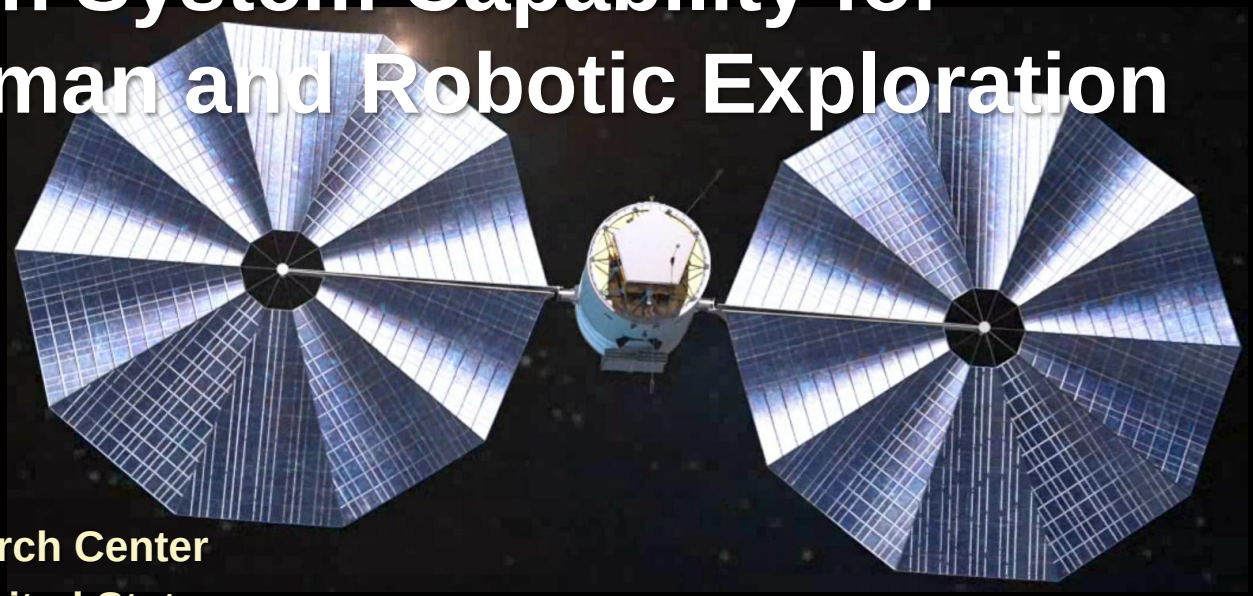
Advancement of a 30kW Solar Electric Propulsion System Capability for NASA Human and Robotic Exploration Missions



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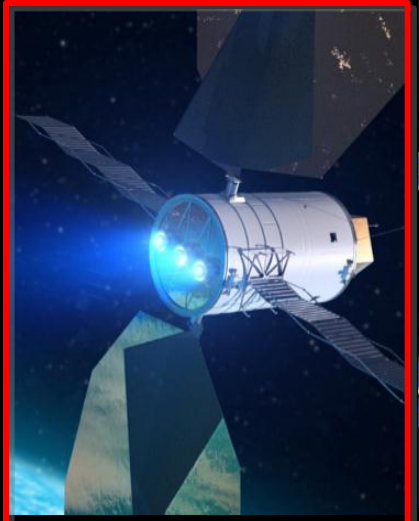
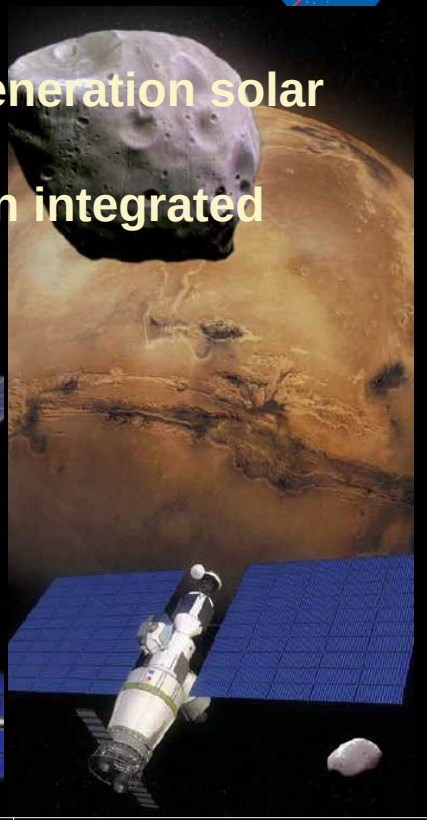
Introduction

- **Develop an enabling propulsion capability based on next generation solar electric propulsion (SEP) technologies**
- **Demonstrate next generation SEP technologies as part of an integrated system with extensibility to higher power systems**



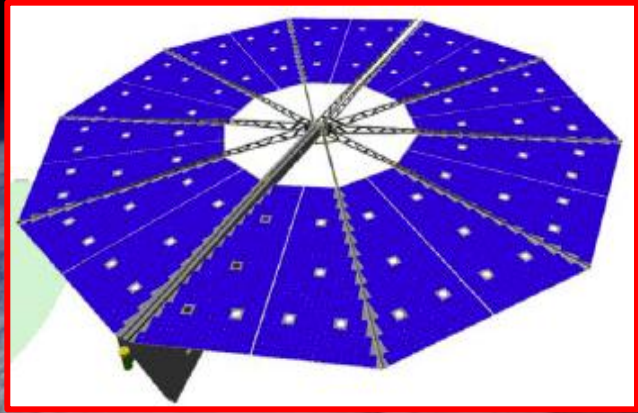


Deep Space 1 1998	Dawn 2007	**30kw-class SEP** **~ 2017**	Med-term Exploration Missions circa 2020's	Far-term Exploration Missions circa 2030's
Technology Demonstrator	Deep-Space Science Mission	Operational mission with advanced technology	Crewed mission to cis-lunar space	Crewed mission beyond Earth space
490kg	1220kg	~2000-5000kg	30,000 kg	70,000 kg
2.5 kW power system 2kW EP system	10 kW power system 2.5kW EP system	~30kW-class power ~20kW-class EP	30kW-class power system 20kW-class EP	350kW-class power system 300kW-class EP
ΔV = 2.7km/s	ΔV = 10km/s	ΔV > 10km/s	$\Delta V \approx$ 3 km/s	$\Delta V \approx$ 8 km/s

Technology Investment

- Current focused NASA OCT investments on advanced next-gen solar arrays and higher power electric propulsion technologies to enable 30kW-class SEP
- Two providers selected through competitive NRA for development of solar array systems (SAS): Alliant Techsystems Inc. (ATK) & Deployable Space Systems (DSS)
- NASA in-house EP development of 15kW class HET system using either direct-drive and/or high voltage power processing unit
- Additional investment in PV cells and HV, radiation-hard electronic parts

ATK MegaFlex:
Partners – AMA, Ball, Emcore, JPL, SpectroLab
Start Date: October 2012
Anticipated Duration: 18 months*



DSS Roll Out Solar Array (ROSA):
Partners - Emcore and JPL
Start Date: October 2012
Anticipated Duration: 19 months*

In-house EP System Development:
Partners - GRC and JPL
Start Date: January 2012
Anticipated Duration: 32 months

SEP Demonstration Trades

Technology

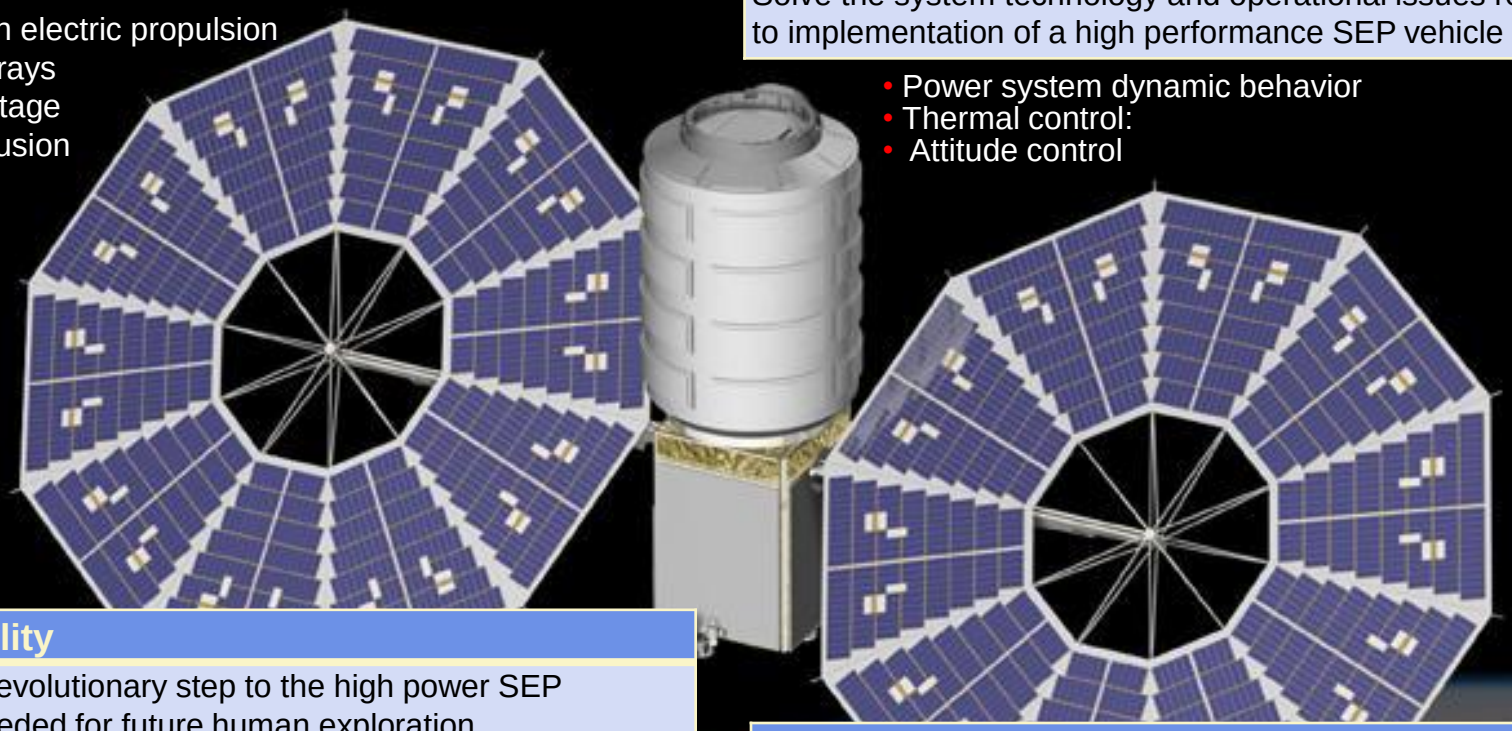
Demonstrate enabling SEP technologies in all relevant space environments (from LEO to beyond GEO)

- Next gen electric propulsion
- Solar arrays
- High voltage
- Tech infusion

Integrated System

Solve the system technology and operational issues related to implementation of a high performance SEP vehicle

- Power system dynamic behavior
- Thermal control:
- Attitude control



Extensibility

Provide an evolutionary step to the high power SEP systems needed for future human exploration

- Prove low thrust systems can deliver heavy payloads
- Build upon the recent success of AEHF
- Inform future exploration architecture studies
- Retire risks associated with Van Allen radiation belts

Capability

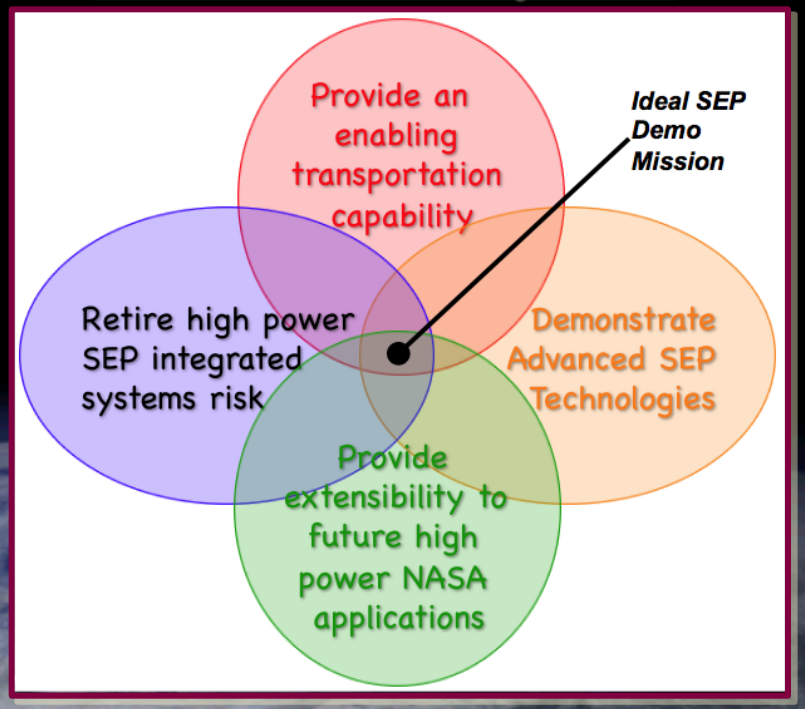
Provide a valuable new beyond-LEO payload delivery capability

- Wide range of potential missions (HEOMD, SMD, comm)
- Enables cost savings via launch vehicle step down
- Operational capability enables partnership opportunities

SEP Demo Mission Project

- NASA OCT funded formulation activity to scope high value approaches for conducting an SEP demonstration mission.
- Investigating concepts that balance 4 different Mission Objectives
- Methodology for evaluating concept's effectiveness in meeting objectives developed

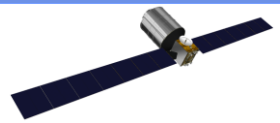
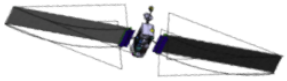
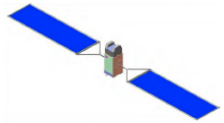
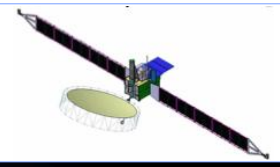
SEP TDM mission objectives



Objective	Measures of Effectiveness
Technology	Number of technologies advanced
	Impact of technologies demonstrated
Capability	Mission payload
	Range of operational environments
	Time in operational environments
	Adaptability
Extensibility	Extensibility of technology
	Extensibility of integrated system
Integrated System	Integrated System Demonstrations
	Integrated System/Environments Interactions
	Transportation capacity
	Executability

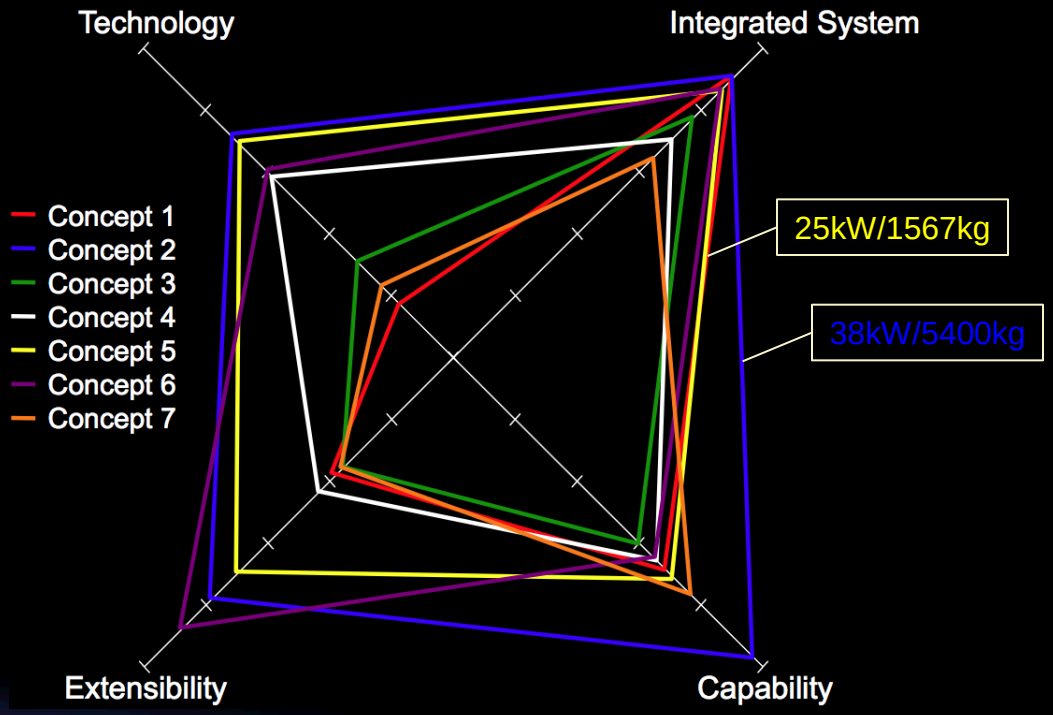
Initial SEP Demo Mission Concepts

- 7 mission concept studies contracts executed:

Concept	Mission	Power	Mass	New Technologies	
1	LEO to E-M L2 payload delivery	40kW	5900kg	none	
2	LEO to heliocentric space (asteroid rendezvous)	38kW	5400kg	Advanced high voltage solar arrays, high-power direct-drive EP	
3	LEO to GEO to LEO	22kW	2100kg	Advanced solar arrays	
4	GTO to LEO	30kW	1600kg	2 different advanced high voltage solar arrays, high power EP	
5	LEO to low lunar orbit (LLO)	25kW	1600kg	Advanced high voltage solar arrays, high-power direct-drive EP, advanced Xe storage	
6	LEO to GEO	40kW	6000kg	Advanced high voltage solar arrays, high-power direct-drive EP	
7	LEO to GEO	12kW	3000kg	Advanced power generation, advanced thermal control system	

Initial SEP Concept Evaluation

- Technical value assessed by evaluating effectiveness in meeting objectives

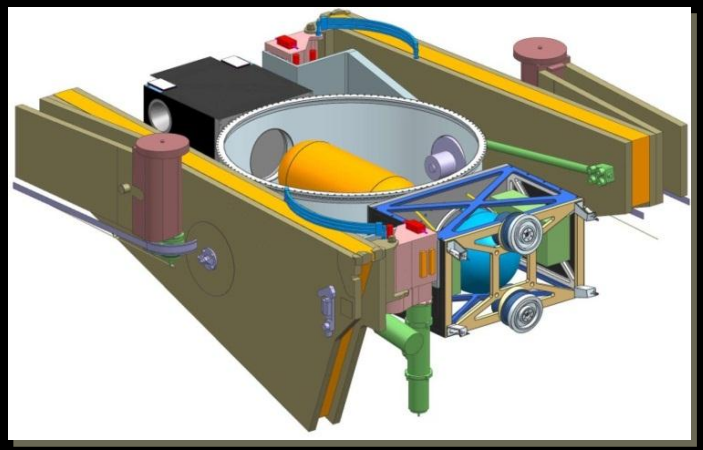


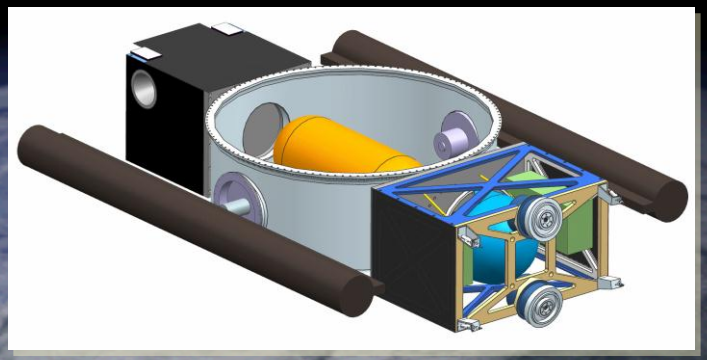
- Data suggest need to adequately constrain power & mass for cost-effective demo system
- A 25kW SEP TDM can provide nearly same value as ~40kW mission (i.e. higher power is not necessarily better); Lower system mass may provide similar benefits as larger systems with lower spacecraft cost (i.e. larger system not necessarily better than smaller system)
- These mission concepts assumed NASA would be responsible for the total life-cycle cost, including launch vehicle

Follow-on SEP Concept Development

- Mission cost constraints have shifted focus to partner-based mission concepts and those capable of being launched as secondary payloads

ESPA based mission concepts





Partner based mission concepts

Partner	Mission Concept
NASA	NEA Precursor mission
NASA	Cargo delivery for deep space hab
NASA	Various science missions
Commercial	Satellite servicing
Commercial	High-power commercial GEO comsat
Commercial	Large hosted payload system demo
DoD	Technology demonstrator
International	Contributed LV and/or subsystems?

NASA SEP TDM Summary

- 30kW-class solar electric propulsion will be developed to satisfy a number of near term applications and to serve as a “stepping-stone” to the high power systems needed for beyond-LEO human crewed exploration missions
- Significant investments are being made in next-generation, advanced solar array system technology and higher power EP technology to support these applications
- Stand-alone missions designed to address all the objectives of a NASA TDM are likely to total-life-cycle cost constraint being used for planning purposes
- Partner-based or secondary payload-based mission concepts that de-scope some of the technical content relative to stand-alone missions may offer better value to NASA
- Development of a range of mission concepts is anticipated to continue through 2015 unless a high-value, cost-effective approach permitting an earlier start is indentified