



## Task Force on Technology Readiness



# Cross-Enterprise Technology

# Roadmap

# for

# Exploration Of the Solar System

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### Technology Roadmaps: Introduction & Background

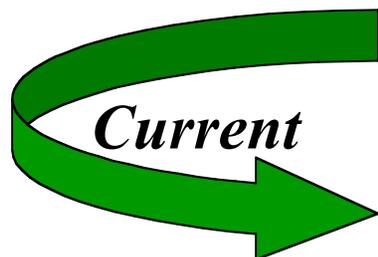
- Roadmaps are best available forecasts by TAM's based on:
  - Currently understood customer requirements & long range plans
  - Reasonable extrapolation of existing funding levels
  - TAM's commitment to work with customers to infuse new, revolutionary technologies that enable revolutionary missions
- Time frame: technology is demonstrated on earth (not flight qualified), given continued funding and successful infusion to higher TRL focussed program
- To achieve the forecasts will require close coordination by the CETDP and its Enterprise customers, and higher TRL focussed programs, where applicable
- Roadmaps will be continually updated based on customer feedback
- The CETDP will only address an affordable subset of customer needs



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## Evolving Capabilities in CETDP Thrust Areas



*Current*

Athena-Class  
Local Rovers;  
Autonomous  
Sampling;  
Science from  
Multiple  
Instruments



**5 years**

High Risk  
Access Multi-  
Robot Systems  
(e.g. cliff  
descent)



**10 years**

Global Area Multi-  
Asset Robotic  
Networks for  
Measurement &  
Communications



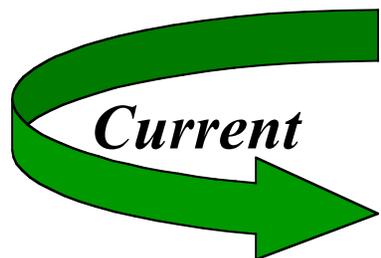
**> 15 years**

Self-Sustaining,  
Permanent Robotic  
Outposts & Deep  
Space  
Infrastructures

## Surface Systems



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## Evolving Capabilities in CETDP Thrust Areas



Data mining  
and  
visualization  
tools

Autonomous  
event  
recognition  
for STEREO  
and  
interferometry

Data fusion  
of multiple  
sensors and  
images into a  
single  
coordinated  
model

Onboard  
planning,  
control, and  
monitoring  
for  
interstellar  
probe

**Thinking Space Systems**



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## Evolving Capabilities in CETDP Thrust Areas

**5 years**

**10 years**

**> 15 years**

Miniature in-situ physical & spectroscopic (TDL, micro Lidar, mass spec) instruments;  
Simple in-situ chemical instruments;  
Miniature remote sensing camera-spectrometer

In-situ sample prep & handle on a chip; In-situ geo-chronology;  
Surface penetrating mini-radar; Lidar and sub mm sensing of atmospheres;  
Thermal IR spectrometers;  
Camera/microscope systems on a chip

Chemical labs in a teacup; In-situ atomic/isotope analysis; Micro-biological analyses and advanced mass spec on a chip;  
Miniature radar sounders & mappers

In-situ chem/bio labs on a chip; Physical meteorological packages for global planet deployment; Rugged instruments for hostile environments (Venus, Jupiter, Neptune, Kuiper bodies)

**Breakthrough Sensors & Instrument Component Technology**



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## Evolving Capabilities in CETDP Thrust Areas



Advanced Thermal Protection Systems and Materials;  
Automated Rendezvous & Docking; Localized Shielding Technology for Space Radiation; Powered Aerobot Concept Designs

Aero-Assist Capability for Entry Speed  $> 7.3$  km/s; Terminal Descent/Propulsion Deceleration Capability; Landing & Hazard Avoidance; Planetary Protection (In-Space )

Balloon technology for Scientific Surveys; Surface Sampling from Airborne Platforms

Aircraft Technology for Surveillance

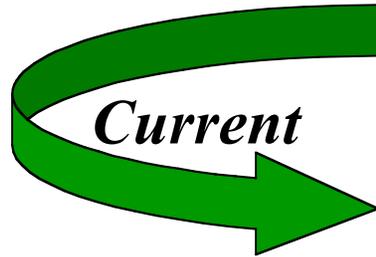
### Atmospheric Systems & In-Space Operations



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## Evolving Capabilities in CETDP Thrust Areas



*Current*

Proof-of-concept inflatable rovers for planetary surfaces; Long-life thin-film materials for inflatables & solar sails; radiation shielding materials to protect S/C electronics



**5 years**

Inflatable ballutes for aerocapture; advanced thermal protection system materials for planetary entry vehicles; light-weight inflatable solar arrays for SEP solar sail demonstration mission



**10 years**

Large inflatable antenna structures; large solar collectors for non-nuclear power; solar sail structures for low-cost rapid transit; balloon materials for planetary atmospheres; tethers for small body sample return



**> 15 years**

Highly integrated gossamer S/C with electronics, sensors, and actuators embedded in multi-functional membranes; evolvable gossamer S/C that reconfigure their shape and function in response to changing mission conditions; Laser propelled sails for precursor interstellar exploration missions

## Ultra-Lightweight Structures and Space Observatories



## Evolving Capabilities in CETDP Thrust Areas



Relative 2-vehicle autonomous navigation & guidance in Earth-orbit experiments

Multi-vehicle relative navigation and high-precision formation flying

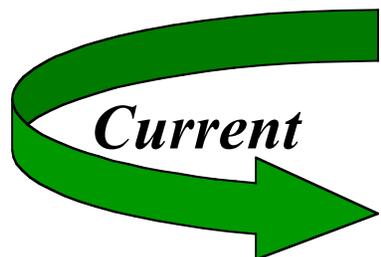
Autonomous reconfiguration; large angle & displacement formation maneuvers

>100 spacecraft constellations in planetary orbits

### Distributed Spacecraft



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## Evolving Capabilities in CETDP Thrust Areas



$\mu$ -subsystems: *In situ* & Distributed Sensors;  $\mu$ - Nav;  $\mu$ -Prop; On-chip power; Multi-function structures



$\mu$ -spacecraft to do all single and multi S/C missions, surface system missions, and to enable gossamer missions to the edge of the solar system



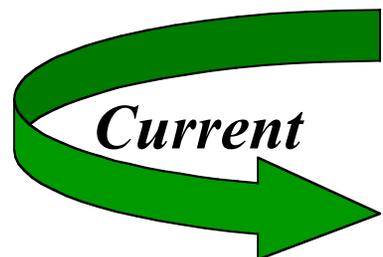
“Nano”, self-repairing spacecraft for missions beyond the solar system; Nano-scale devices and systems

Capability to cut spacecraft power demands for rad-hard devices for all applications; Ultra-Low-Power, Radiation Tolerant Digital Electronics

### Micro/Nano Sciencecraft



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## Evolving Capabilities in CETDP Thrust Areas



Science requirements set independently from engineering solutions yielding costly missions

Collaborative infrastructure in place to support science and engineering integration; Interactive mission design trades; operability prediction

Concurrent science and engineering performed by globally distributed teams; Immersive distributed collaboration

Concurrent science and engineering performed by globally distributed teams

**Next Generation Infrastructure**



## Evolving Capabilities in CETDP Thrust Areas



Both SCARLETT concentrator solar array and 20 cm ion electric thruster demonstrated in space (Deep Space 1); 60 w/kg, 100 volt arrays available commercially

Advanced Stirling converter for the Advanced Radioisotope Power System; 500 volt solar arrays and 2-stage Hall electric thruster

500 w/kg thin film lightweight arrays; 30 kw ion electric thruster available for interstellar missions

2000 w/kg thin film, lightweight arrays; Megawatt-class plasma electric engines

## Advanced Power & On-Board Propulsion