A Process For Technology Prioritization In A Competitive Environment

In Space Propulsion Technology Project
NASA Marshall Space Flight Center
Karen Stephens & Melody Herrmann/NASA MSFC
Brand Griffin/Gray Research Inc.
42nd AIAA Joint Propulsion Conference
July 9 - 12, 2006
In-Space Propulsion Technology (ISPT) Project

Solar Electric

Solar Sails

Advanced Chemical

Aerocapture

Emerging

National Aeronautics and Space Administration
ISPT Focuses On Mid-TRL
Propulsion System Development and Integration

Flight Validation and Mission Implementation:
(Solar Electric Propulsion example)

- NSTAR (Deep Space 1)
- Dawn (In Development)

In-Space Propulsion Technologies
- Advanced Chemical
- Aerocapture
- Solar Electric
- Solar Sail

Research (not part of ISPT)

- Research to Prove Feasibility
- Basic Technology Research
- Technology Development
- System/Subsystem Development
- System Test, Launch & Operations

TRL Levels:
- TRL 9
- TRL 8
- TRL 7
- TRL 6
- TRL 5
- TRL 4
- TRL 3
- TRL 2
- TRL 1
Mission Driven Technology Planning Activity

Objective:
Identify the current, most likely "need date" for each technology and create ISPT technology area development schedules based on this "mission pull"

Base schedules on:
• Launch date of first flight opportunity (pacing mission)
• Historic average for spacecraft program implementation phases

Ground Rules:
• All technologies require flight validation (except NSTAR Heritage or commercial EP)
• Minimum 4 years between successful flight validation and pacing mission

Schedule Driven by Launch Date

<table>
<thead>
<tr>
<th>ISTP Tech Development</th>
<th>Phase B</th>
<th>Phase C/D</th>
<th>Historic Average</th>
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Historic Average:
- ESA Science Missions
- NMP (JPL)
- NASA, Level II Program Office
Why was this activity undertaken?

- Content for upcoming NASA/ISPT NRA (2006 ROSES) was needed. Technology teams needed to formulate acquisition strategy for coming years' requirements. ISPT program management needed to prioritize acquisitions.
- Early planning for POP06 was underway.
- ISPT examining agency mission priorities and ISPT technology progress relative to evolving mission needs. Planning activity would enhance future reprioritization if budget fluctuations required it.
- Majority of ISPT technologies were maturing beyond the "tech push" (TRL 1-3) to "mission pull" (TRL 4-6) phase. Need for the program to orient to "1st mission" for product-focused forward progress.

ISPT needed to identify the "pacing mission" for each technology to determine optimal funding for each of the technology areas within the expected program budget.
Charter of ISPT Systems Analysis:

- Provide quantified inputs to ISPT Technology Project management to support investment decisions through parametric studies to show benefits of in-space propulsion technologies compared to state-of-the-art for destinations approved by the Science Mission Directorate (SMD).

- Drive out technology development challenges by conducting concept definition studies in sufficient detail to identify potential problem areas that help define and focus technology investments

- Develop systems analysis tools to promote common methods for reproducible results within each community

Systems analysis provides a non-biased assessment for critical data used in determining funding priorities and program direction.
Systems Analysis Studies, Trades & Improved Tools to Guide Investments

- Consistent LT Trajectories
- SOA algorithms/methods
- Multi-year, Inter-agency team

- Ion & Hall Engine Performance Sensitivity Studies
- Ion Propulsion Trades for Scout, Discovery & New Frontiers Missions Generating a Reference DRM
- Standard Architecture for Gridded Ion: System Definition & Requirements
- Aerocapture Mars System Study
- Multipass Aerocapture at Multiple Destinations
- Solar Sail Heliostorm Mission Study
- Solar Sail Reqs Definition for Adv Sails & Booms
- MXER Tether Analysis, Systems Planning & Tools

- Advanced Propellant & Engine Comparison Studies
- Advanced Chemical Propulsion System Model (ACPS)
- Aerocapture Probabilistic Risk Assessment
- Technology Infusion Studies
- Direct Trajectory Optimization Model
- Round Trip Mission Analysis Model
Central Question

- How should funding be allocated in a product focused technology development program?
  - Squeaky wheel gets the grease
  - Last up at bat
  - Best track record
  - Manager’s pet project
  - None of the Above!

- Need a priority-driven process for sequencing technology development and allocating funding.
Process for Activity

1. Assemble independent team for assessment & oversight
2. Identify potential "pacing mission" for all ISPT technologies
3. Identify current agency mission priorities and mission definition
4. Assess missions for ISPT technology applicability
5. ISPT Management Input
6. Technology Team Response
7. Assessment Team Guidance
8. Determine corresponding "need date" for each ISPT technology

Iterative Process
References for ISPT Technology Applicability Assessment

CRAI/APIO effort determined most applicable missions for ISPT technologies (2004)

Drafts of both the SSE and SSSC Roadmaps provided the most recent mission priorities for SMD (2005)

STEAM effort assessed ISPT technologies for 52 candidate missions (2002 & 2003)
# SSE Mission Pull

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<tr>
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<th>Mission Title</th>
<th>Launch Date</th>
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*Applicable, studied*  
*Likely Applicable, needs study*
# SSSC Mission Pull

## ISP Technology

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National Aeronautics and Space Administration
Likely Announcement Opportunities

ST 4 Cancelled
ST 5 Selected
ST 6 Selected
ST 8 AO
ST 9 AO
New Frontiers JUNO AO
Discovery AO

History

1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

Calendar Year

New Frontier (3 years)
Discovery (2 years)
New Millennium (1 year)
ISPT (1 year)

Cycle 4 Cycle 5 Cycle 6
Hardware and Software for entire spacecraft

**Pre Phase A**
- MISSION FEASIBILITY
  - Goals and Objectives
  - Concept/Design Evaluation Criteria
  - Mission Concepts
  - Life Cycle Cost Estimates
  - Feasibility Assessment

**Phase A**
- MISSION DEFINITION
  - Mission Need Statement
  - Functional Mission Concept
  - Science Requirements
  - Trade and Analysis Results
  - Technology Development Plan

**Phase B**
- SYSTEM DEFINITION/PRELIM DESIGN
  - Systems Engineering Mgt Plan
  - Risk Mgt Plan
  - Configuration Mgt
  - Science Payloads
  - Verification Requirements
  - Concept of Operations
  - Trades and Analysis

**Phase C/D**
- DESIGN DEVELOPMENT
  - Lower level Design Specs
  - Refine Requirements Doc
  - Refine Verification Doc
  - Interface Doc
  - Mfg Plan
  - End-to-end systems design
  - Integrated Logistics Support
  - Fabrication
  - Integration
  - Verification
  - System Qualification
  - System Acceptance
  - Operations manuals
  - Maintenance manuals
Schedule Logic

Technology Development

Program Implementation

Pre Phase A

Competitive

Phase A

Single Prime Contractor

Phase B

Launch
(Pacing Mission)

Phase C/D

Development to TRL 6+

4 yrs* (<$450m)

5 yrs** ($>450m)

** Average of available data for NASA & ESA missions
Pacing Mission Selection

Similar Development Paths with flight validation and major mission pull

Solar Sail Propulsion
- Flight validation required
- 2016 Heliostorm is pacing mission (optimistic schedule)

Aerocapture Technology
- Flight validation required
- 2020 Titan Explorer is pacing mission for blunt body
- 2025 Neptune System Mission is pacing mission for lifting body

Technologies will be used as soon as developed

Plan to Announcement of Opportunity (Discovery Class ~ every 2 yrs.)

Solar Electric Propulsion
- 2007 Discovery AO for NSTAR with Near Earth Asteroid pacing mission
- 2007 Discovery AO for NEXT with CSSR pacing mission
- 2007 Discovery AO for Hall with Comet Rendezvous pacing mission

Advanced Chemical Propulsion
- 2007 Discovery AO, 2011 Jupiter Orbiter with Probes for High Temperature Rocket
- 2007 Discovery AO, 2013 CSSR for LOX-Hydrazine
- 2007 Discovery AO, 2020 Comet Cryo Nucleus SR for pump fed
Pacing Mission Technologies 1/2

**Solar Sail**
- Areal Density 17 g/m²
- Root area 50 m

**Aerocapture**
- L/D ~ 0.2 (Blunt body)
- L/D ~ 0.7 (Lifting body)

**Inflatables**

**TAM development schedule**
National Aeronautics and Space Administration
### TAM Development Schedule

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**Electric Prop**
- **NSTAR**
  - Phase B: 5 yr
  - Phase B: 4 yr
- **NEXT**
  - Phase B: 5 yr
  - Phase B: 4 yr
- **HALL**
  - Phase B: 5 yr
  - Phase B: 4 yr

**Advanced Chem**
- **High Temp Rocket**
  - Phase B: 5 yr
  - Phase B: 4 yr
- **LOX-Hydrazine**
  - Phase B: 4 yr
  - Phase B: 4 yr

**Pump Fed**
- **Comet Cryo Nucleus SR**
  - Phase B: 5 yr
  - Phase B: 4 yr

**Jupiter Orbiter w/Probes**
- **Discvy AO**
  - (CSSR)
  - (Near Earth Asteroid)
  - (Comet Rendezvous)
Follow-on Activities

- Each Technology Area used the identified technology "need date" to back out a development schedule.
  - In some cases, the need date was either not technically or programmatically possible. A later opportunity would become the pacing mission for technology development.

- A pacing mission that was in the near future served to increase the priority for funding. A pacing mission that was much later decreased funding priority.

- After initial programmatic priorities and budgets were set, Technology Areas updated development flows and corresponding project schedules. The funding negotiation was an iterative process.

- The outcome was a much vetted and thoroughly scrubbed program spending plan that was presented to SMD Management as a technology development plan for FY06 and out years.

- FY06 Mid year (and beyond) budget reductions disallowed total implementation of the development plan produced.
  - The process, resulting priorities and technology development plans allowed for timely restructuring of the budget/content for ISPT after the budget reductions
  - Program remains focused on high-priority product deliveries that will stay as aligned to customer priorities as possible