National Aeronautics and
Space Administration

NASA Technology Area 1: Launch Propulsion Systems

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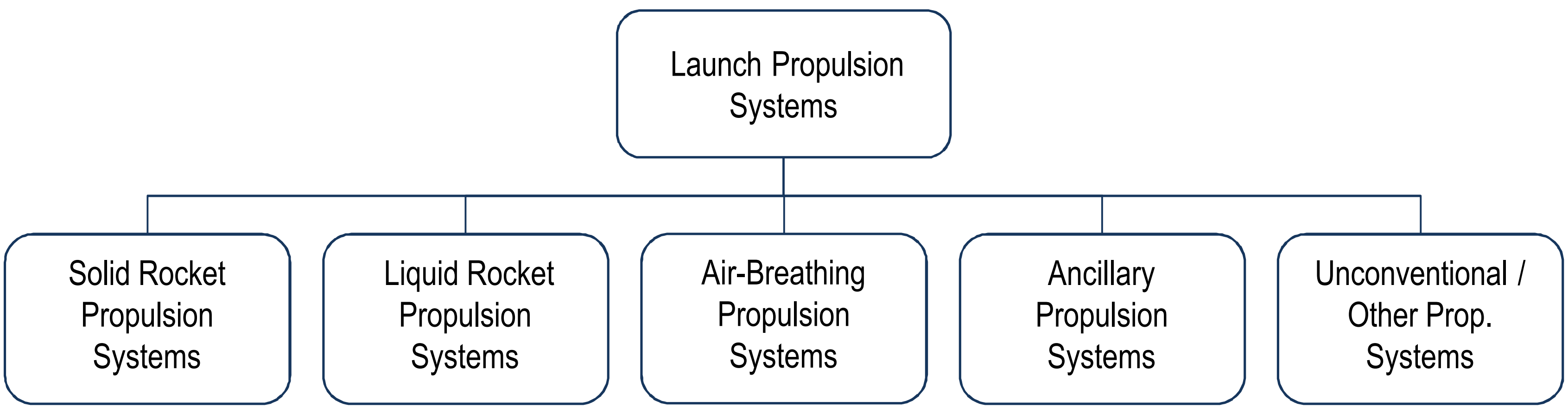
Technology Area Overview

- Domain
  - Earth to LEO Launch Propulsion Systems (Space Access)
- Does not include
  - Beyond LEO Transportation
  - Ground Systems other than launch assist
  - Launch Vehicles
    - Select subsystems in other TAs
- TA divided into 5 technical focus areas

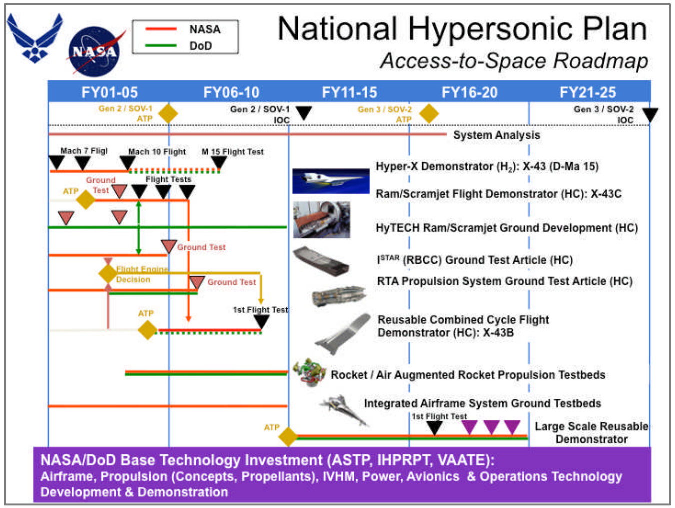


Traceability to NASA Strategic (draft) Goals

Goal	LPSTA Alignment
1. Extend and sustain human activities across the solar system.	Launch propulsion technologies advance human access to space.
2. Expand scientific understanding of the Earth and the universe in which we live.	Launch propulsion technologies facilitate efficient scientific access to space.
3. Create the innovative new space technologies for our exploration, science, and economic future.	Research into launch propulsion technologies builds and sustains the nation's leadership in access to space.
4. Advance aeronautics research for societal benefit.	Advances in air-breathing technologies have strong synergy with access to space.
5. Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.	Launch propulsion technologies provide and maintain a base for NASA programs and institution to build on for access to space.
6. Share NASA with the public, educators, and students to provide opportunities to participate in our mission, foster innovation and contribute to a strong National economy.	Expanding the nation's propulsion technology research leads to new opportunities for academic institutions and for student STEM skills.

Traceability to NASA (and OGA) Missions

- Assessed Agency Mission Planning Manifest
  - 2011 draft
- SMD
  - Continuous tempo of 5–8 payloads per year
    - 3–5 small, 2–3 medium, 1 large payload every few years
  - No investment in LPSTA
  - Needs low cost, reliable access to space
- ESMD
  - Heavy Lift Propulsion Technology Plan (HLPT)
  - Human Exploration Framework Team
  - Commercial Crew
  - Commercial Cargo
- SOMD
  - Depends on ESMD for LPSTA development
- ARMD
  - Hypersonic roadmaps
- DoD
  - HLPT Common Engine Study (NASA/USAF)
  - Hypersonic roadmap joint with USAF/USN



Benefits to Other National Needs

- Emerging Domestic Commercial Space Sector
  - Low-Cost Access to Space
  - Potential New Markets
- Other U.S. Government Agencies
  - Low-Cost, Reliable Access to Space
  - Supports the Need for Large-Diameter Payloads
  - Operationally Responsive Space
- Increased University Involvement in Fundamental Propulsion Research
  - Supports Science, Technology, Engineering and Mathematics Education
- Supports Robust Industrial Base
  - Enhanced Supplier Base Stability
  - Reduced Reliance on Foreign Sources

TA Overview: Planning Approach

- Reviewed existing Launch Propulsion Systems Technology Area (LPSTA) databases
- Solicited input from industry
- Involved Agency experts for input
- Reviewed by Red Team of NASA senior experts
- Documented and summarized per OCT guidance
- Roadmaps were then reviewed by special team established by OCT before submittal to NRC

Databases Consulted

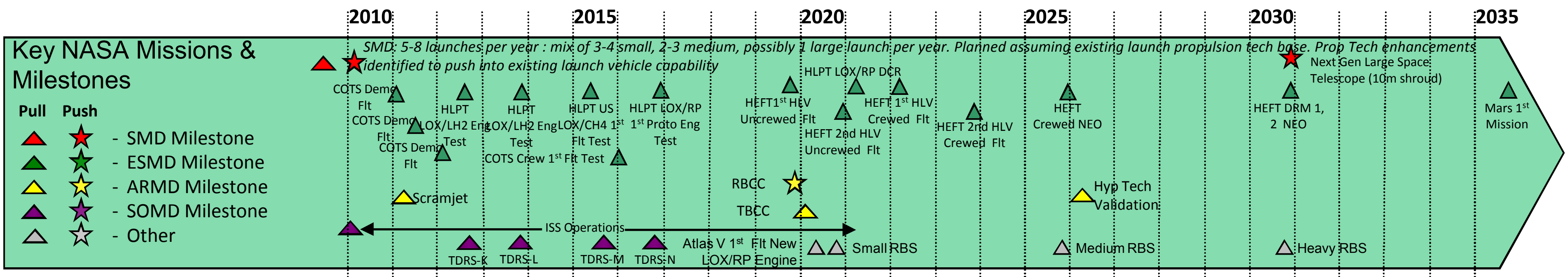
- Space Launch Initiative (SLI) Technology Plan
- USAF/NASA 120-Day Study Technology Team Data Package
- National Aerospace Initiative (NAI)
- Next Generation Launch Technology (NGLT)
- Advanced Planning and Integration Office (APIO) In-Space Transportation Roadmap
- Heavy Lift Propulsion Technologies (HLPT) NASA/USAF Engine Study
- Integrated High Payoff Rocket Propulsion Technology (IHPRPT)
- Capability, Requirements, Analysis, and Integration (CRAI) Database
- Alternate Horizontal Launch Space Access Technology Roadmap
- NASA Fundamental Aeronautics Program Hypersonics Project 6-Month and 12-Month Reviews (with roadmaps)
- "USA Fundamental Hypersonics" presentation to 16th AIAA/DLR/DGLR International Space Planes and Hypersonic Systems and Technologies Conference
- National Aeronautics Research and Development Plan
- Report to Congress: Roadmap for the High-Speed and Hypersonic Programs of the Department of Defense
- National Hypersonics Plan: Access to Space Team Roadmap
- Boeing National Institute of Aerospace (NIA) Hypersonics Report
- National Research Council (NRC) Decadal Survey of Civil Aeronautics
- Gryphon Integrated Product Team (IPT) Kickoff Meeting and Roadmap
- NASA Hypersonics Project Planning Meeting

Industry & Other Government Agencies (OGA) Input

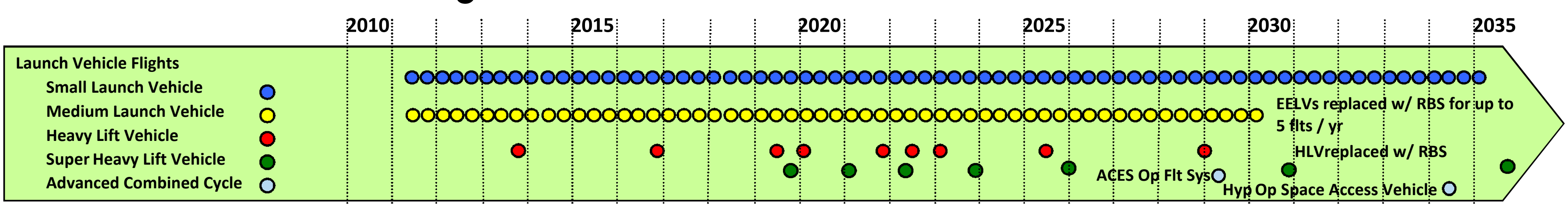
- Aerojet
- Andrews Space
- ATK
- Boeing
- Lockheed Martin
- Northrop Grumman
- Pratt & Whitney/Rocketdyne
- SpaceX
- United Launch Alliance (white papers supplied)
- Department of Defense: U.S. Air Force Research Lab, U.S. Air Force Space & Missile Command, and U.S. Navy

Industry survey was not exhaustive but intended to be representative as validation of TA01 team roadmap assumptions

Mission and Launch Vehicle Manifest Through 2035



- Mission manifest includes a range of flight types
  - Small: 0-2 t payloads
  - Medium: 2-20 t payloads
  - Heavy: 20-50 t payloads
  - Super Heavy: > 50 t payloads
  - Air-Breathing Launch Propulsion/Flight Tests
- Mission manifest generates a launch vehicle manifest



- Propulsion system technologies map to launch vehicles

Focus of Technology Investments (Figures of Merit)

Life Cycle Cost (LCC)

Production — Expendable Systems → $

Reusable Systems → $

Operations — Move from high-maintenance expendable infrastructure to low-maintenance reusable infrastructure $

Performance (Game Changing)

System and Operational Concepts – System or launch concepts that enable new capabilities or efficiencies that are not attained in current operational systems

- i.e., higher reliability and shorter launch centers enable Earth orbit assembly missions

Propulsion System/Subsystem Efficiency and Capability – Propulsion elements or subsystems that significantly improve payload lift efficiency or capability beyond current operational concepts

- i.e., higher Isp, energy density, margins

National needs to sustain and expand world leadership supported by input from other government agencies and industry

To make a significant change in either LCC or system performance, system robustness (margin) and reliability must be increased.

Benefits—Launch Propulsion System Goals

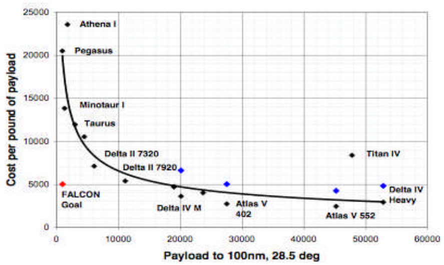
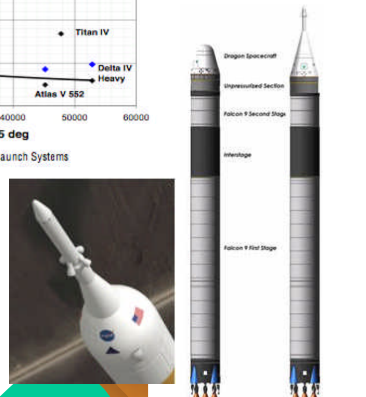
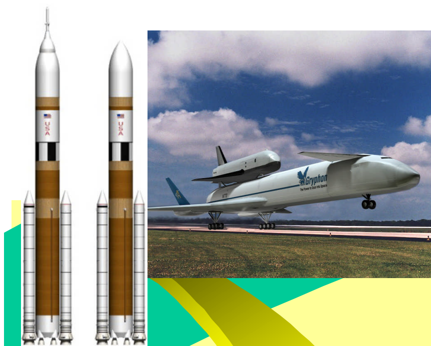
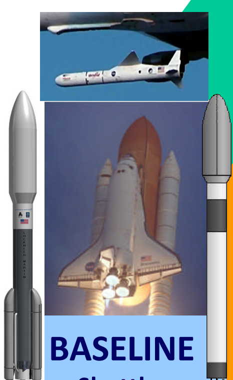


Figure 2. Launch Costs of Common Space Launch Systems







BASELINE
Shuttle, EELVs, Small Launchers

Near Term

- 25% recurring cost reduction
- 5X increase in reliability

Mid-term

- 50% recurring cost reduction
- 10X increase in reliability
- Enable new capabilities

Long Term

- Greater than 50% (game changing) recurring cost reductions
- Greater than 50X increase in reliability
- Enable new capabilities

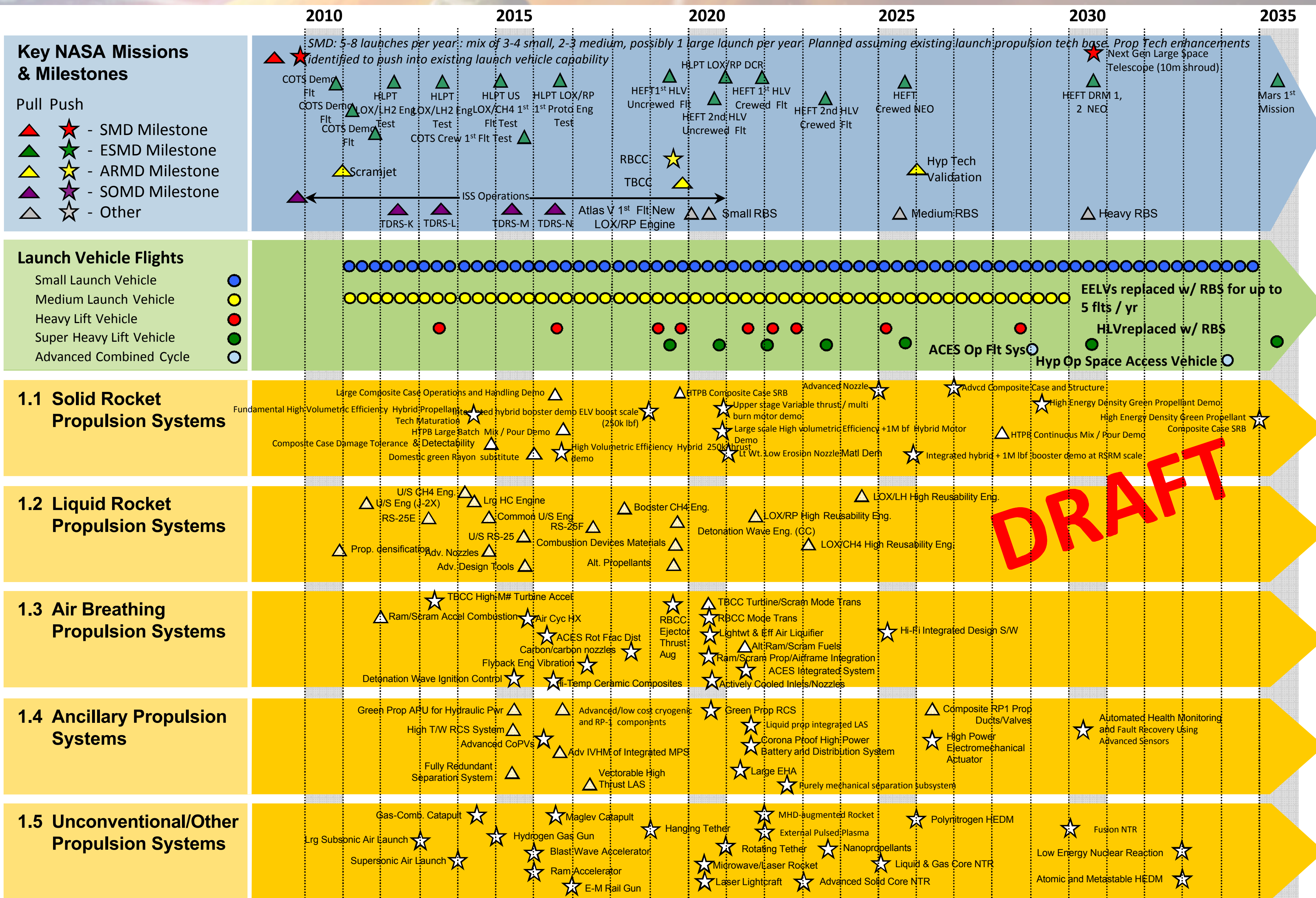
2010 2015 2020 2025 2030 2035

NOTE: Goals developed by TA01 based on past studies and reports. No systems analysis was performed to support these goals.

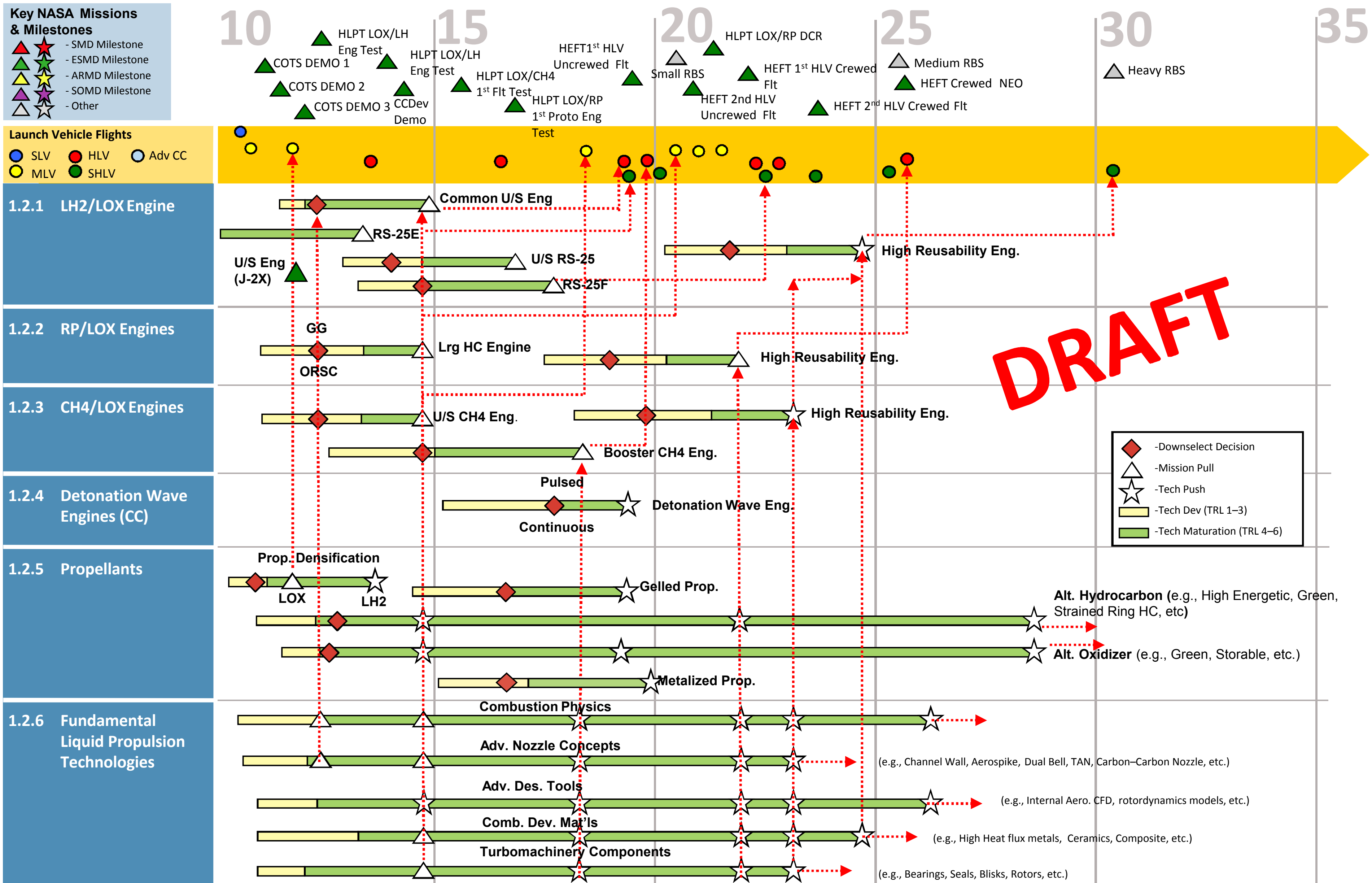
Proposed Launch Propulsion Systems Technology Area Breakdown Structure (TABS)

- **1.0 Launch Propulsion Systems**
  - 1.1 Solid Rocket Propulsion Systems
    - 1.1.1 Propellants
    - 1.1.2 Case Materials
    - 1.1.3 Nozzle Systems
    - 1.1.4 Hybrid Rocket Propulsion Systems
    - 1.1.5 Fundamental Solid Propulsion Technologies
  - 1.2 Liquid Rocket Propulsion Systems
    - 1.2.1 LH2/LOX Based
    - 1.2.2 RP/LOX Based
    - 1.2.3 CH4/LOX Based
    - 1.2.4 Detonation Wave Engines (Closed Cycle)
    - 1.2.5 Propellants
    - 1.2.6 Fundamental Liquid Propulsion Technologies
  - 1.3 Air Breathing Propulsion Sys
    - 1.3.1 TBCC
    - 1.3.2 RBCC
    - 1.3.3 Detonation Wave Engines (Open Cycle)
    - 1.3.4 Turbine Based Jet Engines (flyback boosters)
    - 1.3.5 Ramjet/Scramjet Engines (accelerators)
    - 1.3.6 Deeply-cooled Air Cycles
    - 1.3.7 Air Collection & Enrichment System
    - 1.3.8 Fundamental Air Breathing Propulsion Technologies
  - 1.4 Ancillary Propulsion Systems
    - 1.4.1 Auxiliary Control Systems
    - 1.4.2 Main Propulsion Systems (Excluding Engines)
    - 1.4.3 Launch Abort Systems
    - 1.4.4 Thrust Vector Control Systems
    - 1.4.5 Health Management and Sensors
    - 1.4.6 Pyro and Separation Systems
    - 1.4.7 Fundamental Ancillary Propulsion Technologies
  - 1.5 Unconventional/ Other Propulsion Systems
    - 1.5.1 Ground Launch Assist
    - 1.5.2 Air Launch/Drop Systems
    - 1.5.3 Space Tether Assist
    - 1.5.4 Beamed Energy / Energy Addition
    - 1.5.5 Nuclear
    - 1.5.6 High Energy Density Materials/Propellants

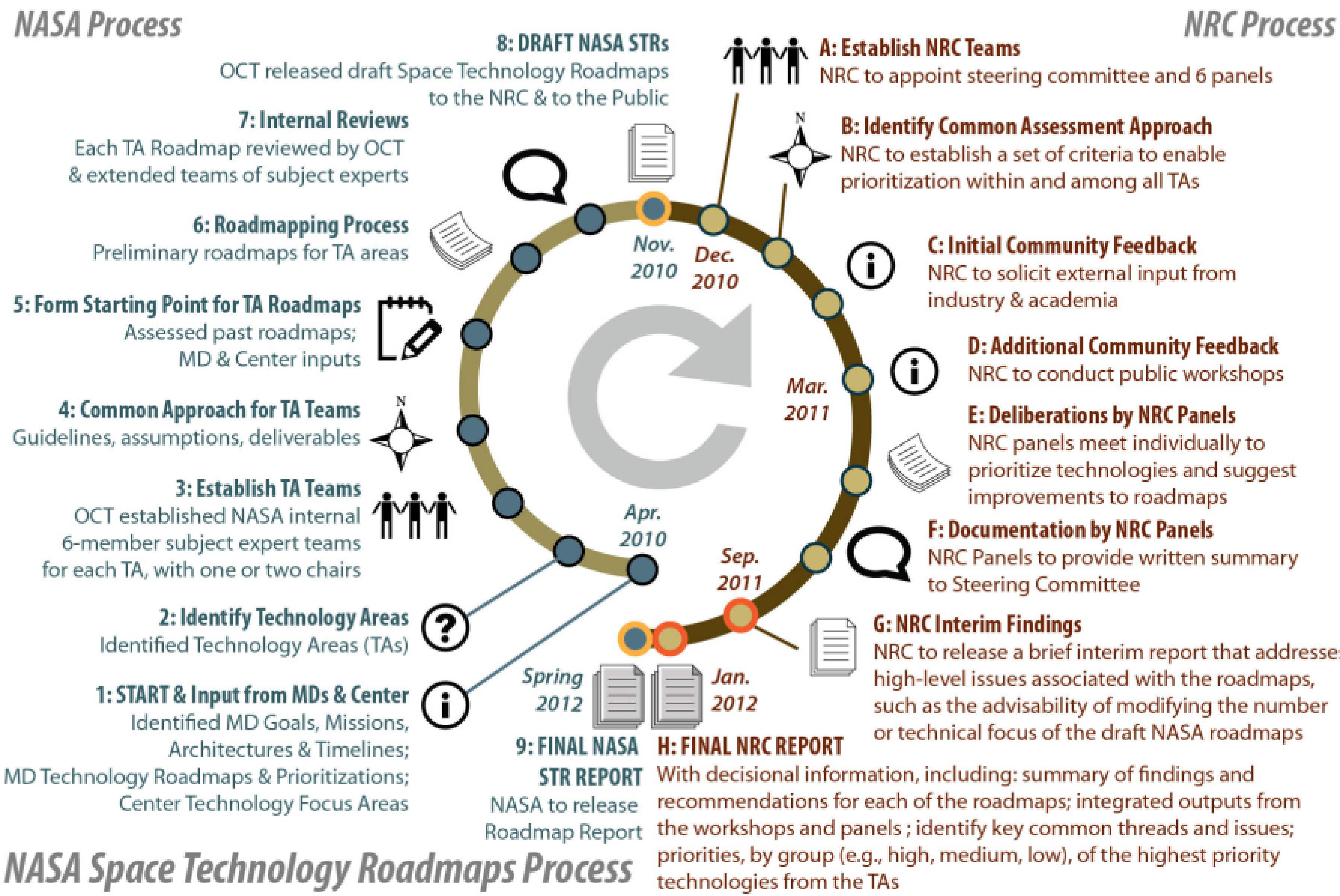
Launch Propulsion Systems Technology Roadmap



1.2 Liquid Rocket Propulsion Systems Roadmap—2010 to 2035



STR Process


NASA Process
NRC Process
8: DRAFT NASA STRs
OCT released draft Space Technology Roadmaps to the NRC & to the Public
7: Internal Reviews
Each TA Roadmap reviewed by OCT & extended teams of subject experts
6: Roadmapping Process
Preliminary roadmaps for TA areas
5: Form Starting Point for TA Roadmaps
Assessed past roadmaps; MD & Center inputs
4: Common Approach for TA Teams
Guidelines, assumptions, deliverables
3: Establish TA Teams
OCT established NASA internal 6-member subject expert teams for each TA, with one or two chairs
2: Identify Technology Areas
Identified Technology Areas (TAs)
1: START & Input from MDs & Center
Identified MD Goals, Missions, Architectures & Timelines; MD Technology Roadmaps & Prioritizations; Center Technology Focus Areas
9: FINAL NASA STR REPORT
NASA to release Roadmap Report
A: Establish NRC Teams
NRC to appoint steering committee and 6 panels
B: Identify Common Assessment Approach
NRC to establish a set of criteria to enable prioritization within and among all TAs
C: Initial Community Feedback
NRC to solicit external input from industry & academia
D: Additional Community Feedback
NRC to conduct public workshops
E: Deliberations by NRC Panels
NRC panels meet individually to prioritize technologies and suggest improvements to roadmaps
F: Documentation by NRC Panels
NRC Panels to provide written summary to Steering Committee
G: NRC Interim Findings
NRC to release a brief interim report that addresses high-level issues associated with the roadmaps, such as the advisability of modifying the number or technical focus of the draft NASA roadmaps
H: FINAL NRC REPORT
With decisional information, including: summary of findings and recommendations for each of the roadmaps; integrated outputs from the workshops and panels ; identify key common threads and issues; priorities, by group (e.g., high, medium, low), of the highest priority technologies from the TAs
N
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Nov. 2010
Dec. 2010
Mar. 2011
Apr. 2010
Sep. 2011
Spring 2012
Jan. 2012
NASA Space Technology Roadmaps Process

Summary

- LPSTA Draft Roadmap is a balanced portfolio of fundamental, midrange, and mature technology needs
- Technology investments address needs for the next 25+ years
- Technologies include evolutionary advancements in existing capabilities and game-changing candidates for the future
- Benefits can be found across all launch vehicle classes
- Opportunities exist to submit comments and additions through the NRC review process
- Several areas have been neglected in the past but must be restored to maintain national capability and leadership

Foundational technology is key to making sustained significant advances in the future.