
- Coordinated which sections of the combustion stability document each partner would contribute
- Working with AFRL, Sandia, and academia on a team to study scaling considerations with respect to liquid rocket engine combustion stability

## Plans:

- Publish a NASA Standard
- Replace "Guidelines for Combustion Stability Specifications and Verification Procedures for Liquid Propellant Rocket Engines," CPIA Publication 655, Columbia, MD, January 1997

**Participants:** USAF/AFRL, NASA, GA-Tech, Aerojet Rocketdyne, JANNAF, & Others



# Collaborative Activities Status

**Objective:** Facilitate collaboration, leveraging multiple “Advanced Manufacturing” efforts applied to propulsion elements. Communicate results and activity points of contact

**Grand Challenge:** Collaborate across Agencies

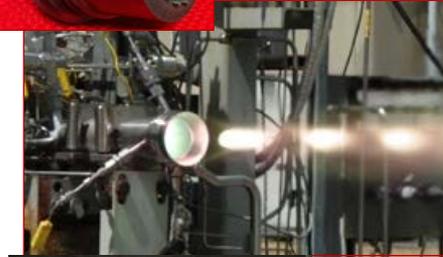
**Status:**

- Supported (throughout FY13) advanced manufacturing efforts at MSFC related to Air Force engine interests (valves – turbopump components, injectors)
- Tracked and communicated propulsion advanced manufacturing efforts across the government and industry (GRC/Aerojet Rocketdyne)

**Plans:**

- Continue investigation and support of propulsion element advanced manufacturing
- Continue to communicate, and facilitate collaboration in advanced manufacturing of rocket elements.

**Participants :** USAF, NASA, Aerojet Rocketdyne, Others



# Collaborative Activities Status

**Objective: Deliver NDAA-1095 Final Report to OSTP; Complete OSTP follow-on action to develop a recommended implementation plan**

**Grand Challenges: Collaborate across agencies,  
Develop Integrated S & T Plan**

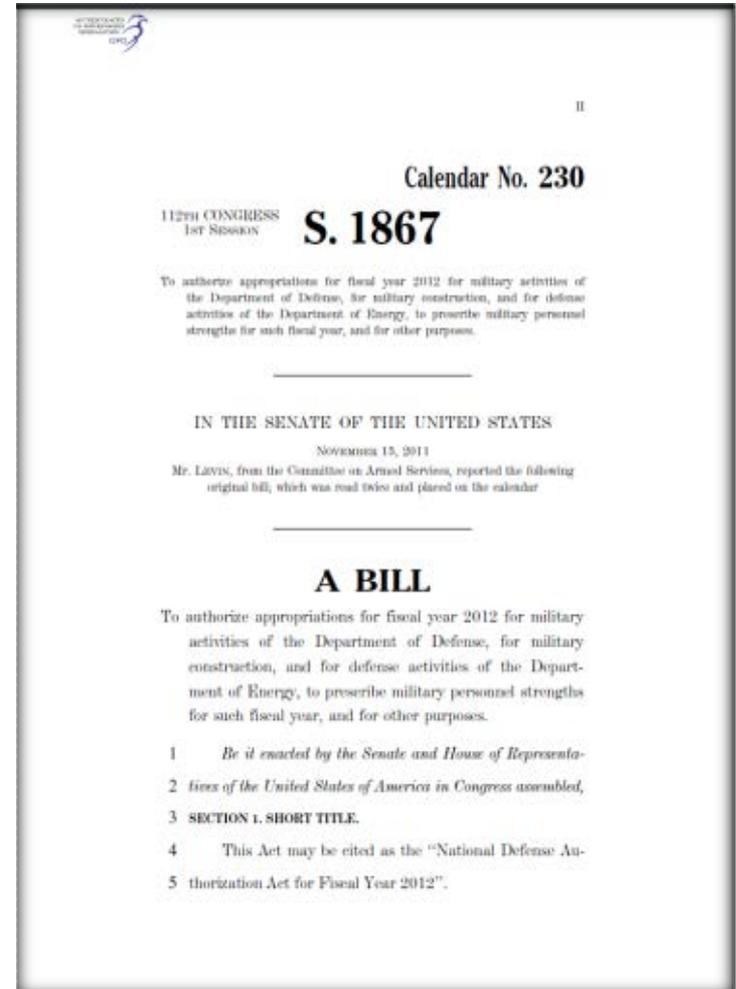
**Status:**

- Led Inter-Agency Task Team in developing National Rocket Propulsion Strategy options
- Delivered NDAA-1095 Final Report to OSTP in January 2013
- Led smaller Inter-Agency Task Team in developing implementation plan
- Senior Steering Group approved Course of Action (COA) July 22, 2013

**Plan:**

- The following section captures this Objective and COA in greater detail

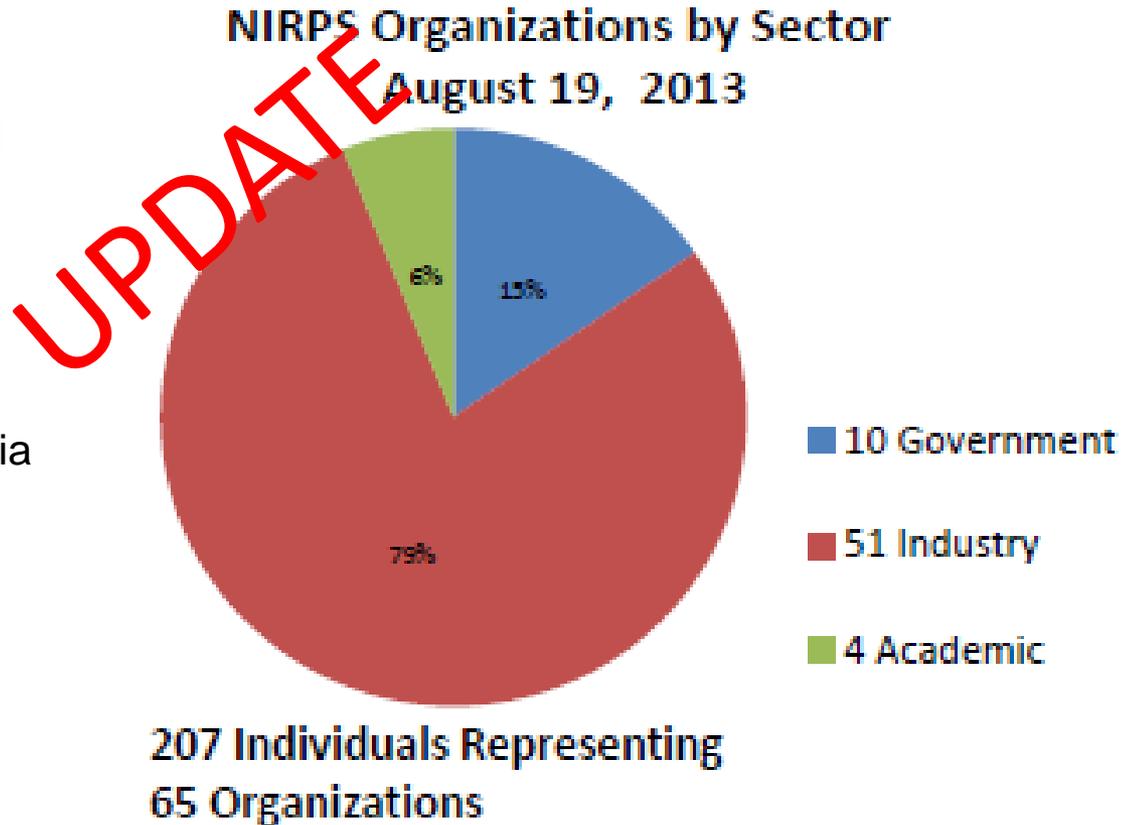
**Participants:** Multiple Government Agency collaboration



# Collaborative Activities Summary

## NIRPS Activities are maturing

- NIRPS is building Propulsion Industrial Base products
- NIRPS is collaborating across the USG, Industry and Academia
- NIRPS is addressing the RPIB National Imperative



# Support Competitiveness of Industrial Base

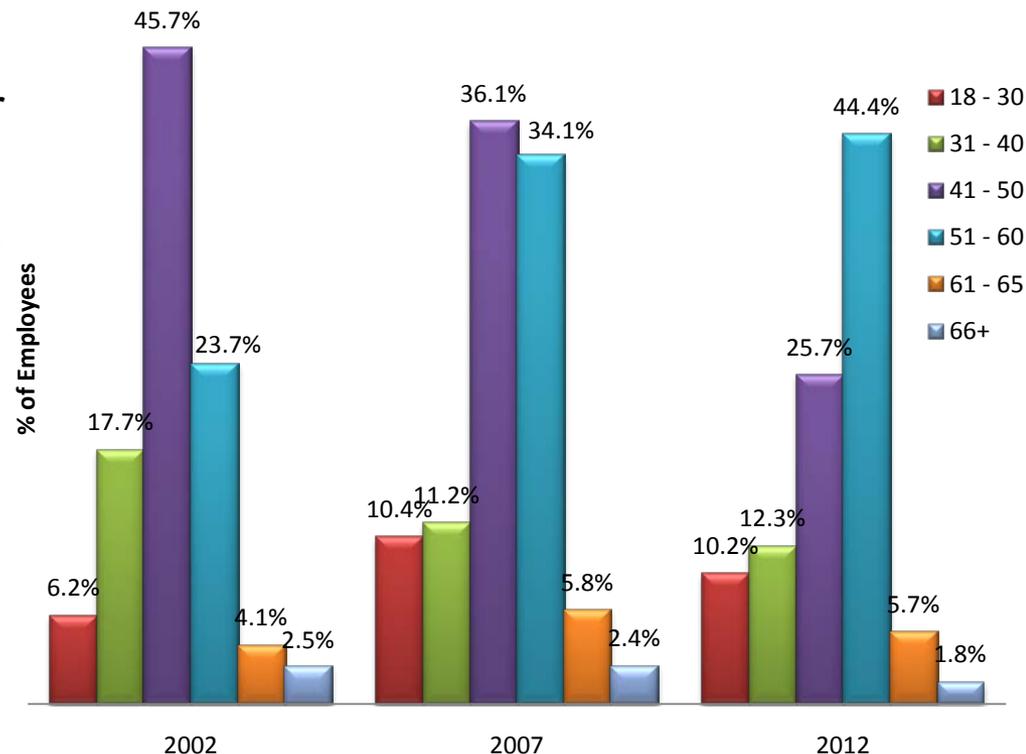
## Industrial Base Health Metrics

- **Objective:** develop useful metrics that can serve as indicators of the overall health of the Propulsion Industrial Base
- **Developed** survey to collect data for Industrial Base Health Metrics
- **Input** from a variety of organizations
- **Analyzed** data was published as an AIAA Space 2013 paper

*Rajiv Doreswamy and Emma K Fry:  
2013 U.S. Propulsion Industrial Base  
Health Metrics Survey Preliminary  
Results*

- **Validate** by comparing with Department of Commerce data for validation

RPS Age Demographics



# Support Competitiveness of Industrial Base

## SLS Supply Chain Analysis

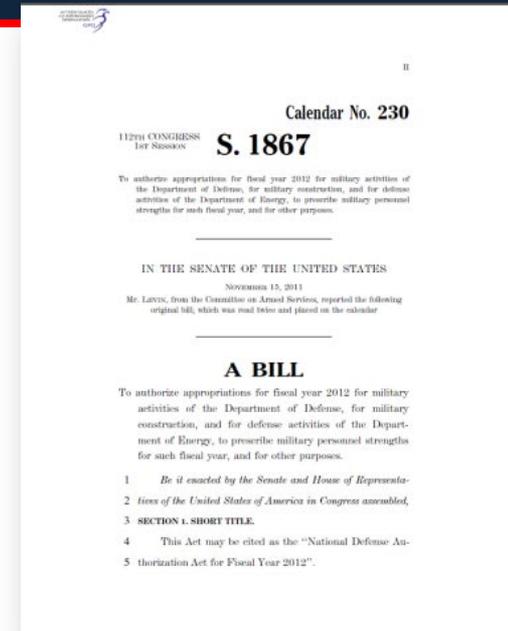
- Objective: Inform Agency Decision makers of the impacts to the Propulsion Industrial Base, due to potential SLS architecture decisions
- NIRPS and Aerospace Corporation to execute in conjunction with NASA HQ and SLS Program
- Primary Task: Determine impacts of SLS Upper Stage Architecture options
  - Exploration Upper Stage (EUS) options: RL10 vs J2-X vs MB60
  - Advanced booster: Liquids vs Solids
  - Order of upgrades: EUS vs Adv. Booster
- USAF PEO M&S and USN SSP insight/review



# National Rocket Propulsion Strategy

## NDAA Sec. 1095

- ***Sustainment of rocket propulsion base is “a national challenge”***
- ***Requires President provide a national rocket propulsion strategy including:***
  - ***Effect on industrial base of Space Shuttle closeout and Constellation termination***
  - ***Administration plans to mitigate impacts to industrial base***
  - ***Consolidated plan w/ key decision points for current and next-generation requirements***
  - ***Options/recommendations for synchronizing plans, programs, budgets for R&D, procurement, operations and workforce among federal agencies to strengthen industrial base***
- **Interagency Task Team formed w/ equity holders from USG including NASA, DoD, NRO, and FAA**
- **Senior Steering Group (SSG) has held seven meetings with Inter Agency Task Team to provide guidance to the team**
- **Delivery of final report to OSTP completed January 2013**
- **OSTP developed draft National Rocket Propulsion Strategy in May 2013 – in review and coordination cycle with Agencies**



# Reduce Development, Sustainment Costs

## Continued Progress in Advanced Manufacturing of Rocket Components

- Single Piece – 3D printed Injector, Design, fabrication and hot fire Demonstration at MSFC ~ 1,200 lbf, June 11, 2013 (RS25 Subscale Simulator Configuration)



3D Printed Single Piece Injector



3D Printed Chamber



Hot-Fire Testing, MSFC TS115  
June 11, 2013  
 $P_c = 780$  psig, MR ~ 5.5 (LOX/GH<sub>2</sub>)

- 3D printed, Channel Wall Chamber also demonstrated with RS25 Simulator Configuration ~ 1200 lbf, June 25, 2013

- Subscale RL10 type Injector, designed by Aerojet-Rocketdyne, hot fired at GRC ~ 2,000 lbf, Press Release July 11, 2013



3D Printed Discharge Housing



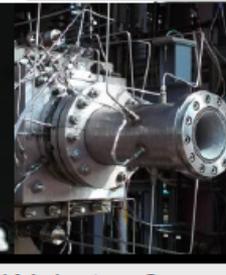
3D Printed Crossover Housing



HIP Consolidated Powdered Metallurgy Titanium Impellers

- MSFC 9K Expander Cycle Test Bed (ECTB) fuel turbopump discharge & cross-over housings, and rotating elements nearing final assembly

- 28 Element Swirl Coax, LOX/LH2 injector designed and demonstrated at MSFC ~ 20,000 lbf, Aug. 22, 2013 (Comparable to earlier J2X Subscale Testing)



28 Element, 20K Injector, Successfully Tested 8/22/2013

# Looking Forward: Challenges and Opportunities

- **FY 2013 was a year of consolidation and execution**
  - **Pivoted from organizational formulation to adding real value to the Propulsion Community**
  - **Developed Industrial Base Health Metrics**
  - **Initiated Rocket Propulsion System Supply Chain Analysis**
- **FY2014 will be a year of continued execution and establishment of pedigree**
  - **Official Charter and Inter-Agency Memoranda of Understanding**
  - **Continued performance of tasks addressing the Grand Challenges**
  - **Leverage current investments in JANNAF to implement Programmatic and Industrial Base (PIB) Committee to provide analysis and recommendations to senior leaders and decision makers**

# NIRPS: Positive Value and Lasting Impact

- **NIRPS is adding positive value to the Propulsion Ecosystem**
  - Enabling Collaboration across the US Government
  - Engaging with Industry and Academia
  - Executing tasks of National Importance, by responding to 2012 NDAA, Sec 1095 actions
- **NIRPS is “resource light” but “results heavy”**
  - Staff consists of 4 full-time equivalents (FTE), augmented by in-kind contributions of the NIRPS community
  - Success would not be possible without the contributions of TRIBE member organizations
- **NIRPS has been reviewed and endorsed by senior leaders with equities in propulsion**
  - **NASA Red Team review: October 2012**
    - Endorsed NASA’s strategies, actions and resources in formulation of NIRPS
  - **Industry workshop: December 2012**
    - Endorsed “Grand Challenges and Initial Concepts
  - **NIRPS Intergovernmental Review with senior government leaders: September 2013**
    - Endorsed JANNAF augmentation for better collaborations and coordination of Policy and Industrial Base issues and analysis

# NIRPS

National Institute for  
Rocket Propulsion Systems

<http://nirps.msfc.nasa.gov/home>