Updating the Fundamental Physics in Space Roadmap

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AGENDA

- *Need for Roadmap*
- *Relationship to NASA Strategic Plan*
- *Roadmap overview*
- *Group Discussion*

Need and Ground rules for Roadmap

- Direction and advice from Mark Lee and Nick Bigelow.
- To continue growing as a discipline, we need to establish a new vision of where we are going that is consistent with today's physics, NASA's strategic plan, and the new OBPR direction.
- 1998 Roadmap focused exclusively on Physics, and did not worry about boundaries between OBPR and OSS
- Roadmap should incorporate some strategic research activities to be fully responsive to the current OBPR direction
- Roadmap should capture the imagination of OBPR leadership, OMB, and Congress.
- Roadmap must delineate OBPR from the "beyond Einstein" program in OSS
- Roadmap must address relevancy to Society explicitly

NASA's Strategic Plan hierarchy

Strategic Plan

- *3 NASA Missions (OBPR 2 prime, 1 supporting)*
  - *10 NASA Goals (OBPR 3 prime, 2 supporting)*
    - *52 Enterprise Objectives (PSR 3 prime, 3 supporting)*

Performance Plan

- *Outcomes (FP 1 - 2 per Objective)*
  - *Annual Performance Goals (1 – 2 per outcome)*

NASA's Missions

To understand and protect our home planet

To explore the Universe and search for life

To inspire the next generation of explorers

…as only NASA can

OBPR: ***Laboratories in Space***

OSS: ***Out-looking Observational instruments and Probes***

OES: ***Earth-looking Observational instruments and Probes***

Mission 1: To Understand and Protect Our Home Planet

Goal 3:

Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

Objective 3.5:

Resolve scientific issues impacting Earth-based technological and industrial applications by using the unique low-gravity environment of space.

FP Outcome 3.5.1: **(support activity)**

Apply physics insights to enable Earth-based applications that promote industrial prowess and enhance national security.

Mission 2: To Explore the Universe and Search for Life

Goal 4:

Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.

Objective 4.2:

Understand the fundamental organizing principles of nature and how they give rise to structure and complexity, using the low-gravity environment of space.

FP Outcome 4.2.1: (prime activity)

Discover new physics beyond today's fundamental laws governing matter, space, and time.

FP Outcome 4.2.2: (prime activity)

Understand organizing principles of nature from which structure and complexity emerge.

Mission 3: To Inspire the Next Generation of Explorers

Goal 6:

Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.

Objective 6.3:

Enhance science, technology, engineering, and mathematics instruction with unique teaching tools and experiences that only NASA can provide, that are compelling to educators and students.

FP Outcome: 6.3.1: **(support activity)**

Incorporate knowledge from physics discoveries into education materials.

Mission 3: To Inspire the Next Generation of Explorers

Goal 7:

Engage the public in shaping and sharing the experience of exploration and discovery.

Objective 7.2 (supportive FP role):

Improve science literacy by engaging the public in NASA missions and discoveries, their benefits, through such avenues as public programs, community outreach, mass media, and the internet.

FP Outcome: 7.2.1: **(support activity)**

Explain the wonder of physics exploration and its benefits to the public.

Enabling Goals: Space Flight Capabilities

Goal 9:

Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.

Objective 9.3 (prime FP role):

Resolve fundamental low-gravity issues affecting technologies for human space travel beyond low-Earth orbit.

FP Outcome: 9.3.1: **(prime activity)**

Apply physics results to enable technologies that allow human space exploration far beyond what is possible today.

Thematic approach for the Roadmap

Theme 1: (prime activity)

Physics Frontiers

Theme 2: (support activity)

Physics and Society

Theme: *Physics Frontiers in Space* (prime activity)

Outcome 4.2.1:

Discover new physics beyond today's fundamental laws governing matter, space, and time.

Outcome 4.2.2:

Understand organizing principles of nature from which structure and complexity emerge.

Outcome 9.3.1:

Apply physics results to enable technologies that allow human space exploration far beyond what is possible today.

Research Outcome 4.2.1: Fundamental Laws

Research area 1: Explore the range of validity of Einstein's relativity theories

- *Measure if all bodies fall at the same rate and if all clocks keep the same time.*
- *Develop the experimental basis to extend the general theory of relativity.*
- *Determine if the special theory of relativity is valid under all conditions.*

Research area 2: Search for new fundamental forces and symmetries and support the development of a unified theory

- *Explore physics beyond the Standard Model.*
- *Determine if vibrating strings are the fundamental building blocks of nature.*
- *Determine if the arrow of time is unidirectional.*
- *Determine if nature's constants are really constant.*
- *Study properties of anti-matter.*

Research area 3: Shed light on questions of cosmological significance

- *Determine properties of the Vacuum energy.*
- *Seek the existence of postulated dark matter particles.*
- *Determine properties of the dark energy.*
- *Measure the local expansion rate of the Universe.*

Research Outcome 4.2.2: Organizing Principles

Research area 4: Study macroscopic samples of matter under ideal and unique experimental conditions

- *Explore critical phenomena and the importance of universal behavior.*
- *Determine finite size, boundary, and dimensionality effects on matter.*
- *Explore non-equilibrium phenomena.*
- *Study self-organization in matter.*

Research area 5: Study few particle samples of matter under ideal and unique experimental conditions

- *Study static and dynamic properties of ultra-cold gasses of atoms.*
- *Measure properties of Bose-Einstein Condensates.*
- *Explore interactions between different species of atoms.*
- *Explore cosmological phenomena in representative model systems.*

Research area 6: Explore macroscopic quantum phenomena

- *Understand the role of vortices in superfluid transitions.*
- *Study quantum gasses, fluids, and solids.*
- *Study matter-wave interferometers.*
- *Search for new many-body quantum mechanical effects.*

Research Outcome 9.2.1: Human Space Exploration

Research area 7: Apply improved technology developed for fundamental physics research to solve human space exploration challenges.

- ***Ultra-stable clocks and inertial navigation devices.***
- ***Laser transponders***
- ***Quantum sensors for displacement, temperature, magnetic field, electric field, vacuum, radiation, rotation, gravity gradients, and accelerometers.***
- ***Optical interferometers and communication technology.***

Research area 8: Apply revolutionary scientific insights to space exploration technologies that enable humans to venture far beyond what is possible today.

- ***Matter-wave technology***
- ***Quantum communication***
- ***Breakthrough propulsion technologies***

Example experiments versus Research Areas

		R&A	LTMPF	DYNAMX	CQ	CP	SUMO	PARCS	TEPEE	MISTE	COEX	EXACT	BEST	SUE	SLES	RACE	CLASS	QuITE	EDM	LATOR	LASER RANGING
NASA Objective 4.2	**Understand the fundamental organizing principles of nature …**																				
Outcome 4.2.1	***Discover new physics beyond today's fundamental laws governing matter, space, and time.***																				
Research area 1	Explore the range of validity of Einstein's relativity theories	●	●				●	●	●						●	●		●		●	●
Research area 2	Search for new fundamental forces and symmetries and support the development of a unified theory	●	●				●	●	●						●	●		●	●	●	●
Research area 3	Shed light on questions of cosmological significance	●	●												●					●	●
Outcome 4.2.2	***Understand organizing principles of nature from which structure and complexity emerge.***																				
Research area 4	Study macroscopic samples of matter under ideal and unique experimental conditions	●	●	●	●	●				●	●	●	●	●							
Research area 5	Study few particle samples of matter under ideal and unique experimental conditions	●						●								●	●	●			
Research area 6	Explore macroscopic quantum phenomena	●	●	●	●	●		●		●	●	●	●	●		●	●	●			
NASA Objective 9.3	**Resolve low-gravity issues for human space travel beyond low-Earth orbit.**																				
Outcome 9.3.1	***Apply physics results to enable technologies that allow human space exploration far beyond what is possible today.***																				
Research area 7	Apply improved technology developed for fundamental physics research to solve human space exploration challenges.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Research area 8	Apply revolutionary scientific insights to space exploration technologies that enable humans to venture far beyond what is possible today.	●	●				●		●						●			●	●	●	●

Theme: *Physics and Society* (support activity)

Outcome 6.3.1:
Incorporate knowledge from physics discoveries into education materials.

Outcome 7.2.1:
Explain the wonder of physics exploration and its benefits to the public.

Outcome 3.5.1:
Apply physics insights to enable Earth-based applications that promote industrial prowess and enhance national security.

Research Outcome 3.5.1: Earth-based applications

Activity 1: Apply new technology developed for fundamental physics research to improve Earth-based applications.

- ***Ultra-stable clocks and timing signals.***
- ***Quantum sensors for displacement, temperature, magnetic field, electric field, vacuum, radiation, rotation, gravity gradients, and accelerometers.***
- ***Cryogenic technology.***
- ***Optical interferometers and communication technology.***
- ***Ultra-high-speed computers.***
- ***Broadband-communications and ultra-high-speed internet.***
- ***New medical diagnostic instruments.***

Activity 2: Apply new scientific insights to enable Earth-based applications far beyond what is possible today.

- ***Matter-wave technology***
- ***Quantum communication***

Research Outcome 6.3.1: Education

Activity 3: Incorporate physics discoveries in education materials

- ***K-6***
- ***7-12***
- ***Higher education***
- ***Class demonstrations***
- ***Virtual class room***
- ***Textbooks***
- ***WWW***

Research Outcome 7.2.1: Public outreach

Activity 4: Share the excitement of physics discovery with the general public

- *Press releases*
- *Open houses*
- *Brochures*
- *WWW*
- *Virtual physics forum*

Activity 5: Share physics discovery with the scientific community

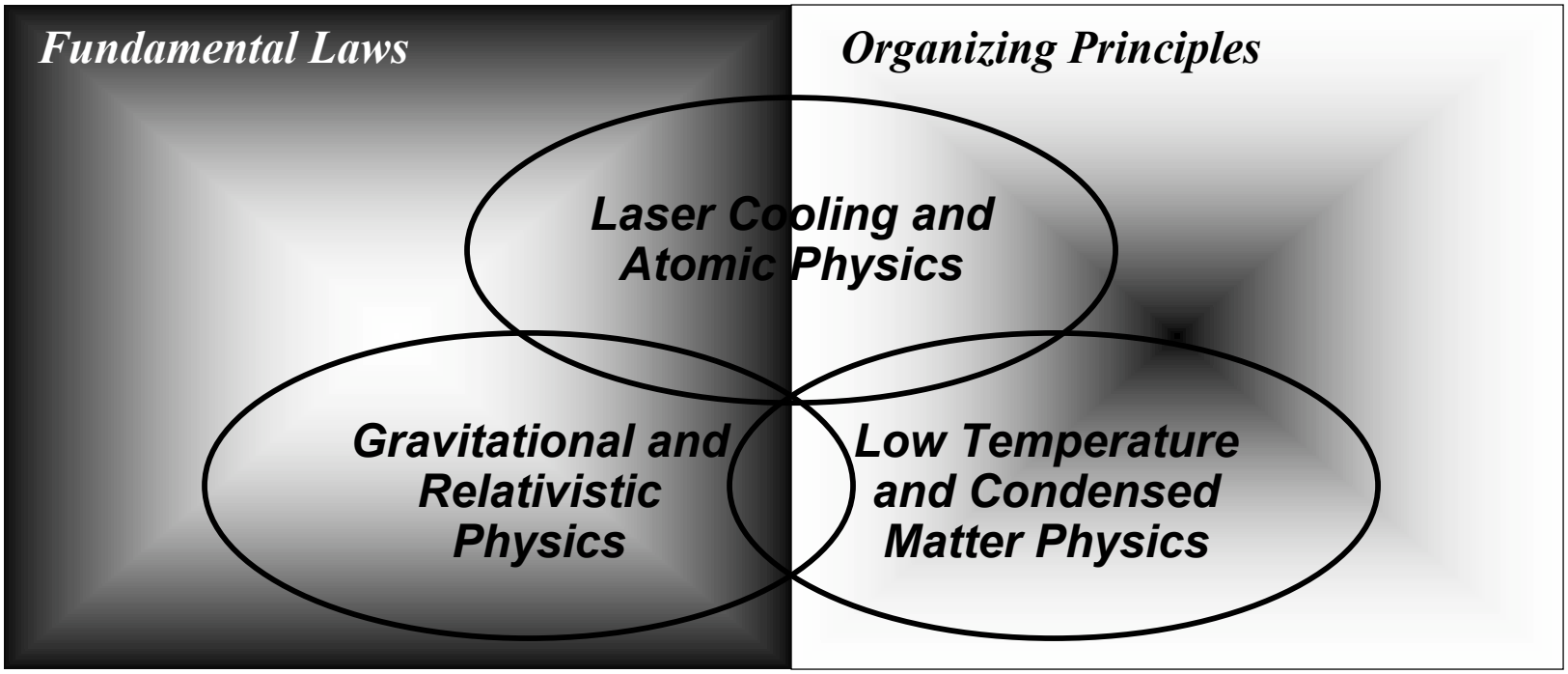
- *Publications in refereed journals*
- *Conferences and workshops*
- *Colloquia and Seminars*
- *WWW*

Example Functions versus Activities

		Physics Research	Education	Public Outreach	PI Interface	Technology watchdog
NASA Objective 3.5	**Resolve scientific issues impacting Earth-based technological and industrial applications by using the unique low-gravity environment of space.**					
Outcome 3.5.1	***Apply physics insights to enable Earth-based applications that promote industrial prowess and enhance national security.***					
Activity 1	Apply new technology developed for fundamental physics research to improve Earth-based applications.	●			●	●
Activity 2	Apply new scientific insights to enable Earth-based applications far beyond what is possible today.	●			●	●
NASA Objective 6.3	**Enhance science, technology, engineering, and mathematics instruction with unique teaching tools and experiences that only NASA can provide, that are compelling to educators and students.**					
Outcome 6.3.1	***Incorporate knowledge from physics discoveries into education materials.***					
Activity 3	Incorporate physics discoveries in education materials.	●	●			
NASA Objective 7.2	**Improve science literacy by engaging the public in NASA missions and discoveries, their benefits, through such avenues as public programs, community outreach, mass media, and the internet.**					
Outcome 7.2.1	***Explain the wonder of physics exploration and its benefits to the public.***					
Activity 4	Share the excitement of physics discovery with the general public.	●		●		
Activity 5	Share physics discovery with the scientific community.	●			●	

The 3 discipline research areas

- *Each discipline research area contributes to the two scientific outcomes as shown below*
- *There is significant scientific and technical overlap across the discipline areas.*
- *Each discipline area contributes to the human exploration outcome and the three Physics and Society outcomes.*



Relating Outcomes to the OBPR Research Mission

OBPR Research Mission	Fundamental Physics Outcomes
1: How can we assure the survival of humans traveling far from Earth?	
2: What must we know about how space changes life forms, so that humankind will flourish?	
3: What new opportunities can our research bring to enrich lives on earth and expand understanding of the laws of nature?	• Discover new physics beyond today's fundamental laws governing matter, space, and time. • Understand organizing principles of nature from which structure and complexity emerge. • Build the foundation for tomorrows breakthrough technologies.
4: What technology must we create to enable the next explorers to go beyond where we have been?	• Expand human space exploration far beyond what is possible today.
5: How can we educate and inspire the next generations to take the journey?	• Inspire future generations to seek knowledge about the physical Universe. • Fulfill the innate human desire to understand our place in the Universe.

Roadmap Outline

- *Foreword*
- *Physics Frontiers*
  - *Goals and Outcomes*
  - *Research areas*
  - *Experiment and Mission Candidates*
  - *Technology*
- *Physics and Society*
  - *Goals and Outcomes*
  - *Activities*
  - *Functions*

Next steps for Roadmap

- **DWG in charge of preparation**

- **Volunteers for writing assignments**
  - **Fundamental Laws area**
  - **Organizing principles area**
  - **Human exploration area**
  - **Education**
  - **Outreach**
  - **Earth technology**

- **New and old graphics**

- **Draft update targeted for June, final in August**

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