

Integrated High Payoff Rocket Propulsion Technologies Program Material Development Plan

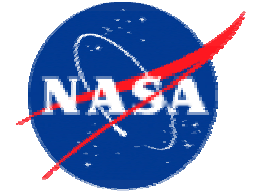
**R.G. Clinton Jr., NASA/MSFC
Dan Cleyrat, AFRL/ML/Anteon
Shawn Phillips, AFRL/PR**

**Michael Stropki, AFRL/ML
Brian Stucke, AFRL/ML
Brian Reed, NASA/GRC**

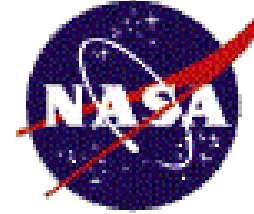
**4th Conference on
Aerospace Materials, Processes, and Environmental Technology
September, 2000**



OUTLINE

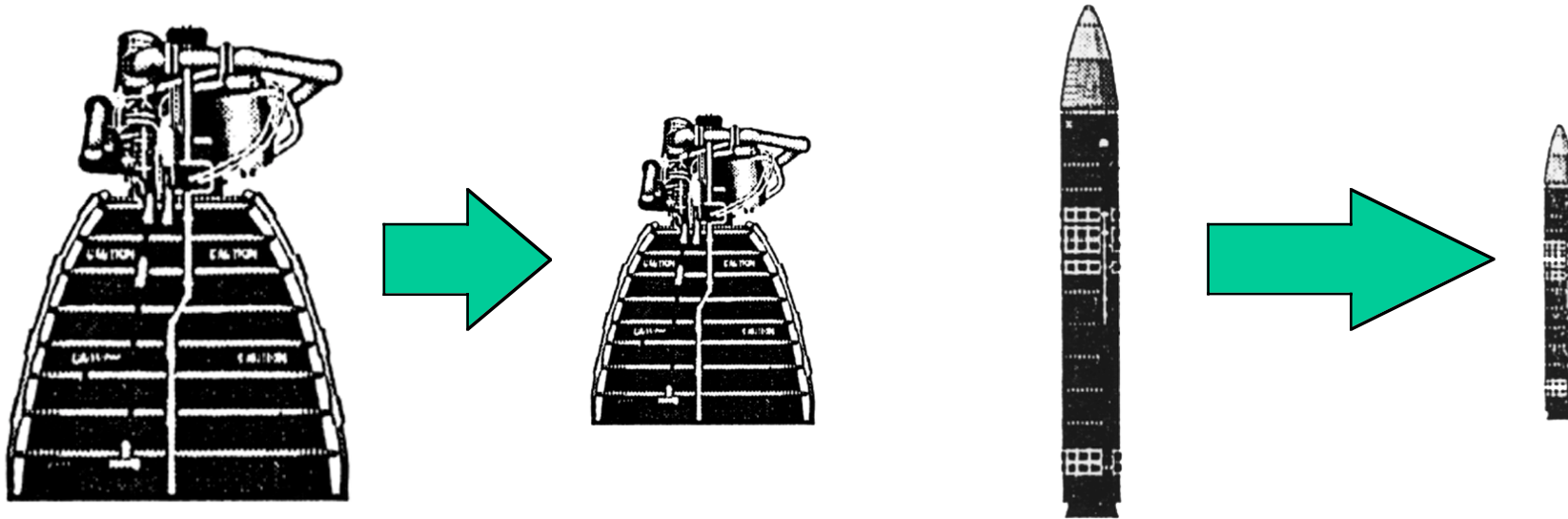
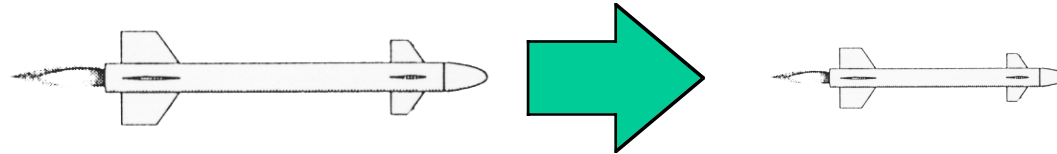


- **IHPRPT Goals**
- **IHPRPT Materials Working Group (IMWG)**
- **Materials Plan Development**
- **IMWG PRDA Status**
- **National Materials Plan for Rocket Propulsion**
- **Summary**



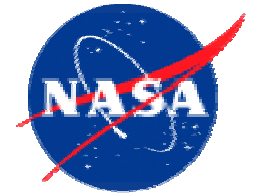
IHPRT Is

A DoD / NASA / Industry Initiative Which Will “Double” Rocket Propulsion Capability by 2010





IHPRPT Goals



Phase I Phase II Phase III

Boost and Orbit Transfer Propulsion

	<u>2000</u>	<u>2005</u>	<u>2010</u>
▪ Reduce Stage Failure Rate 75%		25%	50%
▪ Improve Mass Fraction (Solids)	15%	25%	35%
▪ Improve ISP (sec)	14	21	26
▪ Reduce Hardware Costs	15%	25%	35%
▪ Reduce Support Costs	15%	25%	35%
▪ Improve Thrust to Weight (Liquids)	30%	60%	100%
▪ Mean Time Between Removal (Mission Life-Reusable)	20	40	100

Spacecraft Propulsion

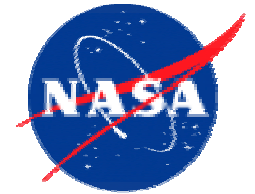
▪ Improve $I_{tot}/Mass_{(wet)}$ (Electrostatic/Electromagnetic)	20%/200%	35%/500%	75%/1250%
▪ Improve Isp (Bipropellant/Solar Thermal)	5%/10%	10%/15%	20%/20%
▪ Improve Density-Isp (Monopropellant)	30%	50%	70%
▪ Improve Mass Fraction (Solar Thermal)	15%	25%	35%

Tactical Propulsion

▪ Improve Delivered Energy	3%	7%	15%
▪ Improve Mass Fraction (Without TVC/Throttling)	2%	5%	10%
▪ Improve Mass Fraction (With TVC/Throttling)	10%	20%	30%



IHPRPT GOALS



Benefits from Achieving Goals ⁽¹⁾

- Payoffs in increased capability, increased reliability and reduced cost are enormous.
- Achievement of the technology goals would provide the following possibilities for system performance improvements:
 - Increase from 25k pounds payload to 65k pounds on a reusable launch vehicle.
 - 92% increase in payload on an expendable launch vehicle.
 - Average annual savings of \$648M per year for space launch (based on the National Mission Model over 20 years with Atlas, Delta, Titan IV and Shuttle and including operations cost, hardware costs and cost of failure).
 - 45% increase in satellite life (approximately \$240M/satellite savings).
 - 500% increase in satellite repositioning.
 - 100% increase in range/payload capability for a tactical missile.

⁽¹⁾ Information from IHPRPT Point Paper by Dr. Robert C. Corley.

IHPRPT Materials Working Group (IMWG) Activities

Feb 97 Materials Working Chartered by IHPRPT Steering Committee

Mar 97 Working Group Membership Established

Apr 97 Status Brief to ODDRE

May 97 Inaugural Meeting of IMWG

Jun-Sep 97 Review/Analysis of ARPP's & 48 SBIR Evaluations

Aug 97 IHPRPT Materials DTO MP.29.01 Established

Oct 97 NASP Lessons Learned Workshop & 2nd Meeting of IMWG

Jan 98 3rd IMWG Meeting & Status Brief to ODDRE

Feb 98 DTO Briefing at Reliance Meeting

Feb 98 Brief to IHPRPT Steering Committee

May 98 4th IMWG Meeting

Jun 98 Status Brief to ODDRE

Jul 98 Brief to IHPRPT Steering Committee

Nov 98 IMWG Chair Meetings at Industry Sites

Dec 98 DTO Briefing at Reliance Meeting

Jan 99 Status Brief to ODDRE

Feb 99 Brief to IHPRPT Steering Committee & Reliance

Jun 99 IMWG Weekly Telcons

Jul 99 Brief to IHPRPT Steering Committee

Oct 99 IMWG - Component Lead Meeting

Feb 00 Brief to IHPRPT Steering Committee

Mar 00 Execution/PRDA Development Meeting

May 00 **Materials PRDA Released**

Liquids B&OT Plan

Solid B&OT Plan

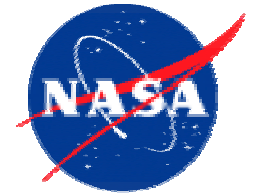
Solids Tactical Plan

Spacecraft Plan

Materials Execution Plan



IHRPT Materials Working Group



Process

- Evaluate Requirements and Develop Materials Plan for IHRPT Liquid, Solid, and Spacecraft Propulsion Goals
- Co-Chairs: **AFRL**- Michael Stropki; & **NASA-MSFC**- Corky Clinton

Team

Government

- USAF**: AFRL Materials & Manufacturing Directorate (ML); Propulsion Directorate (PR)
- Army**: ARL, MCOM
- Navy**: NAWC, NSWC
- NASA**: MSFC, GRC, LaRC

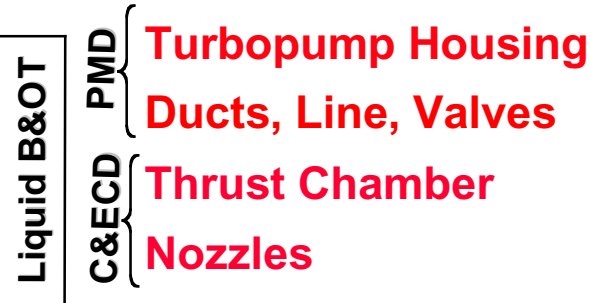
Industry

- | | |
|--------------------------|-------------------------------|
| ARC | Primex |
| Aerojet | Thiokol |
| Alliant | TRW |
| Boeing/Rocketdyne | UT Chemical Systems |
| Kaiser-Marquardt | UT Pratt & Whitney |

Considering Addition of Materials Suppliers

Product - Materials Plan

Materials Weight , Durability, & Performance Improvements For



Chamber **Catalyst/ Thermal Bed** **Case / Insulation**



Optics(Grids)

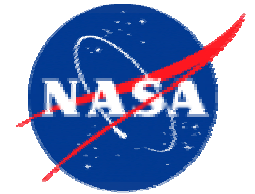
**Exit Cone
Nozzle
Throat**

Spacecraft

Solids: B&OT/Tactical



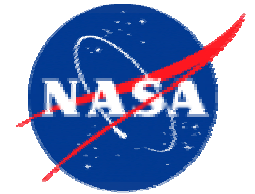
Materials Plan Development



- **Materials Plan for IHPRPT Developed**
 - Developed by IHPRPT Materials Working Group (IMWG)
 - Addresses Liquids, Solids, Spacecraft, Tactical Components
 - Category Prioritization Developed with Industry and Government Representatives - Continuing Iterative Process
- **Air Force Funding Allocated for Materials Development**
- **Formula for Program Execution (Iterative Process)**
 - Materials Execution/Funding Allocation per IMWG Plan
 - Coordinate with IHPRPT Component Leads
 - Coordinated with NASA Plans in Materials Technology for Integrated Space Transportation Plan (ISTP) (Currently part of IMWG process)
 - IHPRPT Steering Committee Approval
 - Execute Plan Through AFRL/ML PRDA Process



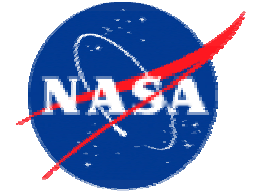
Materials Plan Development



- Materials and Processes Science & Technology Program (Not Component Development)
 - Up to sub-scale development as required
 - Component development *not* part of this M&P program
- IMWG Materials Program Has Transition Path to Component Program (Traceability) Through IHPRPT Component Leads
- Materials Vendors /Propulsion Primes to Be Contractually Connected Through PRDA
- Program Maintains Flexibility to Allow for :
 - New developments in materials and processes
 - Adjustments to materials and processes maturation
 - Phase III initiatives (i.e., new starts)



Materials Plan Development IHPRT M&P Program Progression



Critical Component Requirements

- Determine/Coordinate on Key Components
- Assess Materials Requirements
- Combined DOD, NASA, Industry Activities
- Use ARPP, Tech. Leads, IMWG

Pre-TRL

M & P Dev/Subscale Demonstration

- Develop/Characterize Materials Based on the Assessment
 - Process Development/Evaluation
 - Preliminary Configuration Assessment
 - Measure Preliminary Thermal and Mechanical Properties
 - Conduct Environmental Assessment
 - Assembly Considerations
- Subscale Component Demonstration/Validation

TRL 3/4

Scale-up, Property Verification, Component Dev

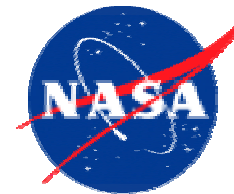
- Take THE Best Materials Approach; Scale-up Process to Verify
 - Material Uniformity
 - Thermal, Physical and Mechanical Properties
 - Process Reproducibility
 - Failure Mechanisms
- IHPRT Scale Up
 - Refine Design
 - Produce Full Scale Components
 - Further Define Component Failure Mechanisms
 - Provide Component for Demonstration Testing
- Validate Demonstration Exit Criteria for Demo Testing

TRL 5/6

Component Verification

- The M&P Technology Transition to IHPRT Demo Team
 - Process
 - Properties
 - Subcomponent Performance
 - Failure Mechanisms
- Participate in Component Demo Phase ATD Development

Demo of
New Material



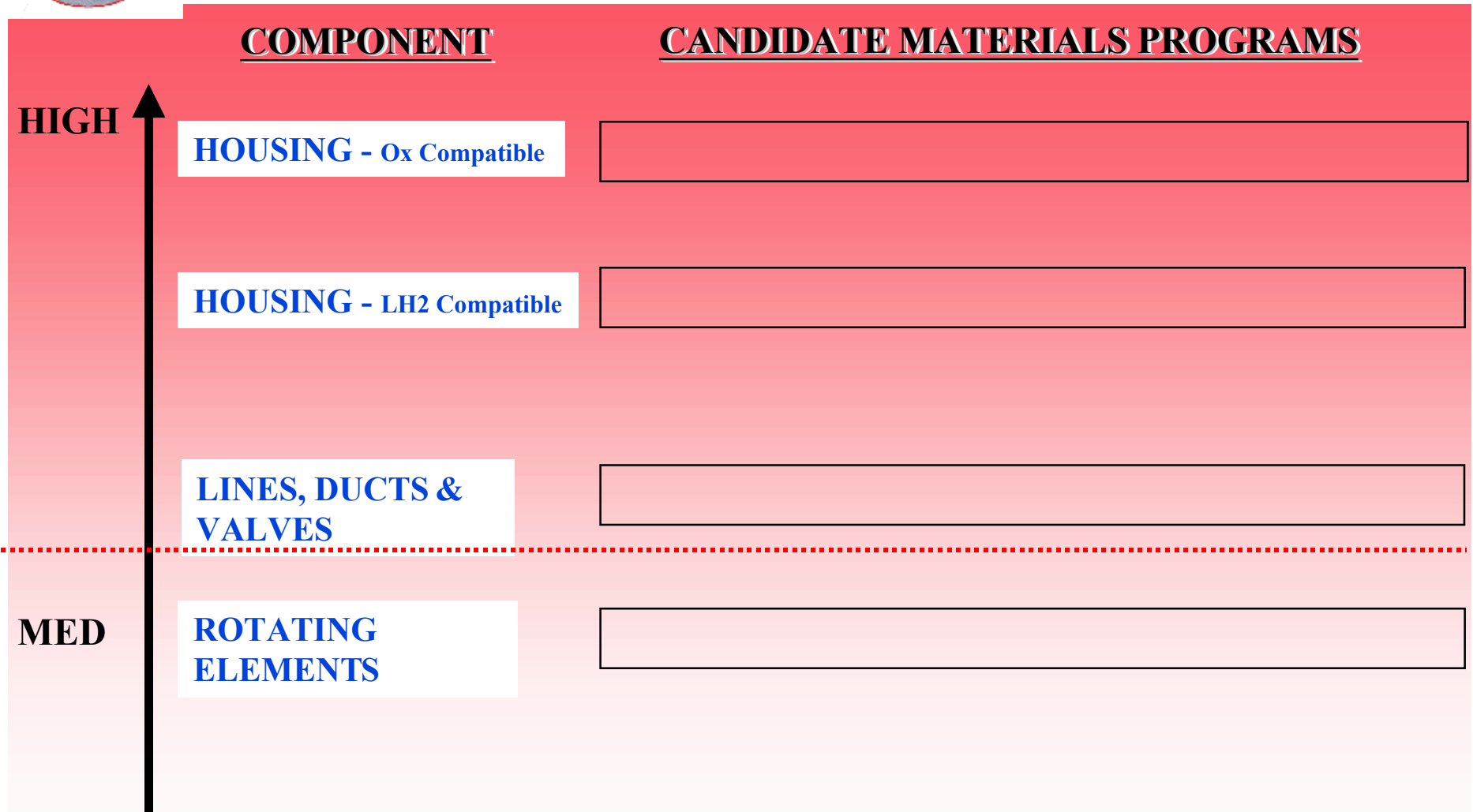
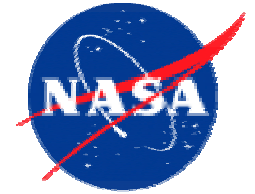
IHPRT Materials Plan

2000

Examples from Plan Development Process



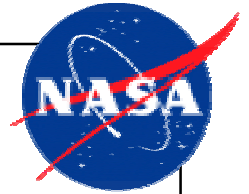
IMWG Program Support To Propellant Management Devices (PMD)



Other M&P Critical Needs May Emerge for Phase II & III Based on Iterative Process



Cryo Boost Phase II PMD



Oxygen-Rich Turbopump Housing

Component Objectives	Material Candidates
<p>Oper. Temp Ultimate Strength (Long./Trans) Shear Strength TBD (Long/Trans) Elastic Modulus (Long/Trans) Shear Modulus Poisson's Ratio Fracture Toughness Thermal Shock Density CTE (Long/Trans)</p>	<ul style="list-style-type: none">• Candidate A• Candidate B

EXAMPLE

Cryo Boost Phase II PMD

LOX Turbopump Housing

Candidate Material A

Current Properties	Technical Issues / Risks
<ul style="list-style-type: none"> ▪ Very little data developed to date ▪ Demonstrated oxidation resistance ▪ Limited matrix strength and ductility data available 	<ul style="list-style-type: none"> ▪ Demonstrate oxidation resistance and promoted combustion resistance; mech properties, characterization ▪ Establish design and analysis methodology; data ▪ Develop interfaces and attachment approaches ▪ Fabricate sub scale components ▪ Validate life/performance

<u>Current Tasks</u>	<u>Total(\$K)</u>	<u>ORG</u>	<u>FY99</u>	<u>FY00</u>	<u>FY01</u>	<u>FY02</u>	<u>FY03</u>	<u>FY04</u>	<u>FY05</u>
Metal Matrix Composite - Turbopump Demo	XXX	NASA	XXX	XXX					
NASA-SBIR	XXX	IRAD NASA	XX	XXX	XXX				
Total Current									

* - M&P portion of total task
 ** - leveraging of Al Based LH2 MMC Program

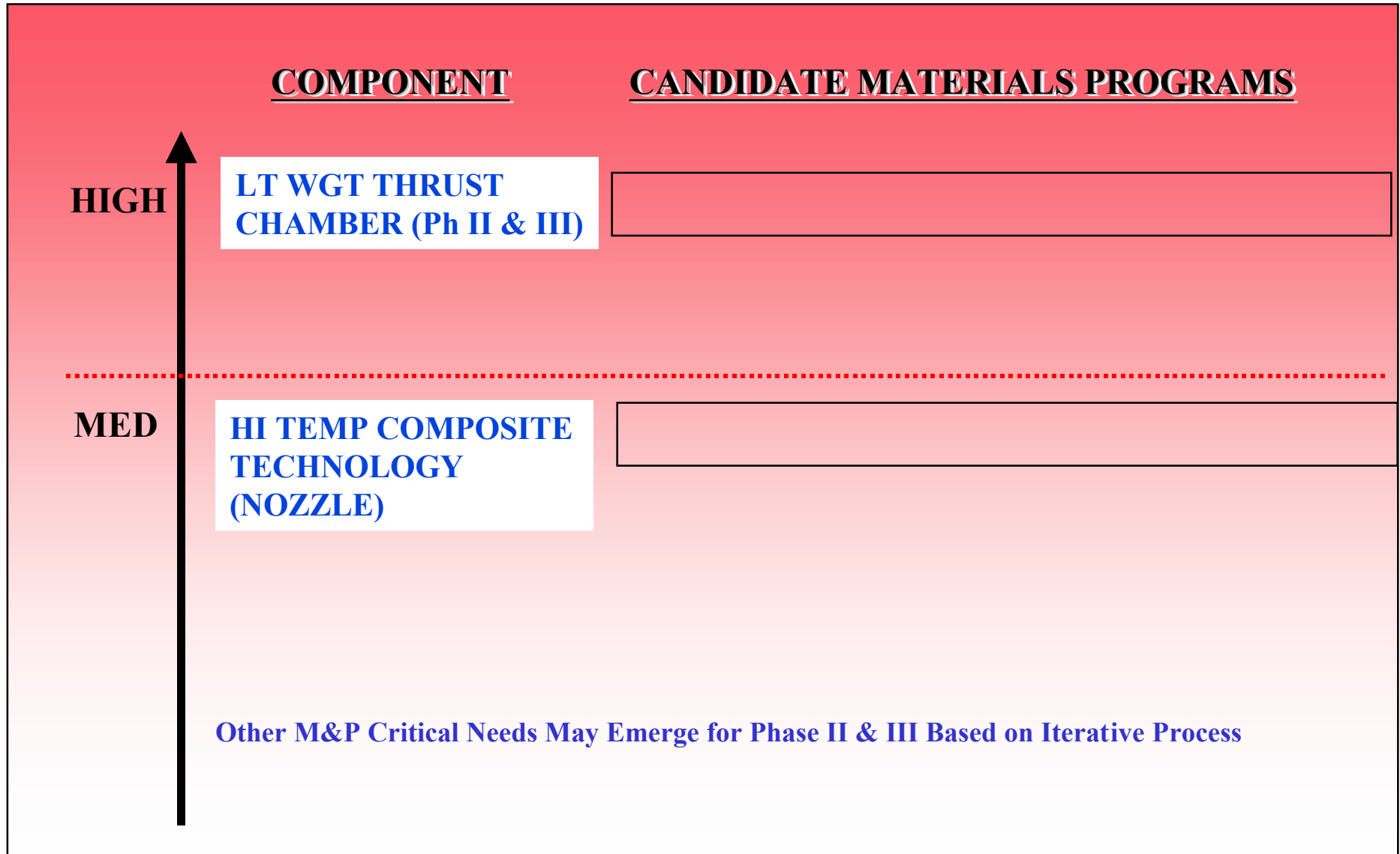
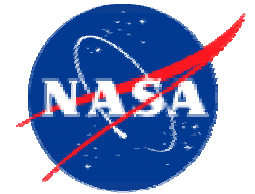
Planned M&P Programs

- D&A to Est. Requirements.
- Develop Interfaces and attachments
- Examine alternative approaches/materials
- Validate life/performance


PRDA Task TBD



IMWG PROGRAM SUPPORT TO Combustion and Energy Conversion Devices (C&ECD)



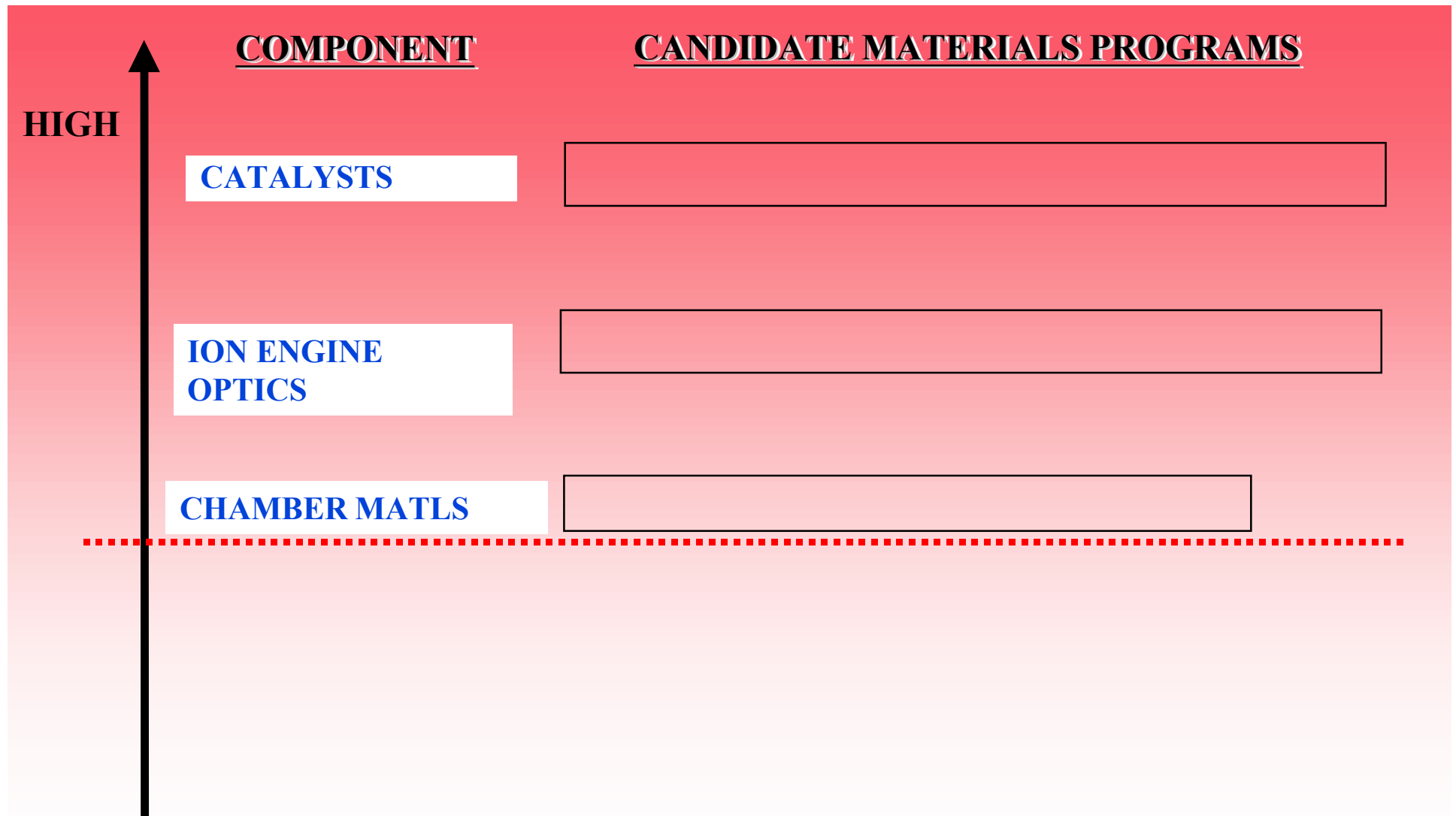
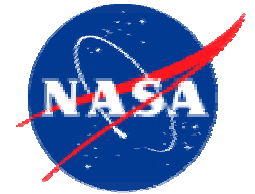
IMWG Program Support To SRM (B&OT and Tactical)

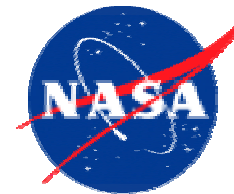
 HIGH	<u>COMPONENT</u>	<u>CANDIDATE MATERIALS PROGRAMS</u>
	NOZZLE - Low-Eroding Throats	
	INSULATION	
	CASE	
	NOZZLE - Low Cost Components	
	CASE	
	NOZZLE - Exit Cone Ablative	

***Programs that will apply to Tactical and to B/OT**



IMWG Program Support To Spacecraft

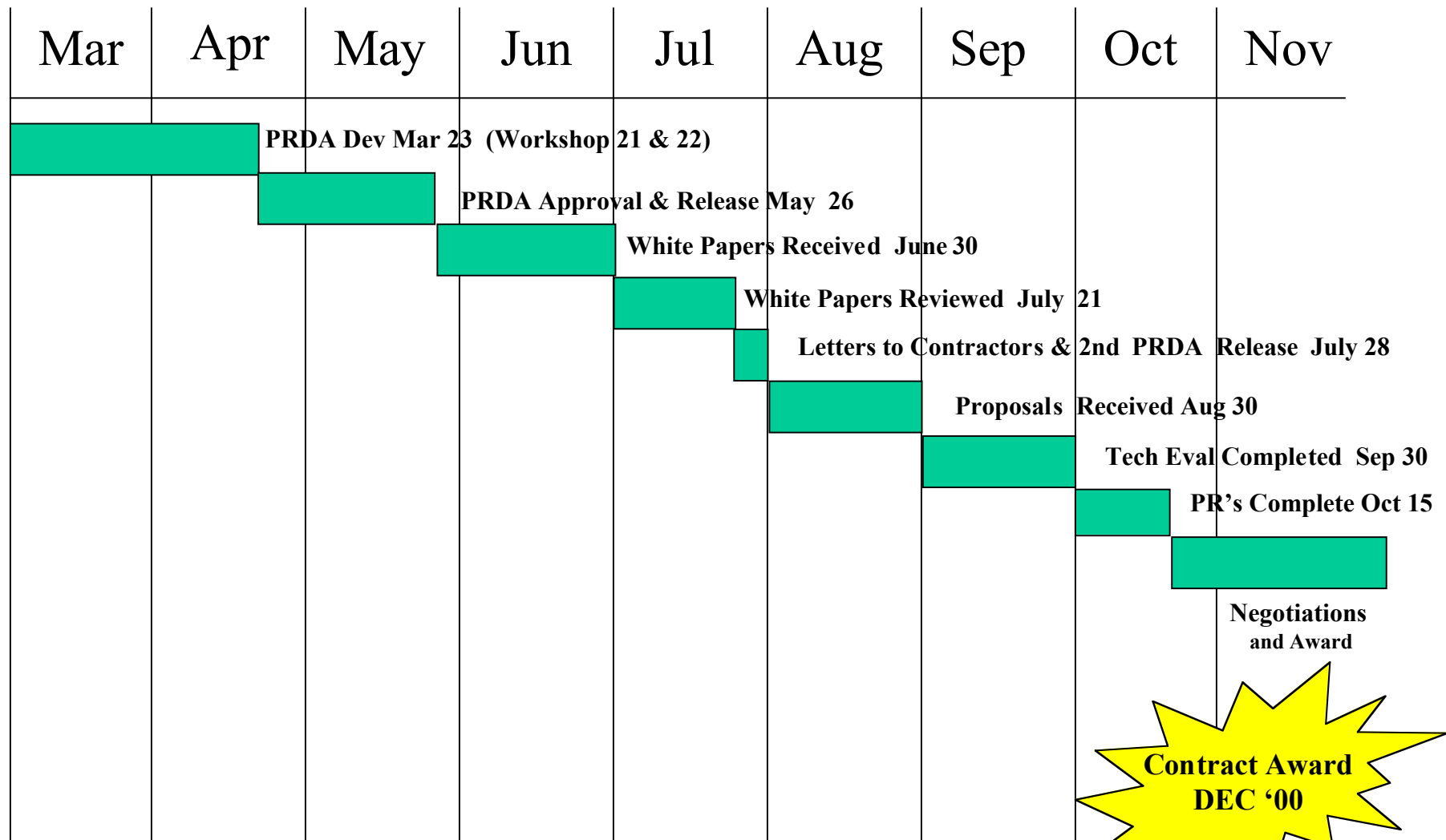
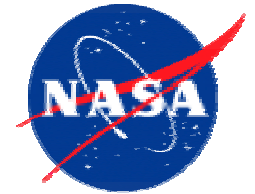




IMWG PRDA Status

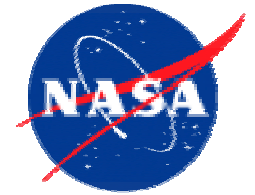


IHPRPT Materials PRDA Schedule





imwg PRDA Topics

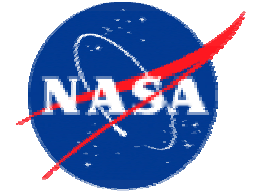


Liquid Boost and Orbit Transfer

<u>Topic</u>	<u>Team</u>	<u>Topic Lead</u>
1. LOX Turbopump Housing	AFRL/ML/PR, NASA MSFC, NASA LaRC, NASA GRC	Benji Maruyama
2. LH2 Turbopump Housing	AFRL/ML/PR, NASA MSFC, NASA LaRC, NASA GRC	Benji Maruyama
3. Lines, Ducts, Valves	AFRL/ML/PR, NASA MSFC, NASA LaRC, NASA GRC	Kumar Jata
4. Thrust Chamber Jacket	AFRL/ML/PR, NASA MSFC, LaRC, GRC	Dan Miracle
5. Nozzle and Coatings	AFRL/ML/PR, NASA MSFC, NASA LaRC, NASA GRC	Steve Steel



IMWG PRDA Topics



Solid Rocket Motor Boost & Orbit Transfer/Tactical

<u>Topic</u>	<u>Team</u>	<u>Topic Lead</u>
6. Nozzles and Inserts	AFRL/ML/PR, NASA MSFC, Aerospace Corp.	Scott Theibert
7. Insulation and Case	AFRL/ML/PR, NASA MSFC, Aerospace Corp.	Derek Linco

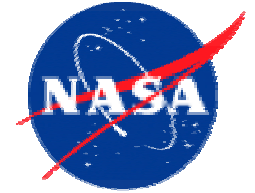
Spacecraft

<u>Topic</u>	<u>Team</u>	<u>Topic Lead</u>
8. Catalyst/Thermal Bed	AFRL/ML/PR, NASA GRC	Steve Steel
9. Optic Grid	AFRL/ML/PR, NASA GRC	Kristen Kearns
10. Oxidation Resistant Chamber Mat.	AFRL/ML/PR, NASA GRC	Kumar Jata

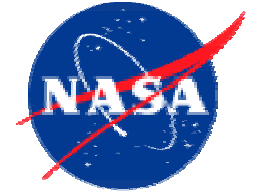


IMWG PRDA Status

OMC Study for Phase III Applications



- OBJECTIVES:
 - Assess OMC technology for feasibility of application to Liquid Propulsion Components. (LH2 turbopump housings, lines, ducts, valves and a thrust chamber structural jacket identified in materials plan for Phase III development).
 - Provide assistance in determining scope and direction to future DOD and NASA investment in OMC's for liquid propulsion components.
- Performed by a "Blue Ribbon" materials and processes group including propulsion expertise with no affiliations to an organization that could bid on topics in a future IHPRPT Materials OMC PRDA.
- Posture for timely Materials PRDA II (6 month duration).
- Present findings at appropriate space materials or propulsion conference (e.g. NSMMS).

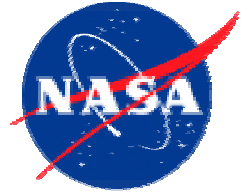


National Materials Plan for Rocket Propulsion

September, 2000



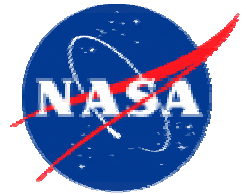
National Materials Plan for Rocket Propulsion



- Under IMWG Initiative, Developing Strategy and Process for Coordinating IHPRPT Materials Plan with NASA Materials Planning for ISTP.
- Product will be a Joint IHPRPT - ISTP Materials Development Roadmap.
- Will Provide for a Combined IHPRPT-NASA Strategy for Materials Development (National Plan).
 - Maximize use of resources (avoid duplication).
 - Provide opportunities for cooperative programs.
 - Rebuild National leadership in propulsion technology.



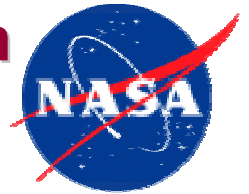
National Materials Plan for Rocket Propulsion



- Coordination of IMWG and NASA ISTP efforts towards development of the National Rocket Propulsion Materials Plan is in progress.
 - Key NASA materials experts participation on IMWG Technical Teams for PRDA drafting and white paper evaluation.
 - NASA/MSFC has assigned specific responsibility for 2nd Gen/3rd Gen RLV synergistic technologies coordination to the RLV Focused Technology Project.
 - Dissemination of 3rd Generation RLV Program planning results to IMWG PRDA Technical Teams supporting white paper evaluation (in progress).
 - NASA-led 2nd Generation RLV proposals will be assessed for potential overlap with IMWG white papers (in progress).
 - Industry-led 2nd Generation RLV proposals will be assessed for potential overlap with IMWG proposals.



National Materials Plan for Rocket Propulsion NASA ISTP - IMWG



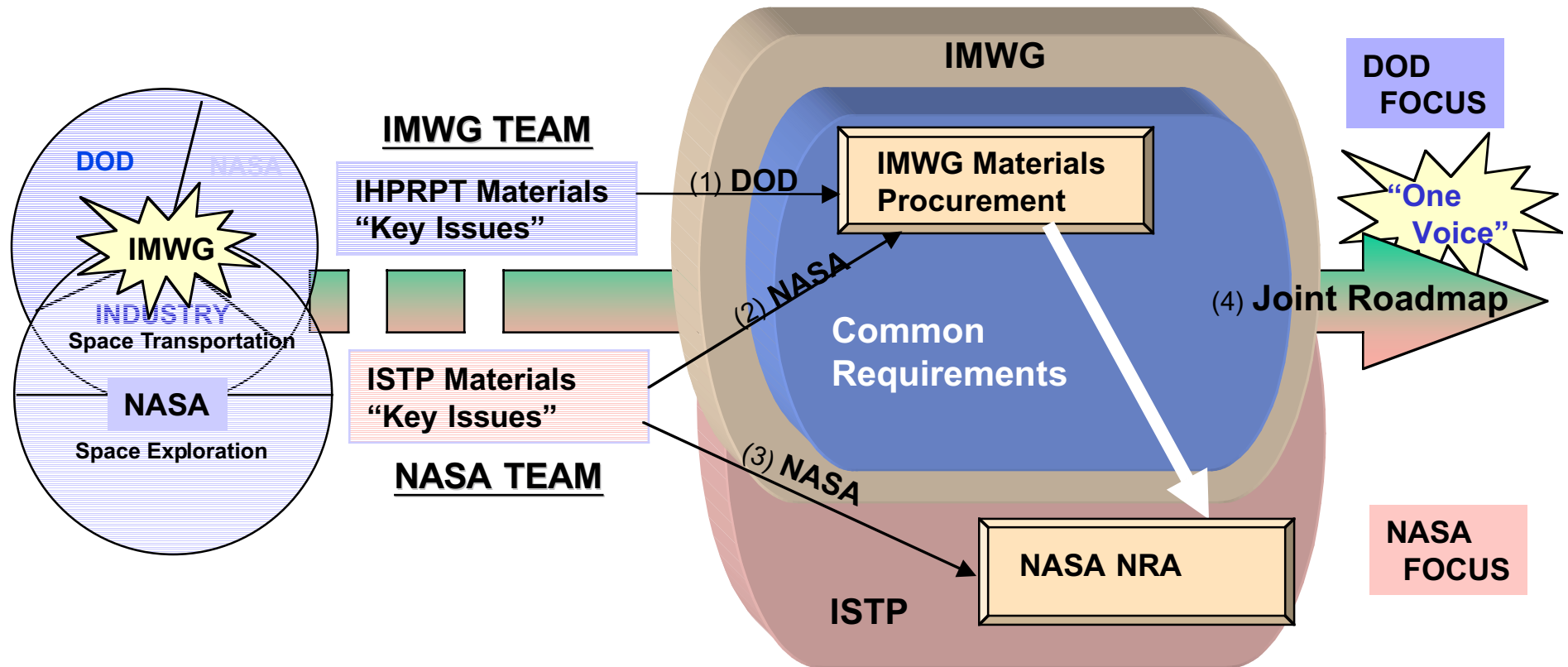
Merging Common Space Propulsion Materials Efforts

NATIONAL EFFORT

TEAMING

COORDINATION

KEY PRODUCT



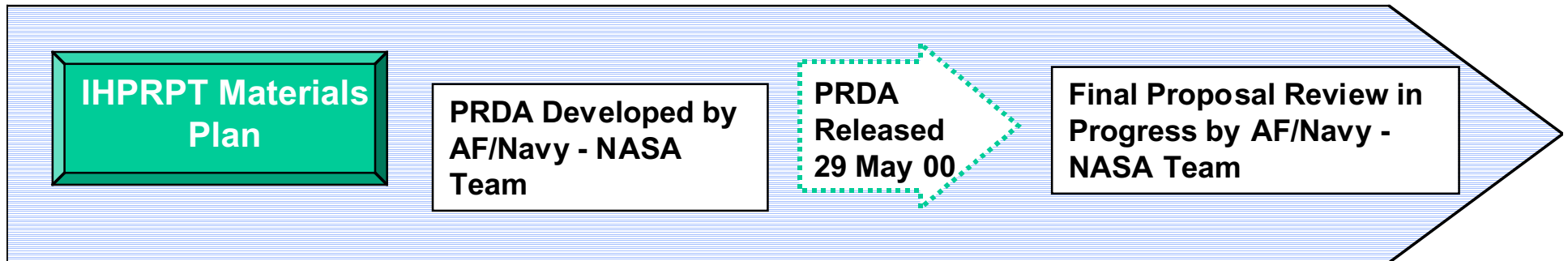
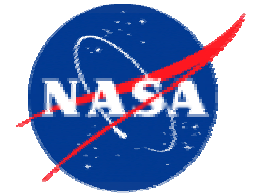
1. DOD (AF) Funds IMWG PRDA for IHRPT Materials Requirements
2. NASA Augments Funding or Specific Tasks for Increased NASA Materials Requirements
3. NASA Funds NRA for ISTP Unique Requirements (Focused on 2nd & 3rd generation goals)
4. IMWG Develops Joint Materials Roadmap as Part of IMWG Plan



National Materials Plan for Rocket Propulsion

NASA ISTP - IMWG

Current Activity

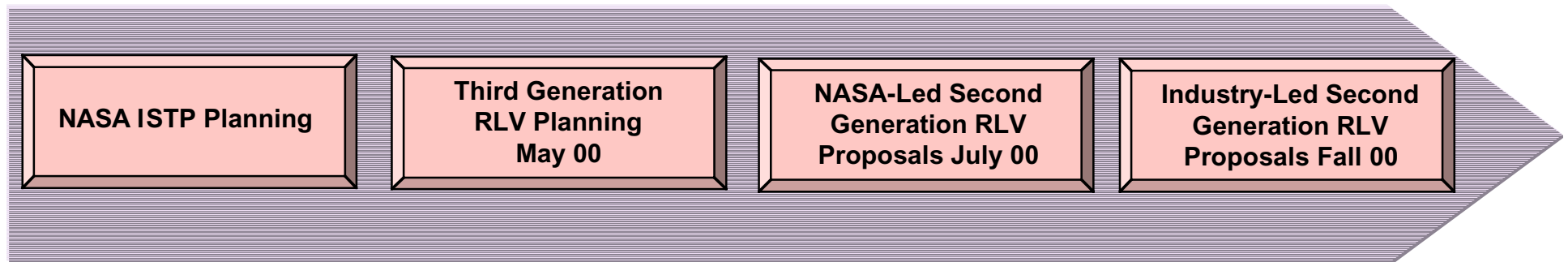


Under the Auspices of the IHPRPT and ISTP Programs

Strategy

Utilizing AF/Navy - NASA Engineers to Develop Plans, Prepare Solicitations, and Evaluate Proposals

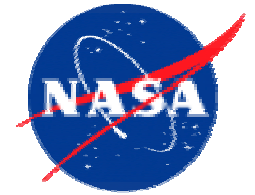
Review Requirements and Approaches for Areas of Commonality



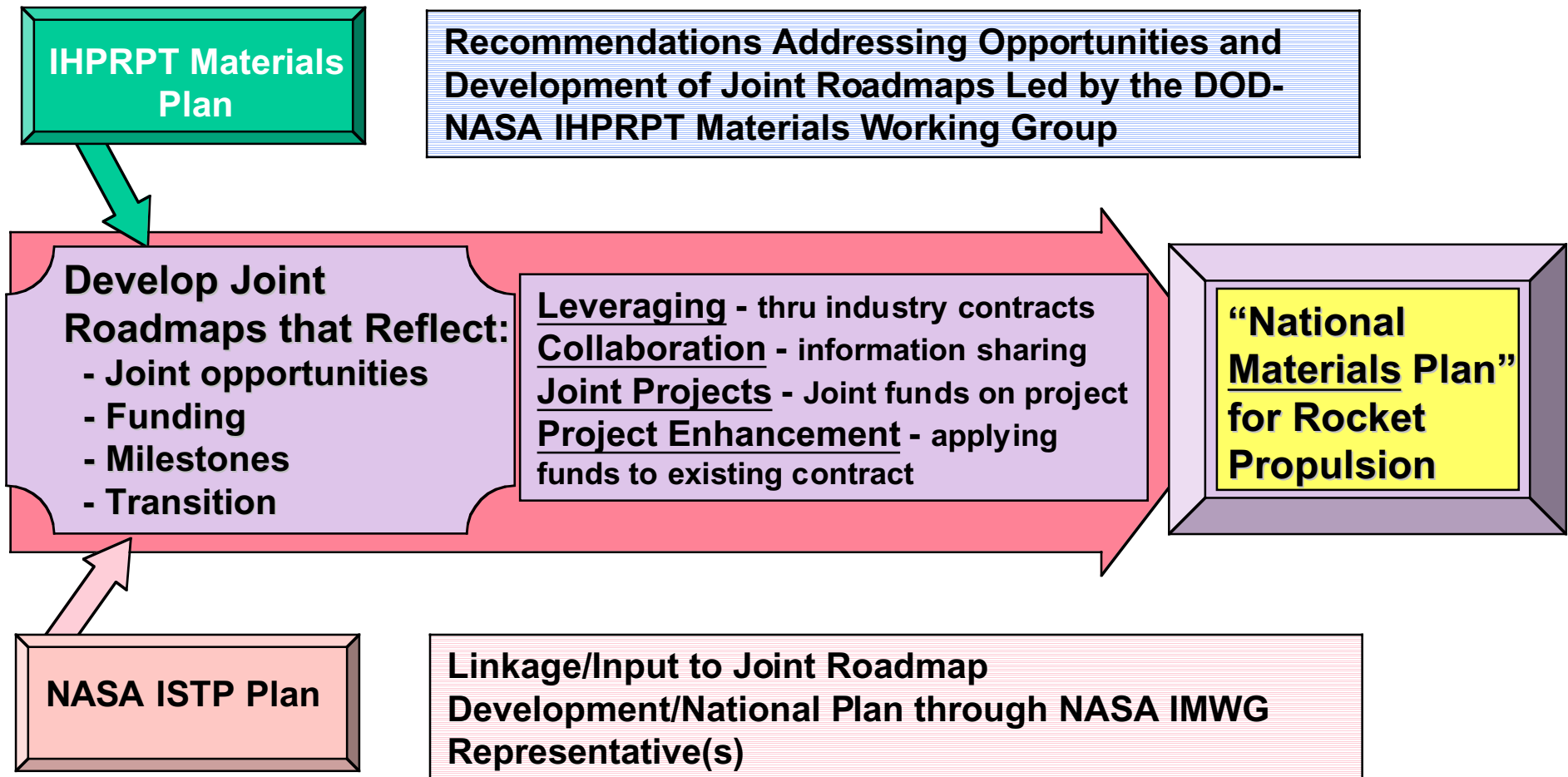


National Materials Plan for Rocket Propulsion

NASA ISTP - IMWG

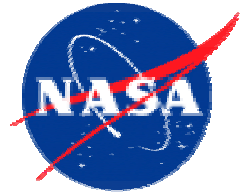


Next Steps





Summary



- **IMWG Government and Industry Members, Together With the IHRPT National Component Leads, Have Developed a Materials Plan to Address the Critical Needs of the IHRPT Community.**
 - Liquids Boost and Orbit Transfer.
 - Solids Boost and Orbit Transfer.
 - Tactical.
 - Spacecraft.
- **Criticality of Materials' Role in Achieving IHRPT Goals Evidenced by the Significant Investment Over the Next 5 Years.**
- **Materials Plan Is a “Living” Document to Assure Appropriate Focus and Progress.**
- **Excellent Response to IMWG PRDA With 50 White Paper Proposals Received for the 10 Topic Areas.**
 - Final Reviews in Progress.
 - On Schedule for December 2000 Awards.
- **National Rocket Propulsion Materials Plan, Coordinating IHRPT and NASA Activities, Being Developed by IMWG.**