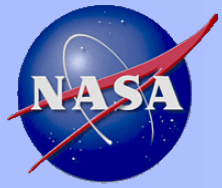




# ***NASA Propulsion Capability Leadership***

***Rocket Propulsion for the 21<sup>st</sup> Century (RP21)  
Spring Meeting***

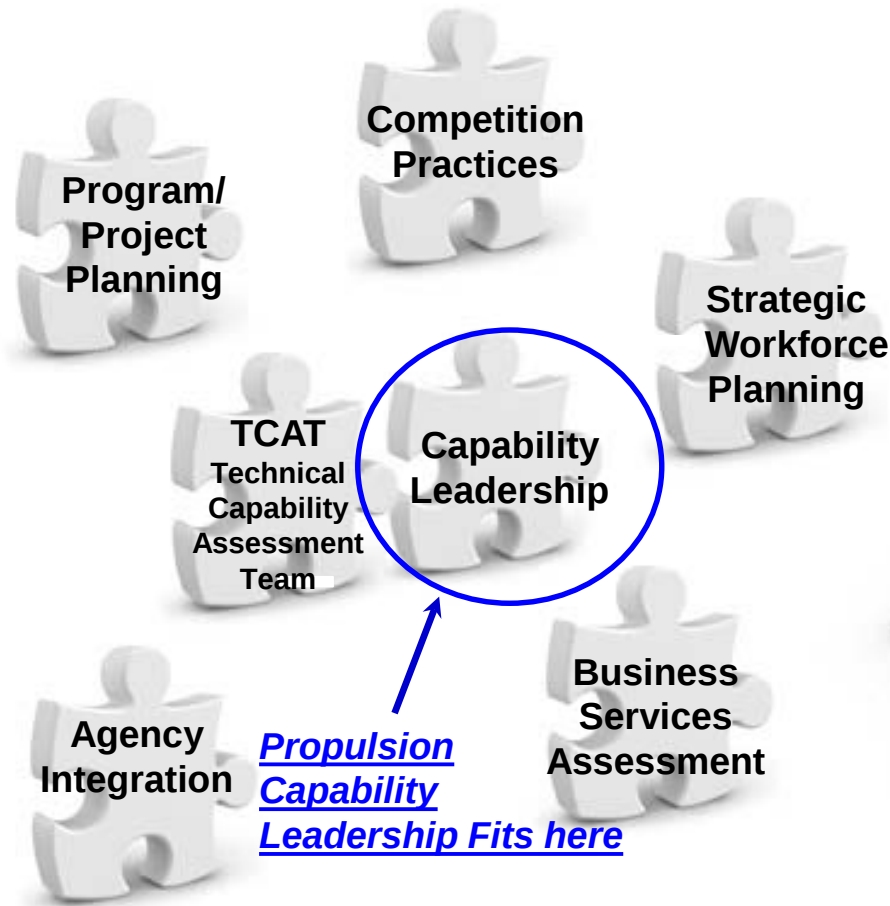
***May 15-16, 2018***



# Completing the Puzzle

<https://nbat.hq.nasa.gov>

## NEW AGENCY OPERATING MODEL



**IMPERATIVE:** Establish a more efficient operating model that maintains critical capabilities AND meets current and future mission needs

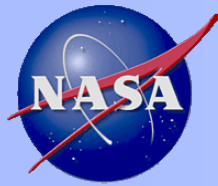


# ***Capability Leadership***

**Capability leadership is part of the overall puzzle**



- **Provides leadership/integration/optimization of distributed agency technical capability**
- **Provide technical based guidance on future needs/gaps investments and solutions for Agency missions**



# ***NASA Capability Leadership Teams***

## **Discipline Capability Leadership Teams:**

Aerosciences  
Avionics  
Electrical Power  
Flight Mechanics  
Guidance Navigation and Control  
Human Factors  
Instruments and Sensors  
Life Support/Active Thermal  
Loads and Dynamics  
Materials Mechanical Systems  
Non Destructive Evaluation  
Passive Thermal  
**Propulsion**  
Software  
Space Environments  
Structures  
Systems Engineering



## ***Technical Capability Leadership: Governance***

- **Office of the Chief Engineer (OCE)** — Administers discipline-level and (interim) system-level Technical Capability Leadership on behalf of Agency
- **NASA Engineering and Safety Center (NESC)** — Designation of Technical Fellows and leadership of technical discipline teams
- **Engineering Management Board (EMB)** (extended as necessary) — Provide integration and communication across technical capabilities and review results of technical assessments to develop agency-wide engineering recommendations for presentation to Agency decision-making forums
  - Core membership includes Engineering Directors or Center Chief Engineers from each Center
  - Extended-EMB include reps from each Center, Mission Directorate, MSD, OSMA, OCHMO, OCS, OCT
- **Agency Program Management Council (APMC)** — Annual review of Agency-level technical capabilities for invest/divest decisions
  - Directs funding source and implementation organization for a specific deliverable, with Capability Leadership Team responsible for oversight of implementation strategy
- **Mission Support Council (MSC)** — Venue for addressing recommendations if appropriate decision thresholds are met
- **Baseline Performance Review (BPR)** — Venue for reviewing Center/MD implementation status of Agency-level technical capability decisions
- **Deputy Associate Administrator** — Address issues when lower level resolution cannot be reached



# ***Propulsion Capability Scope and Decomposition***

## Propulsion

*In Space Transportation*

*Ascent/Descent Transportation*

*Air Vehicles*

**Aero-Propulsion**

*Gas Turbine*

*RamJet/SCRamJet*

*Electric/Hybrid*

**Chemical Space-Propulsion (SP)\_**

*Liquids (including NTP)*

*Solids*

*Ancillary*

*Hybrid*

**Electric SP**

*SEP, NEP, etc..*

**Other Advanced/Propellantless**

*Propellantless?*

*Unconventional*

*Includes part of Nuclear common to other "Propulsion" does not currently include fuel development, reactor neutronics, or power generation*

*Sub capability categories selected to minimize separation of cross cutting sub-disciplines*



# Propulsion Capability Summary

CLT Lead: Thomas Brown, NASA Technical Fellow for Propulsion  
July 2017

## Overall Assessment

SIGNIFICANT ISSUES



ROBUST CAPABILITY

### Top Challenges/Gaps:

- Agency propulsion capability has been on a downward trend since 2010, but has stabilized at a Primary Propulsion workforce of ~ 1400
- Chemical and Electric Sub-Capability Management forums in place and functioning
- Some uncertainty in demand for chemical propulsion sub-capability after current hardware development efforts (post 2019?)

## Capability Distribution

| Chemical Space                           |                                          | Aero                                     | Electric Space                          | Advanced Space                               |
|------------------------------------------|------------------------------------------|------------------------------------------|-----------------------------------------|----------------------------------------------|
| DD&E                                     | OPS                                      |                                          |                                         |                                              |
| <input checked="" type="checkbox"/> MSFC | <input checked="" type="checkbox"/> KSC  | <input checked="" type="checkbox"/> GRC  | <input checked="" type="checkbox"/> GRC | <input checked="" type="checkbox"/> ALL Ctrs |
| <input checked="" type="checkbox"/> GRC  | <input checked="" type="checkbox"/> GSFC | <input checked="" type="checkbox"/> LaRC | <input checked="" type="checkbox"/> JPL |                                              |
| <input checked="" type="checkbox"/> JSC  | <b>Test</b>                              | <input checked="" type="checkbox"/> AFRC |                                         |                                              |
| <input checked="" type="checkbox"/> KSC  | <input checked="" type="checkbox"/> SSC  |                                          |                                         |                                              |
| <input checked="" type="checkbox"/> GSFC | <input checked="" type="checkbox"/> WSTF |                                          |                                         |                                              |
| <input checked="" type="checkbox"/> JPL  | <input checked="" type="checkbox"/> MSFC |                                          |                                         |                                              |
|                                          | <input checked="" type="checkbox"/> GRC  |                                          |                                         |                                              |

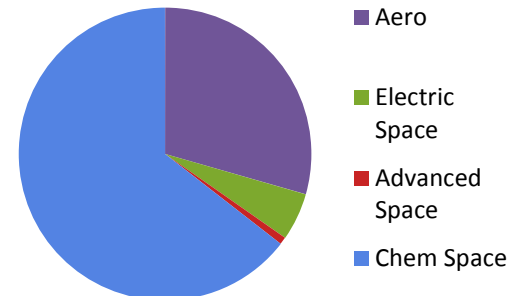
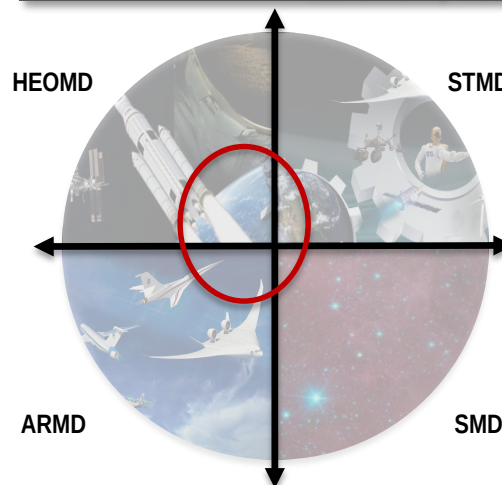
## External Capability

Capability Unique To NASA



Capability Ubiquitous Outside of Agency

## Customers / Resources and Assets



Staffing

1440 FTE/WYE (Primary Propulsion Workforce – within 1% of 2016)

- 728 FTE (including 35 JPL)
- 712 WYE – Driven substantially by contractor test technicians

Facilities

- Rocket Propulsion Test (RPT) board coordinates rocket test facility use
- SETMO Portfolio includes some multi use chemical propulsion test facilities - Utilization and status recommendations from EPSM/CPSM
- Additional small facilities coordinated through CPSM and EPSM

## Outlook/Actions

Chemical and Electric space Propulsion Sub-capability Management (CPSM & EPSM), forums established per APMC actions (see status charts)

2016 Recommendation: Integrated methane propulsion risk reduction/advanced development effort to inform 2020 Mars transportation decisions

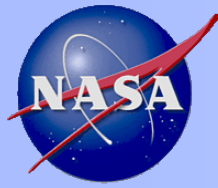
- Individual technology and advanced development efforts continue
- Little progress / traction on integrated effort



# ***Chemical Propulsion Sub-capability Management (CPSM) forum***

**NASAs Chemical Propulsion Sub-capability is led by the Marshall Space Flight Center (MSFC) through the CPSM forum** (*Chair: Mary Beth Koelbl, MSFC Propulsion Department Manager*)

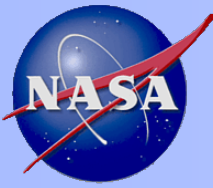
- Initiated CPSM in fall 2016
- Kickoff VITS including all member center representation December 15, 2016
- First Face-to-Face meeting January 19, 2017 to discuss strategy going forward
- Presented Implementation Plan at March APMC
- Developed and instituted Operating Principles and Guidelines
- Established method for early discussion and evaluation of potential Space Act Agreements (SAAs) prior to formal submission/review.
- Accomplishments / Select examples of early wins:
  - Eliminated needs/plans for WYE hiring and duplicate capability buildup through multiple new inter-Center collaborations.
  - Implemented CPSM operating plan that emphasizes day-to-day strategies and twice-a-year accountability for achieving collaboration efficiencies and role alignment. Held first annual Out-Brief Meeting on 6/30/2017.
  - Established Spreadsheet – currently tracking over 100 coordination and cost avoidance items resulting from CPSM activities.



# ***Electric space Propulsion Sub-capability Management (EPSM) forum - Status***

**NASAs Electric Propulsion Sub-capability is led by the Glenn Research Center (GRC) through the EPSM forum** (*Chair: George Schmidt, GRC Propulsion Division Chief*)

- EPSM initiated in Fall 2016 following APMC (Sept 2016)
- EPSM Core Team meetings between GRC (lead) and JPL held in Nov 2016 and Feb 2017
  - Developed and instituted Operating Principles and Guidelines
  - Reviewed status of EP development activities and facility consolidation efforts
  - Established method for early discussion and evaluation of potential Space Act Agreements (SAAs) prior to formal submission/review
- Extended Team meeting in May 2017 included other NASA stakeholders and users, namely GSFC, JSC, MSFC, LaRC and STMD
- Accomplishments / Examples of Early Wins:
  - Completion of EP facility consolidation. All facilities at GRC and JPL engaged in EP testing. Duplicative facilities excessed or repurposed to other areas.
  - Increase in EP workforce via strategic hiring and training to meet project needs.
  - Utilization of center interdependencies on major EP projects, including AEPS/SEP TDM, NEXT-C and Iodine EP technology.



# ***Propulsion Strategic Vector***

***Focus NASA internal propulsion capability on future needs and NASA unique systems while leveraging mature industry where appropriate, in support of human and robotic space exploration/science, manned and unmanned aero vehicles, and technologies that enable the national propulsion industry***

## Sub-Capability

**Chemical Space Propulsion**

**Electric Space Propulsion**

**Aero Propulsion**

**Advanced Propulsion**

## Strategic Thrusts

Future NASA needs for human and robotic exploration/science

Technologies enabling national **propulsion Industry**

Future national needs for manned and unmanned aero vehicles

## Elements of Thrusts

### **NASA Unique**

- Chemical systems for human planetary surface access
- Chemical systems for human in-space transportation
- High power/thrust electric systems for human exploration
- High Isp lower thrust electric systems for science

### **Leveraged Capability**

- Commercial LEO launch providers (CRS and LSP)
- Commercially available mature EP and Chemical propulsion systems and components for robotic science missions

### **Partnerships**

- Commercial Crew
- Nuclear Thermal Propulsion & Systems
- Small spacecraft propulsion (EP & Chemical)
- Hypersonic aero systems in partnership with DOD
- Supersonic aero systems technologies for commercial human transport
- Electric and Hybrid systems for low cost/low emission human and cargo transport

*Potential paradigm shifting propulsion concepts*  
**NASA led and Partnerships**



# Propulsion Strategic Vector

## Details of Evolution

**LEAD | PARTNER | LEVERAGE**

### Yesterday

#### Chemical Space Propulsion



- Shuttle for HSF (launch and in-space)
- Storable in-space prop for science and HSF
- Liquid Rocket Engine suppliers
- Separate vehicle primes/integrators
- Investigating next generation reusable launch vehicle
- Slow evolution of CFM component technologies for in-space use

#### Aero Propulsion



- Conventional architectures and conventional fuel for subsonic propulsion
- Supersonic Flight only over sea and nonconformance of noise reg;
- Small-scale hypersonic flight demo – scramjet technology and mode transition maturation

#### Electric Space Propulsion



- 2.5-kW Xenon ion thrusters – Boeing
- 4.5-kW Xenon ion thrusters – Boeing
- 4.5-kW Xenon Hall thrusters – Aerojet Rocketdyne
- 10-microNewton electro-spray thrusters – Busek

#### Advanced Propulsion



- ROVER/NERVA NTP Programs
- Space Exploration Initiative
- JPL/MSFC Advanced Propulsion Workshops
- ASTP/Revolutionary Propulsion Project

### Today

- Transition to commercial LEO launch
- Launch companies developing their own engines
- Storable hypergols for in-space propulsion
- Development of SLS/Orion for beyond earth orbit
- Investigating Low Cost NTP with low enriched uranium.
- Green Propellant Systems – Advanced Dev.
- Integrating CFM technologies to demonstrate viability of in-space cryo propellant systems
- Hybrids for Ascent systems
- Long Lifetime/Extreme Env. Solid Rocket Motors

- Energy efficient & environmentally compatible subsonic transport - Transition to more integrated architectures (HWB, Double Bubble, etc. – alternative fuels)
- Supersonic Flight over land (low boom) – small jets (6 – 90 Pax)
- Hypersonics Technology program through partnership with DOD
- Hybrid-electric aero-propulsion

- 12.5-kW Xenon Hall thrusters – Aerojet Rocketdyne (AEPS)
- 7-kW Xenon ion thrusters – Aerojet Rocketdyne (NEXT-C)
- Commercially available systems and buses

- STMD/ESI – Breakthrough Propulsion Formulation
- STMD – Interstellar Roadmap
- NIAC Program & CTR IRAD/CIF Efforts
- NEA Scout – Solar Sail Development

### Tomorrow

- **Cryogenic In-space Prop (LOX/CH<sub>4</sub>)**
- **Descent and Ascent Lander engines and systems**
- **Use of ISRU produced propellants**
- **SLS Operations & Orion Operations**
- **NTP Engine & System Development**
- **Commercial Crew**
- **Launch service providers for LEO (LSP & CRS)**
- **Green Propellant Systems**
- **Advanced Chem for Science Missions**
- **Traditional Chem for Science Missions**



- All electric, alternative powers sources & cycles for subsonic propulsion
- Commercial supersonic jets over land – 100 to 200 Pax & increased cruise efficiency – economic viability
- Advanced large scale hypersonic air-breathing systems – Aircraft-like operation and Access to Space

- **Gateway Power and Propulsion Module (~40 kW class EP system, solar powered)**
- **Mars Cargo or Hybrid systems (150 kW – 300 kW, solar powered)**
- Low-power EP (<1 kW) for small, deep-space science missions
- High-Isp, high-total impulse multi-kW EP for deep-space science missions
- Advanced Mars Crew Transportation (multi-MW EP with low  $\alpha$  nuclear power systems (~1 kg/kW))

- STMD/GCD – Breakthrough Propulsion Initiative
- STMD/ESI – Interstellar Propulsion R&D
- Interstellar 2069 – Alpha Centauri Flyby Probe
- NEA Scout – Solar Sail Flight
- NIAC Program – Propulsion Efforts