NIRPS Status Update
JANNAF
May 20, 2014

Dale Thomas, Ph.D, P.E.
Associate Director, Technical
Marshall Space Flight Center
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
Highlights of the 2013 National Space Transportation Policy

Goals

• Promote and maintain a dynamic, healthy, and efficient domestic space transportation industrial base;
• Encourage and facilitate the U.S. commercial space transportation industry to increase industry robustness and cost effectiveness, foster innovation-driven entrepreneurship and international competitiveness, and benefit the U.S. economy;

US Space Transportation Industrial Base

To promote a healthy and efficient United States Government and private sector space transportation industrial base, departments and agencies shall:

• Make space transportation policy and programmatic decisions in a manner that considers the health of the U.S. space transportation industrial base; and
• Pursue measures such as public-private partnerships and other innovative acquisition approaches that promote affordability, industry planning, and competitive capabilities, infrastructure, and workforce.

NIRPS aligns with the NSTP
NIRPS Accomplishments and Activities Underway

Community Solutions
- NASA Interface to the JANNAF Propulsion Industrial Base (PIB) Committee
- Management of the JANNAF Contract
- NIRPS Web Portal – Skills and Capabilities Directory
- Establish and foster industry and academia relationships in propulsion

Ecosystem Modeling
- Propulsion Supplier Integrated Modeling and Analyses (PropSIMA): Propulsion Supply Chain visualization tool

Health Metrics
- Monitor and Report Propulsion Industrial Base Health Metrics (most recent survey and study report published in 2013)

Technology Road Mapping
- Leverage Technology Roadmaps for collaborations and complimentary activities
- Sponsor/Coordinate the JANNAF Additive Manufacturing Technical Interchange Meeting, September 2014
National Rocket Propulsion Strategy

NDAA of 2012, Section 1095

• OSTP tasked NIRPS to lead study March 2012

• NASA – USAF co-leadership
  – Dr. Dale Thomas – MSFC Associate Director, Technical
  – Mr. Roger S. Correll – SAF/AQ Air Force PEO Space Launch

• Report delivered to OSTP 14 JAN 2013

• Redacted Report delivered to OSTP March 2014

• National Rocket Propulsion Strategy anticipated to be released in 2014
## Proposed Senior Advisory Group (SAG)

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Rocket Propulsion Sectors

ROCKET PROPULSION TEST SECTOR

SCIENCE AND TECHNOLOGY SECTOR

SMALL LIQUID ROCKET ENGINE SECTOR

LARGE SOLID ROCKET MOTOR (SRM) SECTOR

LARGE LIQUID ROCKET ENGINE SECTOR

SMALL SRM SECTOR

“Representative, Does not include all vehicles and munitions. Not Proportional”

Orion
LAS

Block I
Block IA
Block II
SLS

Atlas 5
Falcon 9
Antares

Russian Produced LREs

Minotaur
IV

Minuteman
I

 Trident II D5

GBI

SM-3
BLK IIA/IIB

THAAD

PAC 3

Hydra 70 2.75

TOW

Javelin

AIM-120B and C AMRAAM

GMLRS

AIM-9X Sidewinder

ATAM

ATACMS T2K

Hellfire

NATIONAL SECURITY SPACE

HUMAN AND CIVIL SPACEFLIGHT

STRATEGIC

TACTICAL
NIRPS Activities at JANNAF May 2014

Mon 5/19 – NIRPS Industrial Base Meetings (Industry Briefs)

Tues 5/20 – NIRPS Status Update
- NIRPS Web Portal
- PropSIMA presentation
- PIB Rollout/ Announcement
- Large SRM Working Group

Wed 5/21 – JANNAF PIB Executive Committee (PEC)
- Inaugural Meeting of the PEC
- PEO Briefings (gov’t only)
- Establish Working Groups
- Industry & Academia engagement

Wed 5/21 – NIRPS Academic Workshop

Thurs 5/20 – Working Group Meetings
- Large LRE
- Small LRE
- Small SRM
- S&T
- T&E
NIRPS to assume responsibility for the JANNAF/Data Management & Logistics effort currently managed by the DoD Defense Technical Information Center (DTIC), due to change in DTIC strategy

Status:
- NASA-MSFC asked to assume responsibility for execution and management of new procurement, continuing JANNAF support activities as part of NIRPS – October 2012
  - 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
**Objective:** Inform Agency Decision makers of the impacts to the Propulsion Industrial Base and other Government programs due to potential SLS architecture decisions

- **Scenarios**
  - Demand model
    - Demand rates for Engines and/or motors for specific scenarios

- **Development**

- **Certification**

- **Supply chain model**
  - Production capacity
  - Alternate suppliers
  - Relative % of overall business (from Dept of Commerce)

- **Launch**

- **Outputs**
  - Production throughput
  - Supply chain health
  - Small business impact
  - Delays switching to alternate suppliers

Scenarios drive the demand model, which is specified by demand over time for each engine type.

- When production drops below a threshold, supplier shuts down production line or goes out of business. Model switches to alternate supplier with potential delays.

- When production exceeds a % of capacity, suppliers experience delays. Model switches to alternate suppliers beyond some threshold.
Additive Manufacturing (AM) of Rocket Propulsion Hardware

• Affordability is critical for space launch systems

• Selective Laser Melting (SLM):
  – Enables rapid manufacturing of components which are typically complex, high value, small quantities, and require long lead times
  – Offers the ability to manufacture high performance propulsion components with unique features and improved performance
  – Cuts down design-build-test times
  – Reduces costs
  – Shortens DDT&E
  – Supports supply chain expansion and vendor obsolescence cost reduction

• Rocket Engine Parts using SLM being designed, fabricated, and tested:
  – J-2x Hot Gas Duct Hot Fire Tested w/Workhorse Gas Generator
  – 20K injector design and hot fire tested
  – 9K Expander Cycle fuel turbopump discharge & cross-over housings, and rotating elements nearing final assembly

• Quality Certification Plan for flight hardware still needs to be developed
Rocket Propulsion Additive Manufacturing TIM

JANNAF Liquid Propulsion Subcommittee (LPS) Advanced Materials Panel
Additive Manufacturing TIM

**September 3-5, 2014**, Jackson Center, Huntsville, Alabama

- **Focus areas:**
  - Where are we today in Propulsion AM?
  - What is required to take AM parts to flight?

- **Scope:**
  - Technology Roadmaps
  - Additive Manufacturing Techniques and Machines
  - Post Build Processing, Finishing, and Inspection
  - Materials
  - Design for Additive Manufacturing
  - Component Fabrication and Test
  - Process Qualification & Specifications
  - Process Analysis, Sensing, and Control, Non-Destructive Evaluation
  - Economic Considerations, ROI, Schedule
  - Panel Discussion

- Call for presentations issued April 7th
- Presentation abstracts due June 4th
- Encourage organizations to bring hardware examples - a limited number of tables will be available to display hardware
- A bus tour of MFSC's Advanced Manufacturing proposed for the afternoon Tuesday September 2nd, sign-up will be through the JANNAF web site if enough interest.
Green Propulsion Roadmap

Current activities:
- TDM investment in GPIM.
- MSFC is testing 0.2 lbf (1 N) AF-M315E and 5 lbf (22N) LMP-103S thrusters.
- MSFC utilizing discretionary funds to test green prop in power units.

Pilot test projects leading to scale up:
- Use of green prop in F-16 EPU’s.
- Materials compatibility and stability testing.
- Flight results of GPIM.
- Use of advanced manufacturing to reduce costs and schedule.

Future implementation:
- Scale up thruster technology to 100 lbf (440N class).
- Integrate thrusters into cubesat and LEO sat missions.
- Focus on duty cycles for HEOMD thrusters and sustained thrust for landers.
- Demonstrate in APU hardware.

Future implementation:
- APU application
- Landers
- HEOMD thrusters
- SMD missions
- SLS
- Asteroid/Mars
- Replace bi-prop up to 200 lbf (880N) class

Green propulsion will enable replacement of hydrazine monopropellant over a large range of applications.
NASA Green Propulsion In-House Efforts

• **Cubesat Propulsion [MSFC IRAD]**
  - Low-cost Nitrous Oxide based system
  - Targets low-cost propulsion for small satellite market
  - Uses automotive racing nitrous pack as the backbone of a propulsion system

• **DMLS Catalyst for Green Monopropellants [MSFC IRAD]**
  - Tri-gas (Tridyne™) catalyst optimization – monolithic substrate for catalyst
  - Additive Manufacturing (Direct Metal Laser Sintering or DMLS) of the catalyst substrate
  - Targets small satellite market with cold-gas alternative

• **AF-M315E Microthruster [MSFC IRAD]**
  - Partnership with Plasma Processes, Inc. via SBIR Phase 3
  - Leverage existing PPI SBIR investments to further develop 1N thruster.
  - Future work will probably target lower thrust applications

• **22N ADN Thruster Testing [MSFC IRAD, 2012]**
  - Purchase and test 22N ADN thruster at MSFC
  - Further advance the TRL of ADN-based thrusters
  - Provide hands-on experience at MSFC with green monopropellants.
  - Testing Planned for 4Q, FY14 at MSFC

• **SRB for Green Propellant Infusion Mission (GPIM) [OCT TDM Award]**
  - Ball Aerospace is contractor
  - MSFC provides chair and propulsion membership on the GPIM SRB
NIRPS Intergovernmental Review (NIR) Scope and Objectives

Intergovernmental Review held on September 4, 2013 to:

- Assess the proposed implementation model, identify weaknesses, and recommend changes for moving forward
- Assess the NIRPS initiated products/activities as well as the products/activities identified in the NDAA 1095 Report, identify weaknesses, identify missing products/activities and recommend changes moving forward
- Identify the key challenges facing the continuing implementation of the NIRPS
- Validated NIRPS approach & the strategic importance of the problems facing the Nation’s rocket propulsion industrial base
- Praised the NIRPS accomplishments to date • “accomplishment heavy, resource light”
- Endorsed the NIRPS strategic plan and intergovernmental coordination construct
NIRPS Academic Workshop

December 16-17 2013, University of Alabama in Huntsville (UAH)

Objectives:

• Define robust metrics & funding strategies for academic propulsion research
• Assess the NIRPS Grand Challenge propulsion statements (vision for the future)

The team provided NIRPS with a comprehensive out-brief and recommendations for follow-up

Participants from 9 Universities

Dr. Roy Hartfield, Auburn
Dr. Alan Wilhite, Georgia Tech
Mr. Pete Zeender, Johns Hopkins
Dr. Eric Boyer, Penn State
Dr. William Anderson, Purdue
Dr. Jason Cassibry, UAH
Dr. William Dick, Unv. of Illinois
Dr. Kenneth Yu, Unv. of Maryland
Dr. Walter O’Brien, Virginia Tech
Growing Participation in NIRPS

November 2011

- 72% Government
- 21% Industry
- 7% Academic

80 Individuals
29 Organizations Represented

April 2014

- 75% Government
- 14% Industry
- 11% Academic

221 Individuals Representing
80 Organizations
NIRPS Path Forward

- Additive Manufacturing TIM, September 2014, Huntsville, AL

- Next JANNAF PIB Meeting TBD 4th quarter 2014
  - Goals:
    - Initial review of PIB products
    - Working Groups status updates to PEC and SAG

- Release RFP and award NIRPS/JANNAF contract

- Continued engagement with Industry & Academia
National Institute for Rocket Propulsion Systems

http://nirps.msfc.nasa.gov/home
Backup Material
Green Propulsion HEOMD Applications

• Hydrazine fueled APU’s for SLS booster nozzle gimballing

• Hydrazine roll control thrusters for launch vehicles

• Twelve 160 lbf thrusters in the Orion crew module.

• Sixteen 25 lbf and the eight 100 lbf thrusters in the Orion service module.

• Hydrazine thrusters on the HTV (four 490N, twenty-eight 110N), ATV (four 490N, twenty-eight 200N) and Commercial Cargo resupply missions.
Green Propulsion SMD Applications

- Looking at the last 5 years of SMD missions, the majority of those have required hydrazine propulsion for either apogee and/or RCS functions.

- Examples include:
  - IBEX
  - Chandrayaan (one 440N biprop, eight 22N)
  - Kepler/Planck
  - SDO (one 440N biprop, 12 hydrazine)
  - Grail (single 22N)
  - Suomi NPP (eight hydrazine)
  - NuStar
  - Van Allen Probes (eight 0.2 lbf)

- Recurring missions that could aid the infusion to green prop include the GOES and Landsat spacecraft as well as adoption by spacecraft vendors (ie OSC Leo Star-3 bus).
Coordinated Ammonium Perchlorate Buy

- **Ammonium perchlorate (AP)** used by every armed service and many commercial firms

- **Historical decline** in demand for ammonium perchlorate, increasing costs and threatening remaining domestic supplier

- **NIRPS facilitated** coordination between government users in early 2012, stabilizing demand, production, and pricing.

- **NIRPS AP Team presented** Technical Achievement Award from the Air, Space and Missile Defense Association January 25, 2013
Material Processes and Properties

- Small list of materials utilized with SLM process
  - AL, CoCR, Ti, Inco718, Inco625, Stainless, and Cu (Limited)
- Limited material mechanical property data are available on SLM-produced components
  - Currently assume a percentage of wrought or forged properties to design development parts
  - Statistically significant material properties are needed to optimize designs and ensure safety
    - For rocket propulsion each material requires an array of mechanical properties design data over a wide range of temperatures and pressures and propellants
- Process parametric data are needed to optimize fabrication of components
  - Correlate with microstructure for example
- Establishing AM Processing Protocol for Processing and Powder is next step
  - ASTM F42 Committee on Additive Mfg. Tech, formed in 2009, has been working on processing specs for several materials such as
  - ASTM has other AM processing as well as powder specification in work
  - These specs can be tailored to meet specific needs of an organization
**Advanced Manufacturing of Rocket Components to Reduce Development & Sustainment Costs**

**Recent Milestones:**

- 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, 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** *(not pictured)*
- MSFC 9K Expander Cycle Test Bed (ECTB) fuel turbopump discharge & cross-over housings, and rotating elements nearing final assembly
- 3D printed 28 Element Swirl Coax, LOX/LH2 injector designed and demonstrated at MSFC ~ 20,000 lbf, **Aug. 22, 2013** *(Comparable to earlier J2X Subscale Testing)*
- 3D printed (film cooled) JSC Morpheus Chamber/Nozzle manufactured at MSFC and tested with Morpheus Engine at SSC ~ 4500 lbf, **Sep. 14, 2013**
- 3D printed, 100 lbf LOX/Propane (Nanolaunch) injector hot fire November 2013
- Printed Solid Rocket Motor (PSRM-10) hot fire test November 2013
- 3D printed aft fin structure and forward solid motor dome flight tested on Nanolaunch flight demonstration November 16th 2013 *(using High Power Hobby Rocket Motor Grains)*

**Upcoming and continued Efforts:**

- Static test and Flight demonstration of PSRM-30
- Continued testing and population of “printed” material properties dataset
- Development of potential NDE techniques
- We are working with AMRDEC on the DMDI solicitation, the selection announcement is imminent. Also working with AMRDEC, America Makes/NAMII and UAH forming an IPT in additive manufacturing
## NIRPS Intergovernmental Review Panel Members

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