NIRPS

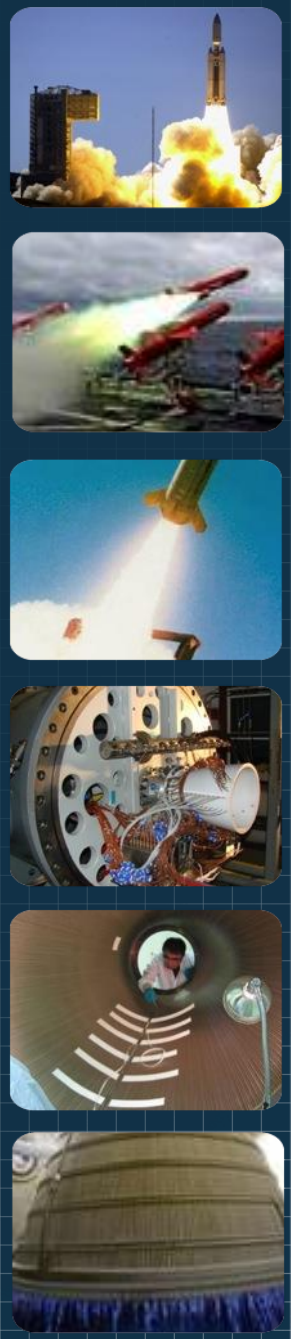
NATIONAL INSTITUTE FOR ROCKET PROPULSION SYSTEMS

NIRPS Status Update

JANNAF

May 20, 2014

Dale Thomas, Ph.D, P.E.
Associate Director, Technical
Marshall Space Flight Center



NIRPS: Where we started

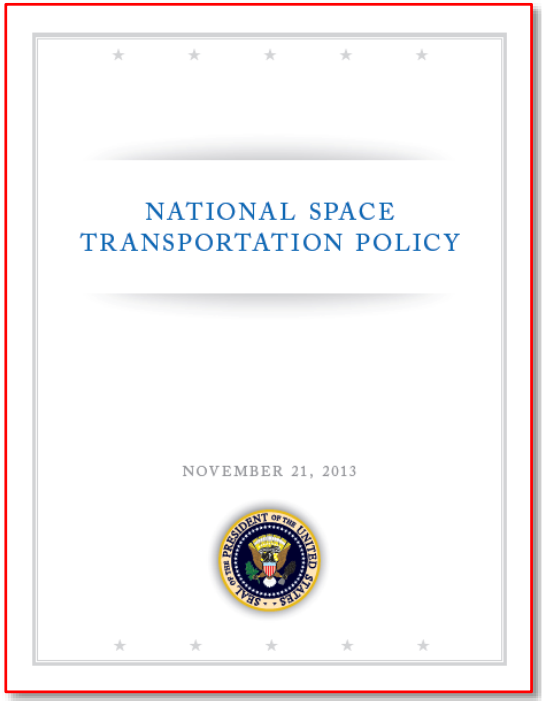
- Widespread recognition of the problem
- September 16, 2011 NIRPS authorization letter signed by NASA Administrator Bolden
- Established MSFC as NASA lead, in cooperation with USAF, NRO

Highlights of the 2013 National Space Transportation Policy

Goals

NIRPS aligns with the NSTP

- 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;

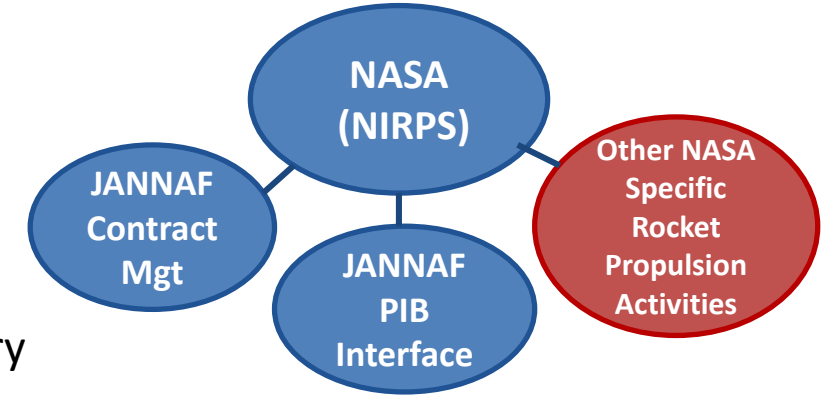


US Space Transportation Industrial Base

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 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)

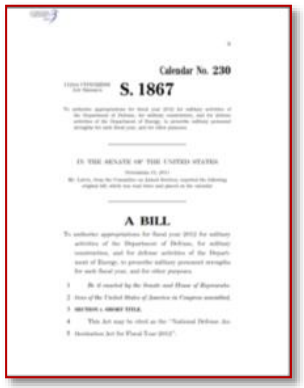
Technology Road Mapping

- Leverage Technology Roadmaps for collaborations and complimentary activities
- Sponsor/Coordinate the JANNAF Additive Manufacturing Technical Interchange Meeting, September 2014

National Rocket Propulsion Strategy

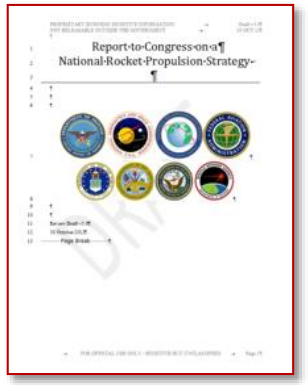
NDAA of 2012, Section 1095

- 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

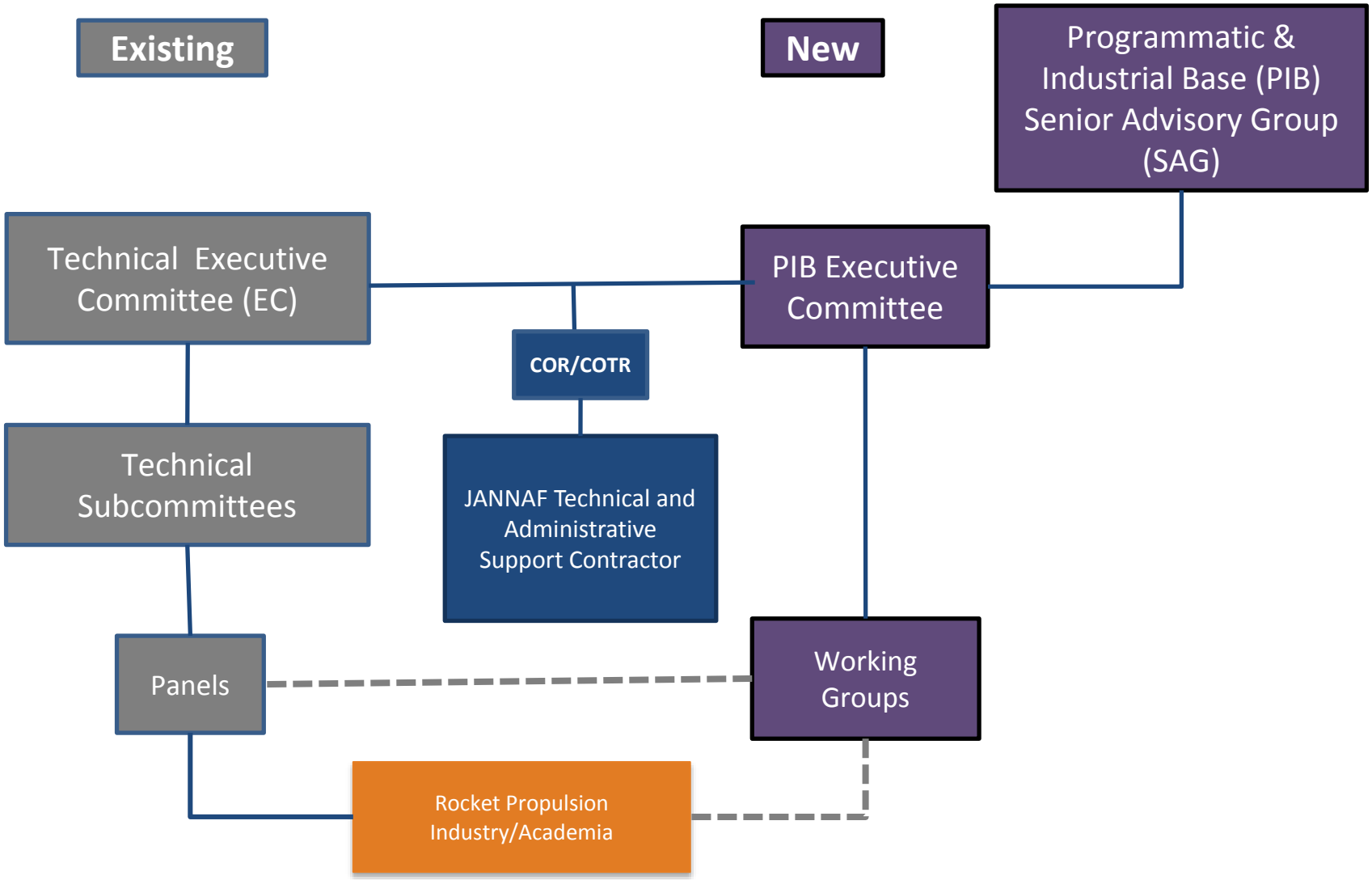

Calendar No. 230

S. 1867

A BILL


Report-to-Congress-on-a¶
National-Rocket-Propulsion-Strategy-¶

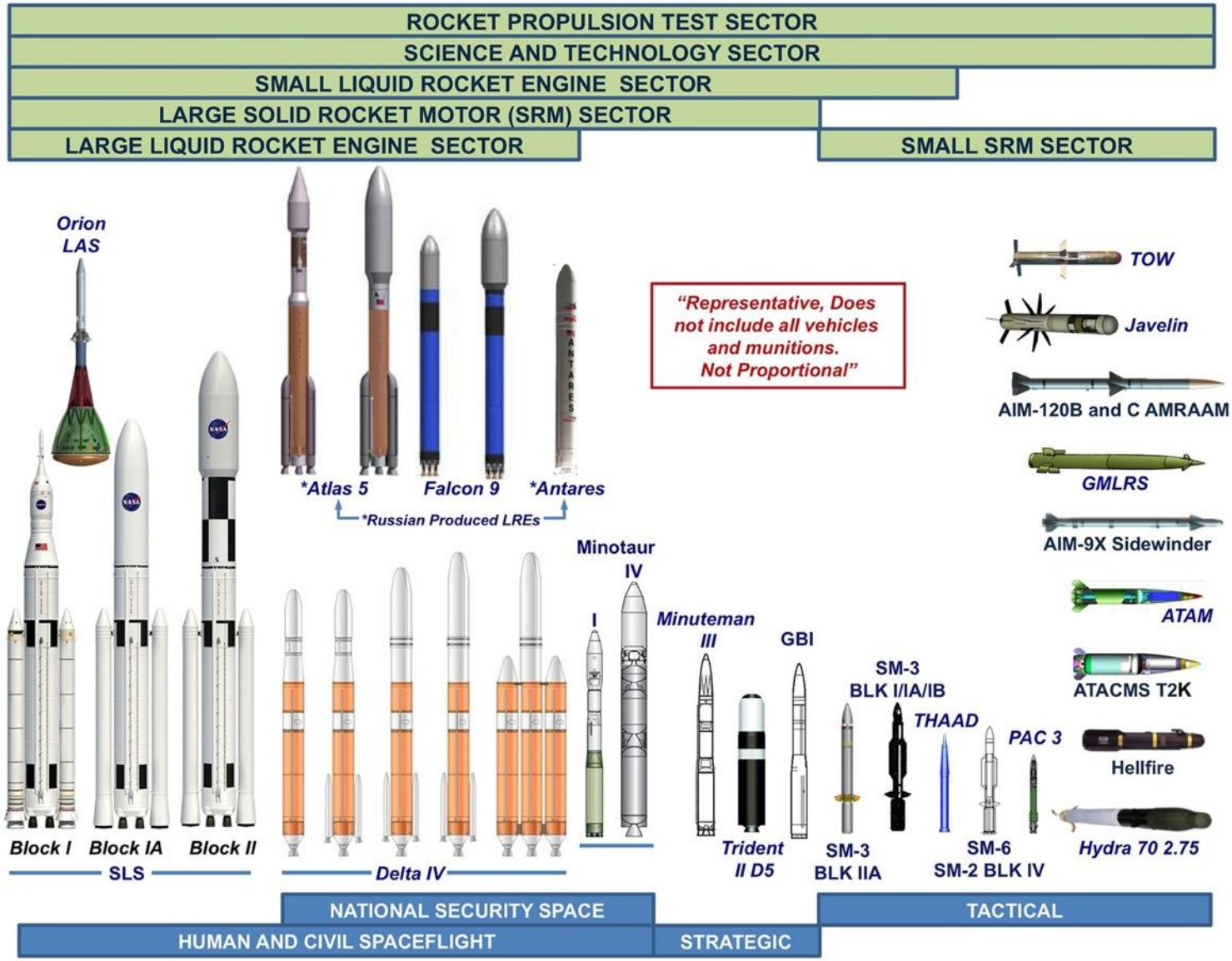
Updated JANNAF Operational Structure



Proposed Senior Advisory Group (SAG)

Name	Organization	Title
Dr. Dale Thomas (Co-Chair)	MSFC/DA01	Associate Center Director, MSFC
Ms. Elana Broitman (Co-Chair)	DASD (MIBP)	Deputy Assistant Secretary of Defense (Manufacturing and Industrial Base Policy)
Brig Gen Mark Baird	USAF/SMC	Executive Director for Space Launch Enterprise
Dr. Billy Mullins	SAF/A-10	Assistant Chief of Staff, Strategic Deterrence and Nuclear Integration
Maj Gen Whelan	AFSPC	A5 Director of Requirements
Brig Gen Hauck	AFPEO/SS	Program Executive Officer for Strategic Systems
VADM Benedict	Navy SSP	Director, Strategic Systems Programs
Ms. Patricia Gore	MDA	MDA, Director of Industrial Manufacturing and Technology
Mr. Greg Hulcher	AT&L/S&TS/SW	Director for Strategic Warfare
Mr. Gil Klinger	AT&L/SIO	Deputy Assistant Secretary of Defense for Space and Intelligence
Mr. Barry Pike	Army	Deputy PEO, Missiles and Space
Mr. Jim Norman	NASA/HQ	Assistant Associate Administrator for Launch Services
Mr. Dan Dumbacher	NASA/HQ	Deputy Associate Administrator for Exploration Systems Development
Mr. Benjy Neuman	NASA/HQ	Division Director for Human Spaceflight Capabilities
Dr. Spiro Lekoudis	AT&L/R&E	Research and Engineering
Ms. Mary Lacey	USN/DASN RDT&E	Deputy ASN for Research, Development, Test and Evaluation
Brig Gen Anthony J. Cotton	NRO	Deputy Director, National Reconnaissance Office
Lt Gen Ellen Pawlikowski	SMC/CC	Commander, Space and Missile Systems Center, Air Force Space Command

Rocket Propulsion Sectors



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

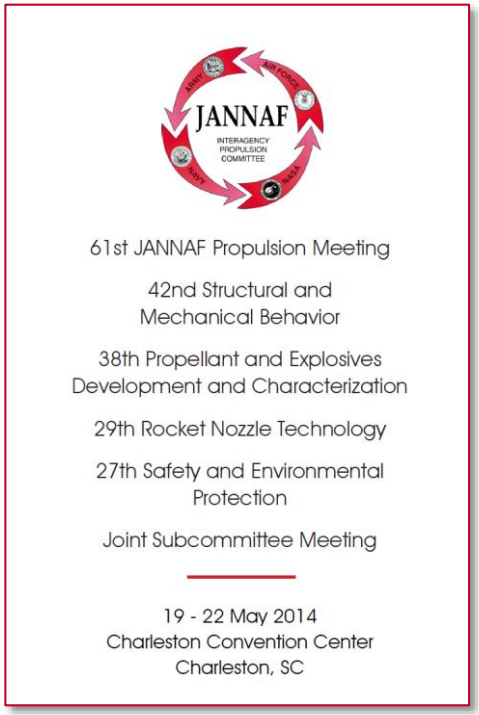
Wed 5/21 – JANNAF PIB Executive Committee (PEC)

- 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



JANNAF/Data Management and Logistics Contracting Strategy

- **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
  - 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

Propulsion Supplier Integrated Modeling and Analyses (PropSIMA) Environment

Objective: Inform Agency Decision makers of the impacts to the Propulsion Industrial Base and other Government programs due to potential SLS architecture decisions

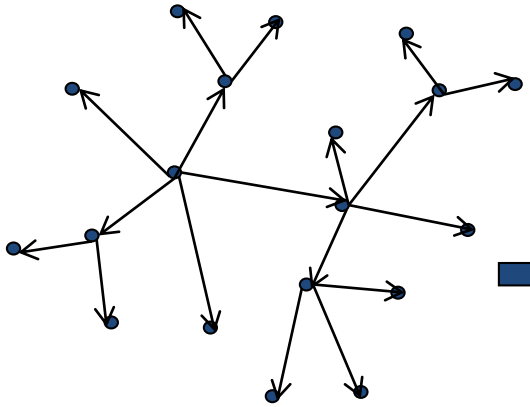
Scenarios

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

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.

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

AEROSPACE

11

Propulsion IB/SC Assessment Strategy

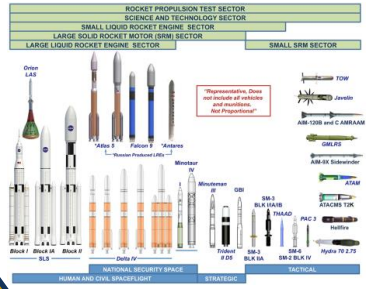
Reports

Actions

JANNAF PIB

Document, Publish, Archive

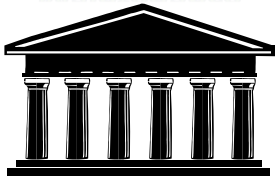
Strategic



Propulsion Ecosystem Metrics

Academia

Update Supplier Metadata Maintenance



Dunn & Bradstreet

Morningstar

AMCOM

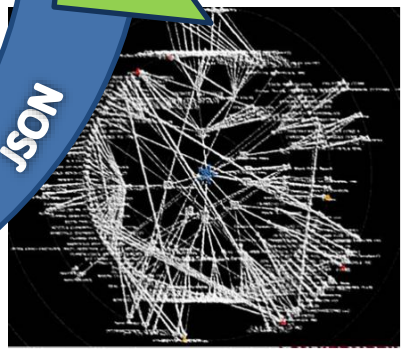
DLA

DCMA

Excel Database

NIRPS SUPPLY CHAIN DATA DASHBOARD

JSON



Aerospace Corp

PropSIMA Environment

Tactical

MOBIUS

DoC

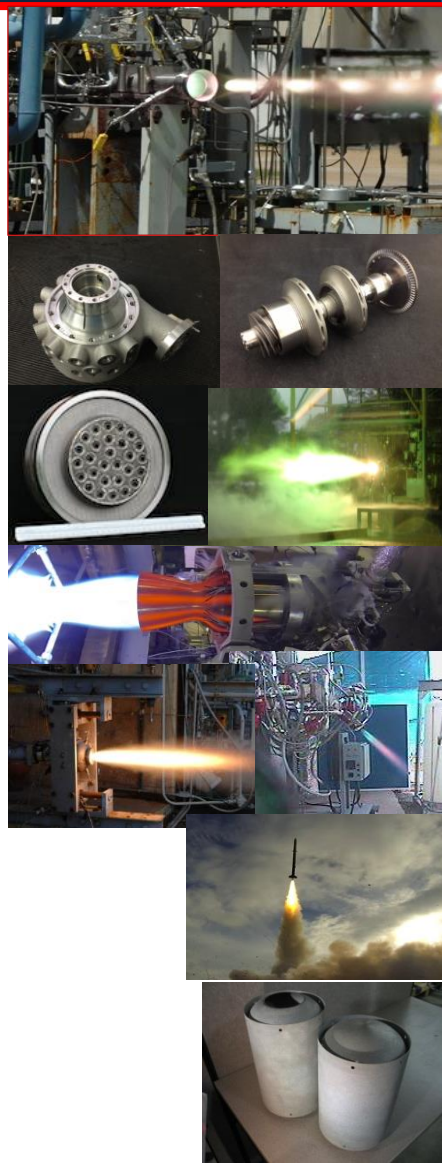
HSF Data Set

Deep Dive Data Set

Prop Subset

Additive Manufacturing (AM) of Rocket Propulsion Hardware

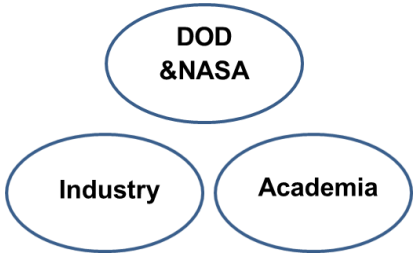
- Affordability is critical for space launch systems
- Selective Laser Melting (SLM):
  - Enables rapid manufacturing of components which are typically complex, high value, small quantities, and require long lead times
  - Offers the ability to manufacture high performance propulsion components with 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

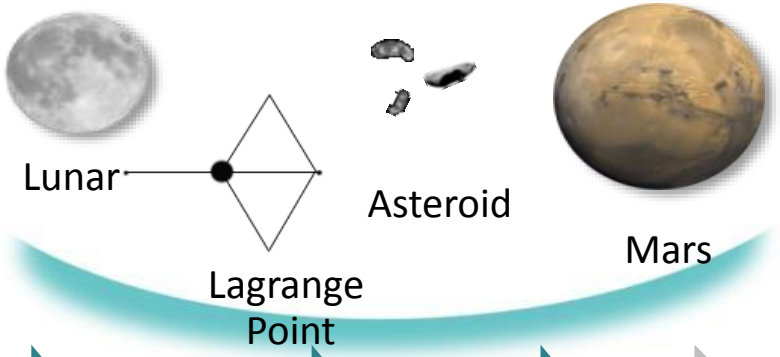


- Call for presentations issued April 7th
- Presentation abstracts due June 4th
- Encourage organizations to bring hardware examples - a limited number of tables will be available to display hardware
- A bus tour of MFSC's Advanced Manufacturing proposed for the afternoon Tuesday September 2nd, sign-up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

Green Propulsion Roadmap

International

WE ARE HERE!



Pre-2012

- *The Swedes have worked over the past decade with propellant blends, material compatibility and resultant space mission with PRISMA.*
- *The USAF investigates their propellant blend.*

2014

Current actvities:

- *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.*

2016

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.

2018

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.

2020-25

Lunar, Lagrange

- APU application
- Landers
- HEOMD thrusters
- SMD missions

2025

Asteroids

Future implementation

- SLS
- Asteroid/Mars
- Replace bi-prop up to 200 lbf (880N) class

2030 - 40

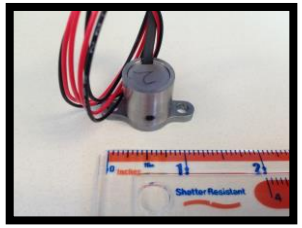
Mars

Green propulsion will enable replacement of hydrazine monopropellant over a large range of applications.

NRPS

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



Pulsed Thruster Valve

- **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

22 N ECAPS LMP-103S Thruster

Piston Propellant Tank Body

- **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)

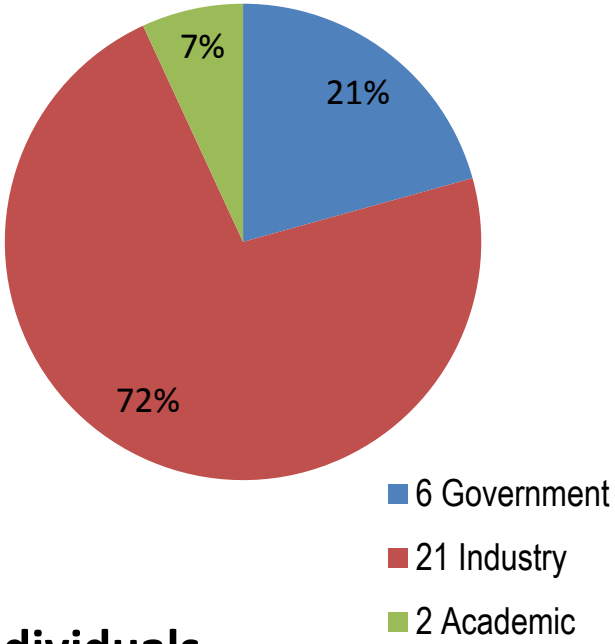
The team provided NIRPS with a comprehensive out-brief and recommendations for follow-up

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

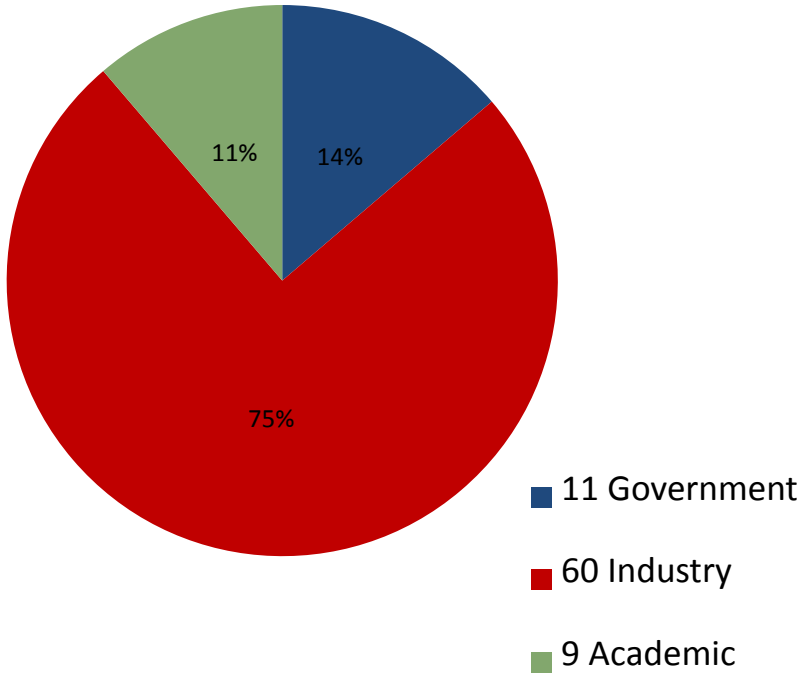
Growing Participation in NIRPS

November 2011



80 Individuals
29 Organizations Represented

April 2014



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

NIRPS

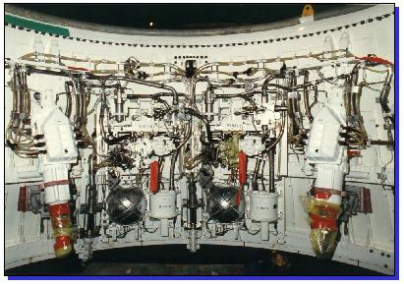
National Institute for
Rocket Propulsion Systems

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

Backup Material

Green Propulsion HEOMD Applications

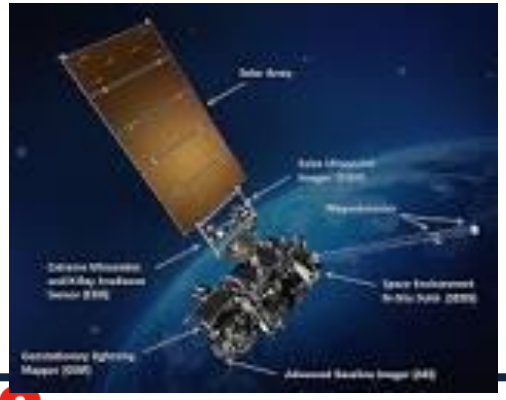
- Hydrazine fueled APU's for SLS booster nozzle gimballing
- Hydrazine roll control thrusters for launch vehicles
- Twelve 160 lbf thrusters in the Orion crew module.
- Sixteen 25 lbf and the eight 100 lbf thrusters in the Orion service module.
- Hydrazine thrusters on the HTV (four 490N, twenty-eight 110N), ATV (four 490N, twenty-eight 200N) and Commercial Cargo resupply missions.



ATV

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

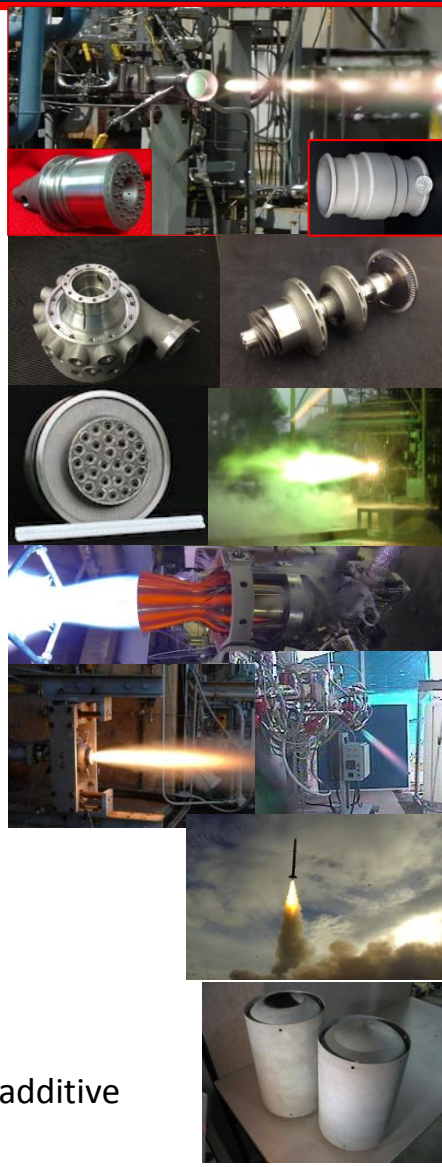
Material Processes and Properties

- 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 being work Processing Spec's for several materials such as
    - ASTM F3001 – 14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion
    - ASTM F3055 - 14 Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion
  - 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

Name	Organization	Title
Mr. Scott Correll	AFPEO, SL	Air Force Program Executive Office for Space Launch, Office of the Assistant Secretary of the Air Force for Acquisition
Brig Gen Daryl Hauck	AFPEO/SS	Program Executive Officer for Strategic Systems
Maj Gen Martin Whelan	AFSPC	A5 Director of Requirements
Mr. Barry Pike	Army	Deputy PEO, Missiles and Space
Dr. Ronald Jost	AT&L/DASD	Deputy Assistant Secretary of Defense, C3&Cyber
Mr. Greg Hulcher	AT&L/S&TS/SW	Director for Strategic Warfare
Mr. Gil Klinger	AT&L/SIO	Deputy Assistant Secretary of Defense for Space and Intelligence
Mr. Brett Lambert	DASD(MIBP)	Deputy Assistant Secretary of Defense (Manufacturing and Industrial Base Policy)
Mr. Richard Gallman	DAU	Associate Dean, Outreach and Mission Assistance at Defense Acquisition University
Mr. Mike Kelly	FAA	Chief Engineer, Office of Commercial Space Transportation
Dr. George Schmidt	GRC/R000	Deputy Director for Research & Technology
Mr.Brian Muirhead	JPL/1010	Chief Engineer, JPL Executive Council
Mr. Jeff Hanley	JSC/AB111	Human Exploration Development Support Office Director
Dr. David Burns	MDA	MDA Director of Science and Technology
Dr. Patricia Gore	MDA	Director of Industrial Manufacturing, Missile Defense Agency
Dr. Dale Thomas	MSFC/DA01	Associate Center Director, MSFC
Mr. Daniel Dumbacher	NASA, HQ	Deputy Associate Administrator for Exploration Systems and Development
Mr. Alex Priskos	NASA, MSFC	Booster Manager, Space Launch System
Mr. Jim Norman	NASA/HQ	Assistant Associate Administrator for Launch Services
RADM Terry Benedict	Navy SSP	Director, Strategic Systems Programs
Mr. John Schaefer	NAVY, SSP	Chief Engineer, U.S. Navy Strategic Systems Programs
Mr. David Janiec	NAWC	Director, Weapons and Energetics Department, U.S. Navy, Naval Air Warfare Center
Maj Gen Susan Mashiko	NRO	Deputy Director, National Reconnaissance Office
Mr. Dennis McLaughlin	NSWC	Technical Director, Naval Surface Warfare Center, Indian Head
Mr. Ted Bujewski	OSD ATandL	Principal Director, Manufacturing and Industrial Base Policy, Office of the Deputy Assistant Secretary of Defense
Dr. Spiro Lekoudis	OSD ATandL, RandE	Director Weapons Systems, Office of the Assistant Secretary of Defense for Research and Engineering
Col(s) Matt Lupone	OSD ATandL, SIO	Office Secretary of Defense for Space and Intelligence
Maj Gen William Chambers	SAF/A-10	Assistant Chief of Staff, Strategic Deterrence and Nuclear Integration
Mr. Rich McKinney	SAF/SP	Deputy Under Secretary of the Air Force for Space Programs
Mr. Stephen Cornelius	USA, AMRDEC	Director, U.S Army Aviation and Missile Research Development and Engineering Center