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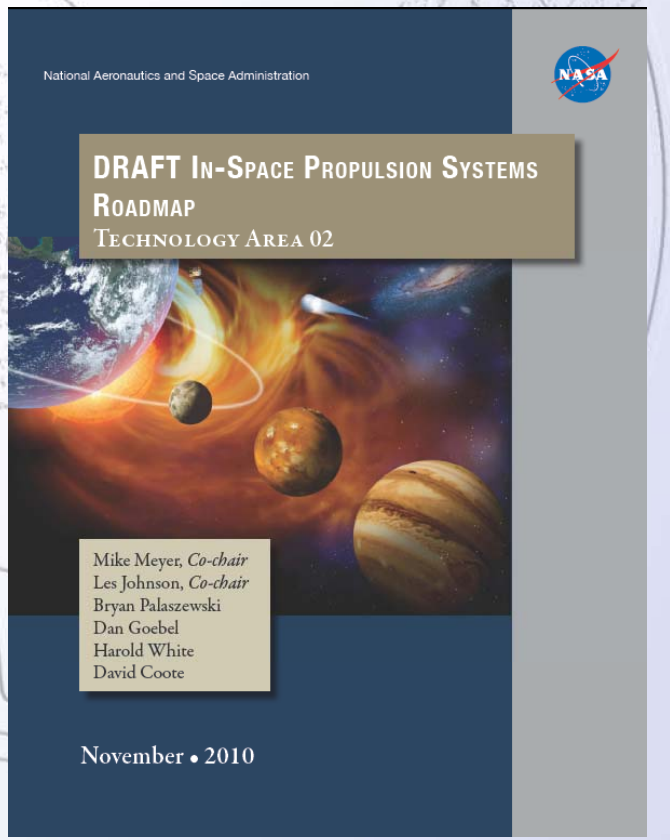
NASA TA-02 In-space Propulsion Roadmap Priorities



Russell Joyner
Technical Fellow – Pratt Whitney Rocketdyne
March 22, 2011

The Overarching Questions

- **What should our NASA (We=Nation) invest in to make biggest benefit and why?**
  - *What have We invested in We can build on? We have a Foundation*
  - *What more can We do Affordably with High Payoff?*
- **How do We invest to accomplish more within $ limits**
  - *Provide game-changing capability for NASA (our) space missions within 20 years (affordably)?*
  - *Improve mission capability, meet NASA mission needs?*
  - *Align with all aerospace & non-aerospace technology needs*
  - *What is the technical risk, can it be managed within a schedule*
  - *Can We achieve success with the technology and implement*

Prioritize TA-02 In-space Technologies Based on Benefits to Mission Speed, Mass, and Cost

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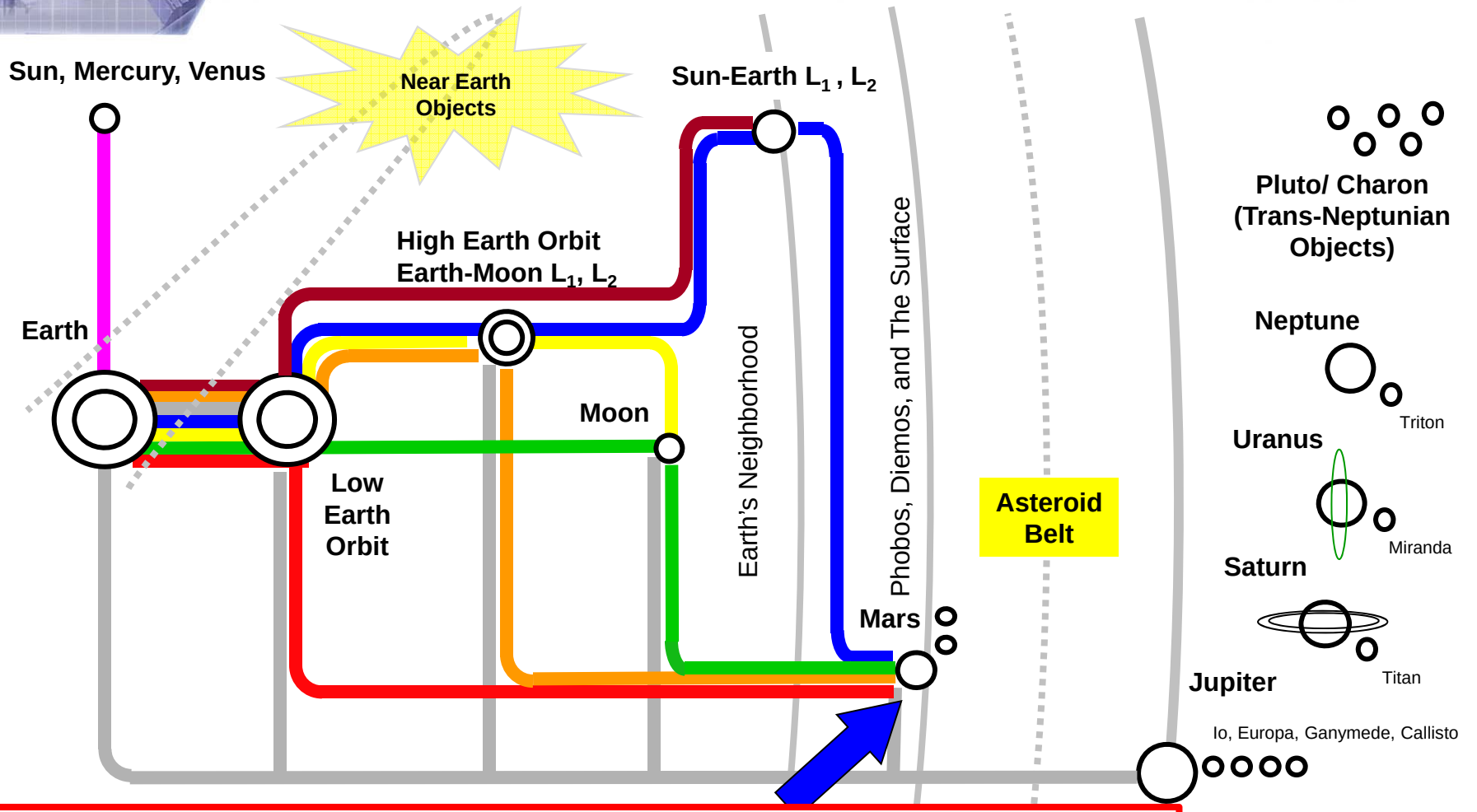

Focus on "Vision Mission" for Technology Prioritization

CR Joyner Version of NASA Metro Map

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Missions Drive Technology Need

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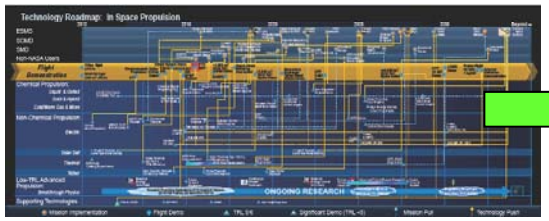
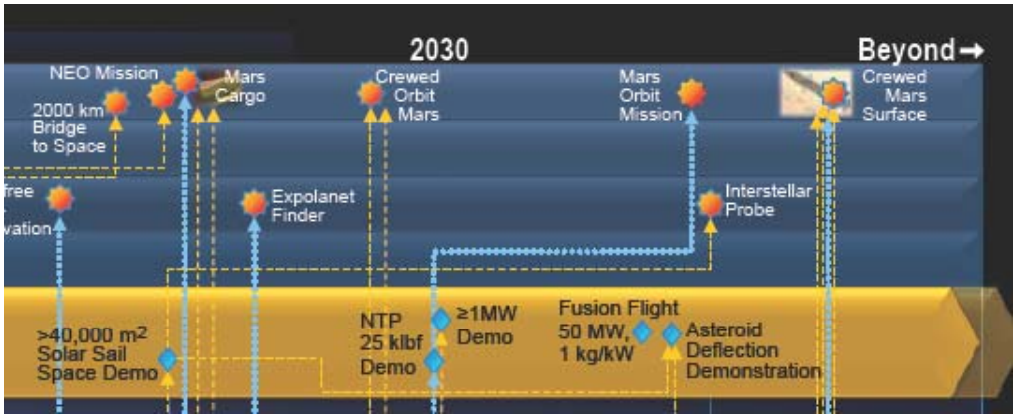
- **Need to prioritize based on <u>Need to Execute a Mission</u> – then look at other missions that benefit from the technologies within fiscal constraints**

TA-02 Roadmap





- **The "Vision Mission" in this Roadmap is Mars and Beyond?**
  - **Technologies should be focused to that direction**
    - The same technologies can be applied to other missions
- **How can We do the "Vision Mission" in 20 years?**
  - **By investing to get more capability and affordability with technology**

Build Off Investments, Do Not Throw Them Away

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Prioritized TA-02 – In-space Propulsion Technologies List

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TA-02 Roadmap Technologies Assessed

	Benefit	NASA Needs	Non-NASA aerospace needs	Non-aerospace national needs	Risk and Reasonableness	Sequencing and Timing	Time and effort	Score
Multiplier:	27	5	2	2	10	4	4	
Options:	0f1f3f9	0f1f3f9	0f1f3f9	0f1f3f9	1f3f9	-9f-3f-1f1	-9f-3f-1f0	
TECHNOLOGIES (Rank only the Level 3 technologies)	Benefit	Alignment			Risk / Difficulty			
2. TA02 - In-Space Propulsion Technologies								
2.1. Chemical Propulsion								155
2.1.2. Liquid Cryogenic	9	9	9	3	3			342
2.1.1. Liquid Storable	3	3	9	0	9			204
2.1.7. Micro-propulsion	3	3	9	1	3			146
2.1.6. Cold Gas/Warm Gas	3	3	3	1	3			134
2.1.4. Solid	1	1	1	0	9			124
2.1.3. Gels	1	1	1	3	3			70
2.1.5. Hybrid	1	1	1	0	3			64
2.2. Non-Chemical Propulsion								187
2.2.3. Thermal Propulsion	9	9	3	1	9			386
2.2.1. Electric Propulsion	3	3	3	0	9			192
2.2.4. Tether Propulsion	3	3	3	0	1			112
2.2.2. Solar Sail Propulsion	1	3	3	0	1			58
2.3. Advanced (TRL <3) Propulsion Technologies								197
2.3.3. Fusion Propulsion	9	9	3	1	3			326
2.3.6. Advanced Fission	9	3	3	3	1			280
2.3.5. Antimatter Propulsion	9	3	3	0	1			274
2.3.2. Electric Sail Propulsion	3	3	3	0	3			132
2.3.4. High Energy Density Materials	3	3	9	1	1			126
2.3.7. Breakthrough Propulsion	1	1	1	0	1			44
2.4. Supporting Technologies								353
2.4.3. Materials & Manufacturing Technologies	9	9	9	3	9			402
2.4.1. Engine Health Monitoring & Safety	9	3	9	3	9			372
2.4.2. Propellant Storage & Transfer	9	9	3	3	3			330
2.4.4. Heat Rejection	9	9	3	3	3			330
2.4.5. Power	9	9	3	3	3			330

Performed Qualitative Assessment Based on "Vision Mars Mission"

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Highest Priority Areas

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Prioritized based on highest benefit, alignment, reasonable risk, achievable within finite time and cost

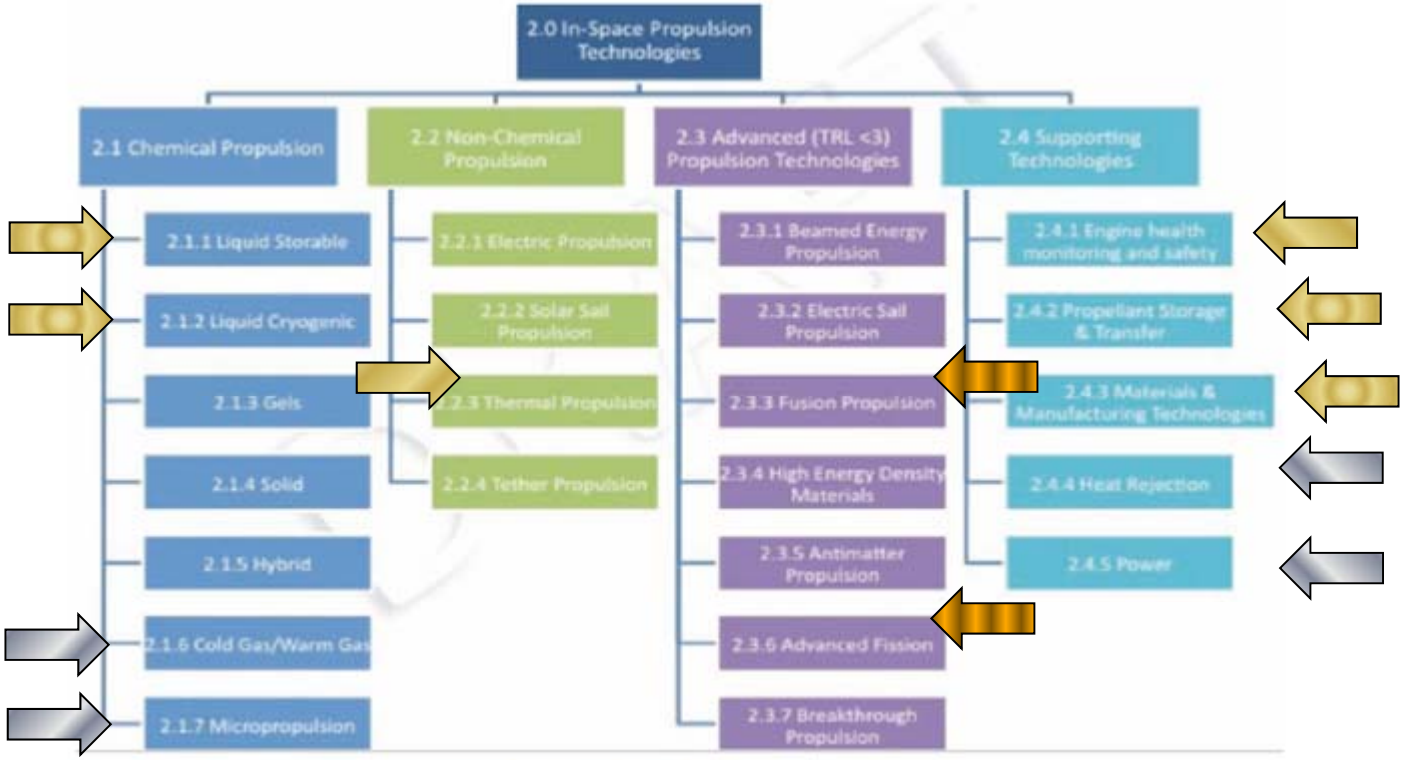

Figure 1. *In-Space Propulsion Technology Area Breakdown Structure*

Focus on "Gold": Cryogenic Propulsion, Nuclear Thermal, Health Management, Propellant Storage In-orbit

TA-02 – In-space Chemical Propulsion

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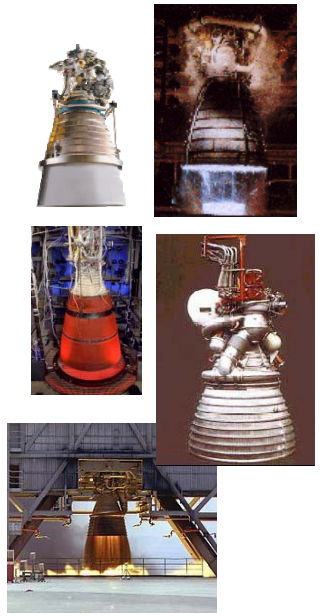
Liquid Cryogenic and Liquid Storable

- **USA leads in Liquid Cryogenic (LOX/LH2) propulsion technology – <u>Should Be Highest Priority to Maintain</u>**
  - Capability established: SSME (RS-25), RL10, J-2X
    - Focus on enhancing upper stage and in-space reliability
- **We (USA) have capability <u>Now</u> – leverage our investments and new technology to create <u>Affordability</u> and <u>Reliability</u>**
- **Current Liquid Storable technology adequate, prioritize new investments on "<u>Greener</u>" propellants**
  - LOX/CH4 versus NTO/MMH where there is mission/architecture payoff like Mars In-situ resource applicability
  - Leverage already applied technology and enhance for use beyond Earth orbit (e.g. RL10, RS-18)



Technology Priority Should Be on Reducing Cost and Increasing System Reliability

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TA-02 – In-space Non-chemical Propulsion

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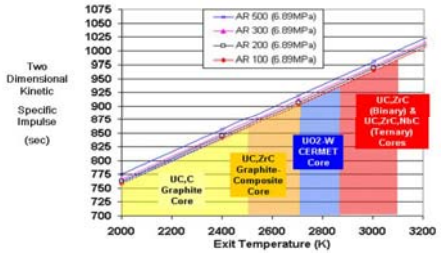
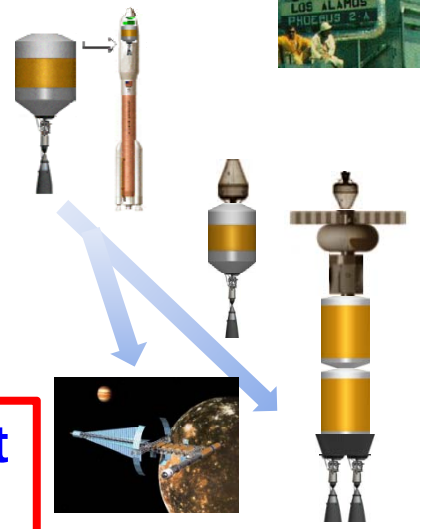
Thermal Propulsion



- **<u>USA has already invested and proven nuclear thermal propulsion</u>, leverage and demonstrate it in Space**
  - Nuclear thermal propulsion has 2X the efficiency as LOX/LH2
    - It is game-changing: quicker missions, more science, fewer launches for human missions
- **Thermal propulsion has application to robotic and human missions**
  - High-thrust >20k-lbf, Isp > 900-sec, T/W>3, Orbit departure in minutes not weeks
  - High power density for surface power and in-space power for Electric Propulsion
  - Focus on maturing core fuel for commonality and robustness
  - Perform Ground and flight demonstrator with no environmental impact, fly on unmanned mission



Investment Priority – Prove NTP in Unmanned Flight Demo in Next 15 Years

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TA-02 – In-space Non-chemical Propulsion

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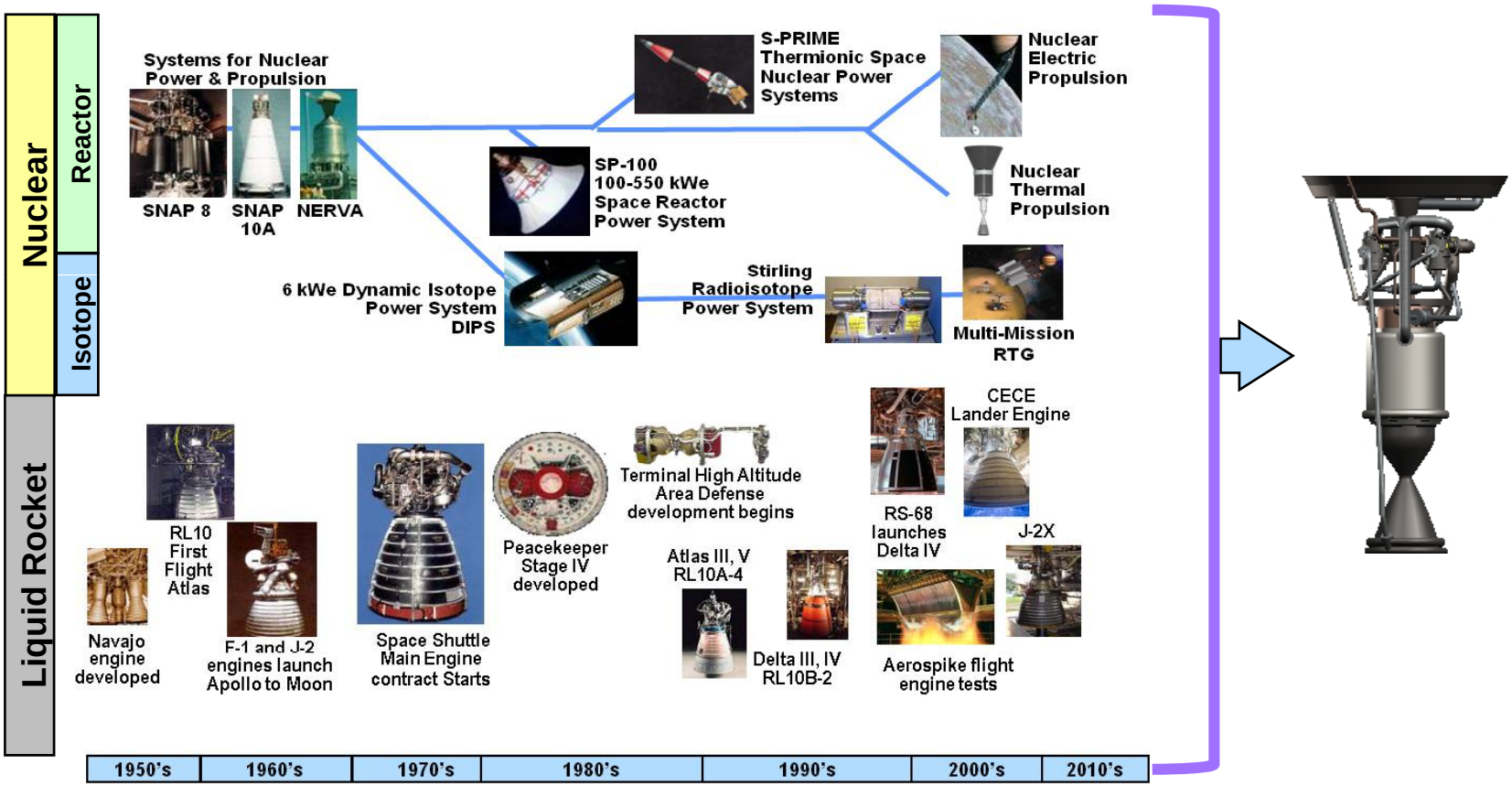

Prioritize Based on Leveraging Previous Technology Investments in Nuclear & Cryogenic Propulsion

TA-02 – Other "Gold" Priorities

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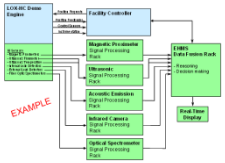
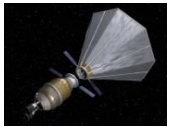
Materials & Manufacturing, Engine Health Monitoring & Safety, Propellant Storage & Transfer

- **Mature manufacturing and materials technologies**
  - Manufacturing technology infusion opportunity for next launch system, in-space systems and
  - Materials technologies for less weight, radiation shielding, entry/decent devices
- **Engine health monitoring technologies for improved safety and reliability**
  - Focus prioritization on integrating technologies on flight systems
    - In orbit flight demonstration of monitoring engines
- **Propellant storage & transfer for depots or large tank assemblies**
  - Need technology for future human missions; for propellant depots or large in-orbit tank set assembly for human Mars missions





Focus Priority On Manufacturing, Materials, Health Monitoring and Propellant Storage

ULA, B. Kutter presentation

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TA02 – Summary

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- **An extensive list Introduced – but limited funds to address**
- **Considering nation's budget challenges**
  - Demands prioritization based on contribution of the technologies towards a Challenge Goal – such as a human mission to Mars
  - Need to categorize: have-to-haves, nice-to-haves…and interesting science
- **NASA must define a driving mission, leverage technologies with DoD and Commercial**
  - Implement technologies that are game-changing, scalable, multi-mission capable (Science, Human Exploration, Human Settlement, etc.)
- **NASA (We) must leverage past technology work**
  - Cryogenic propulsion, Nuclear, Materials, EHMS

Prioritize Technologies Relative to Affordability, Capability, & Mission Impact