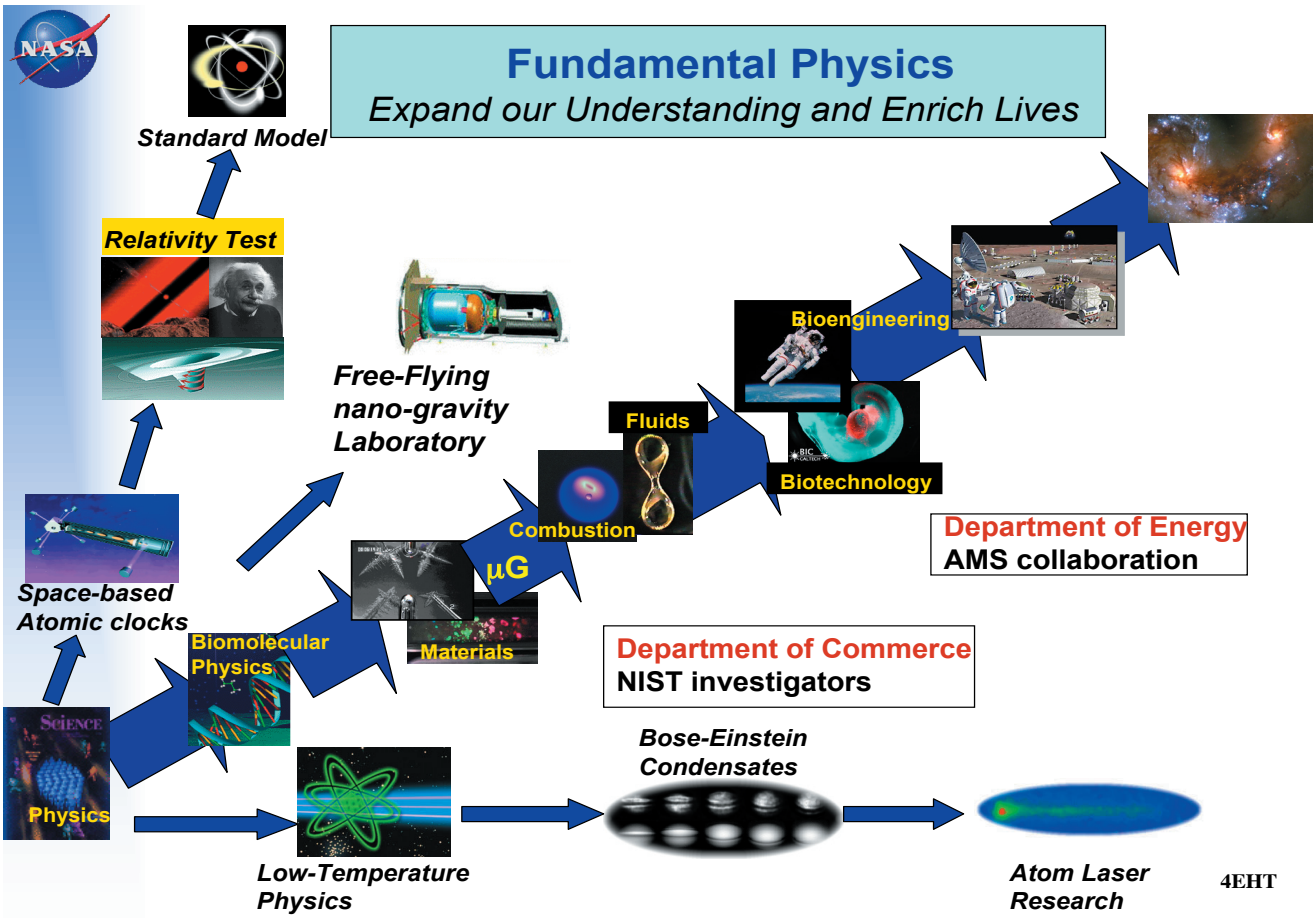
Chapter 1
Programmatic Talks



4EHT

2003 NASA/JPL Workshop for Fundamental Physics in Space

APRIL 14-16, 2003

The 75 persons attending the 2003 Fundamental Physics workshop enjoyed presentations ranging from forces acting on RNA, to properties of clouds of degenerate Fermi atoms, to techniques to probe for added space-time dimensions, and to flight hardware for low temperature experiments, amongst others. The wide range of subjects kept everyone scrambling to follow the rapid changes of reference frames.

Randy Hulet

Randy Hulet, of Rice University, talked about Li-6 atoms cooled to Fermi degeneracy by sympathetic cooling with Li-7.

Wolfgang Ketterle of MIT, shown here in his lab, also described a degenerate Fermi system.

Wolfgang Ketterle

Mark Lee from NASA Headquarters described the new strategic plan that NASA has developed under Administrator Sean O'Keefe's leadership. Mark explained how the Fundamental Physics community now needs to align its research program and the Roadmap describing the long-term goals of that program with the NASA plan.

Ulf Israelsson of JPL discussed how the rewrite of the roadmap will be implemented under the leadership of the Fundamental Physics Discipline Working Group. Nick Bigelow, chair of the DWG, outlined how investigators can contribute to the writing of the roadmap.

Rob Duncan

Rob Duncan, of the University of New Mexico, spoke of new technology for studying superfluid helium. He is PI of the DYNAMX flight experiment.

John Lipa, of Stanford University, described SUMO, a flight experiment to explore Gravitation and Relativity Physics.

John Lipa

O
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P
R

Status of Fundamental Physics Program

Presented to the
Fundamental Physics Workshop
Oxnard, California

April 14-16, 2003

Mark C. Lee

1ML

Update of the Fundamental Physics Program

- JEM/EF Slip
  - 2 years delay
  - Reduced budget
  - Community support and advocacy led by Professor Nick Bigelow
  - Reprogramming led by Fred O'Callaghan/JPL team
    - LTMPF M1 mission (DYNAMX and SUMO)
    - PARCS
    - Carrier re baselined on JEM/EF
- New Roadmapping led by Dr. Ulf Israelsson
- 02NRA due day extended to May 30, 2003

Fundamental Physics Program and the NASA Mission

Presented to the
Fundamental Physics Workshop
Oxnard, California

April 14-16, 2003

Eugene Trinh

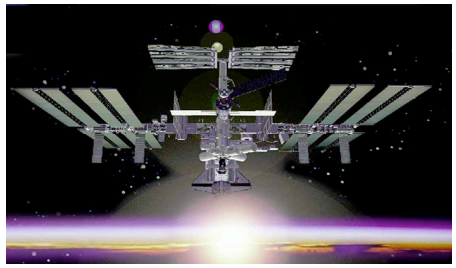
1EHT

Physical Sciences Research (PSR) and the NASA Mission

OBPR

- To understand and protect our home planet → *PSR Fundamental and Applied Research*
- To explore the universe and search for life → *PSR Fundamental Research* *PSR Strategic Research*
- To inspire the next generation of explorers → *PSR Fundamental Research* *PSR Strategic Research*

… as only NASA can



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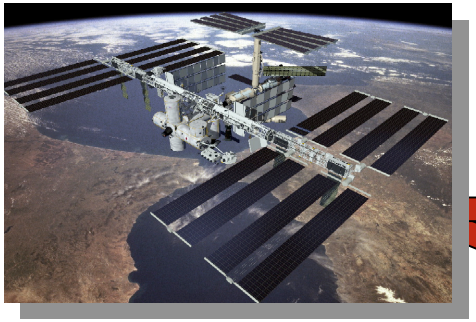
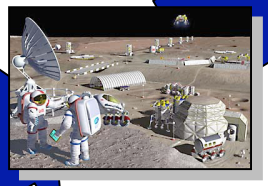
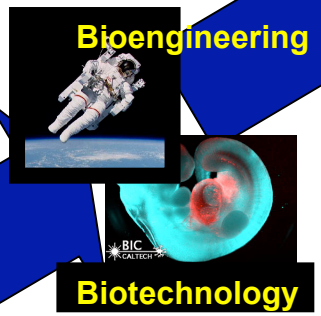
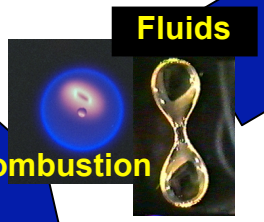


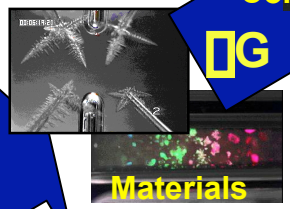
Research for Science and Exploration

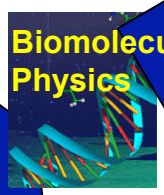
"The common ideas of physics have been applied over distances ranging from the realm of string theory to the furthest reaches of the universe. The results have allowed an understanding of a staggering variety of phenomena and lay the foundation for further research as we probe new frontiers at all distances." (NRC/BPA report)









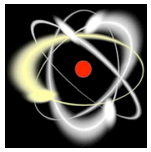


OBPR Physical Sciences Research Discipline Elements

3EHT

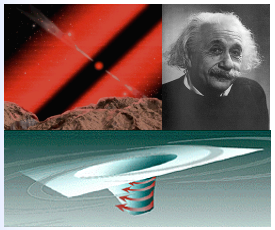
Fundamental Physics

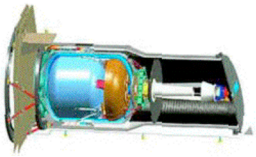
Expand our Understanding and Enrich Lives



Standard Model

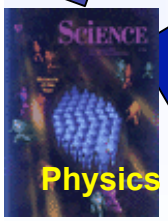
Relativity Test

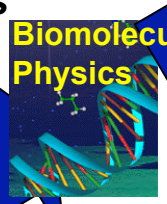


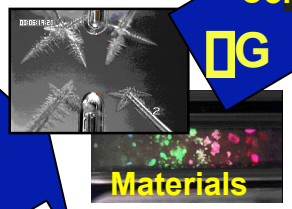


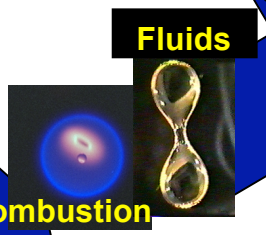
Free-Flying nano-gravity Laboratory

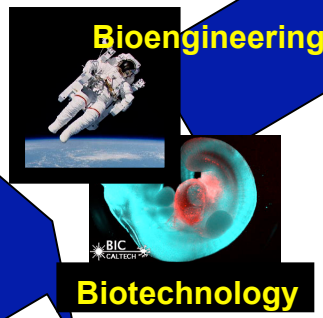
Space-based Atomic clocks





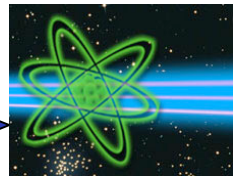






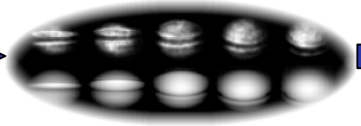
Department of Energy
AMS collaboration

Department of Commerce
NIST investigators



Low-Temperature Physics

Bose-Einstein Condensates



Atom Laser Research

4EHT

Physics in a New Era: An Overview
2001 National Research Council Report

Physics Survey Overview Committee
Board on Physics and Astronomy (BPA)

OBPR

"The accomplishments of Physics, the increasing power of its instruments, and its expanding reach into other sciences have generated an unprecedented set of scientific opportunities". The committee has identified six such "Grand Challenges" listed below in no particular order:

- *Developing quantum technologies* *
- *Creating new materials* *
- *Understanding complex systems* *
- *Unifying the forces of Nature* *
- *Exploring the universe*
- *Applying Physics to Biology* *

* *OBPR Physical Sciences research content relevant*

5EHT

Fundamental physics changes in response to evolving NASA needs

April 14, 2003

Ulf Israelsson

Jet Propulsion Laboratory

California Institute of Technology

AGENDA

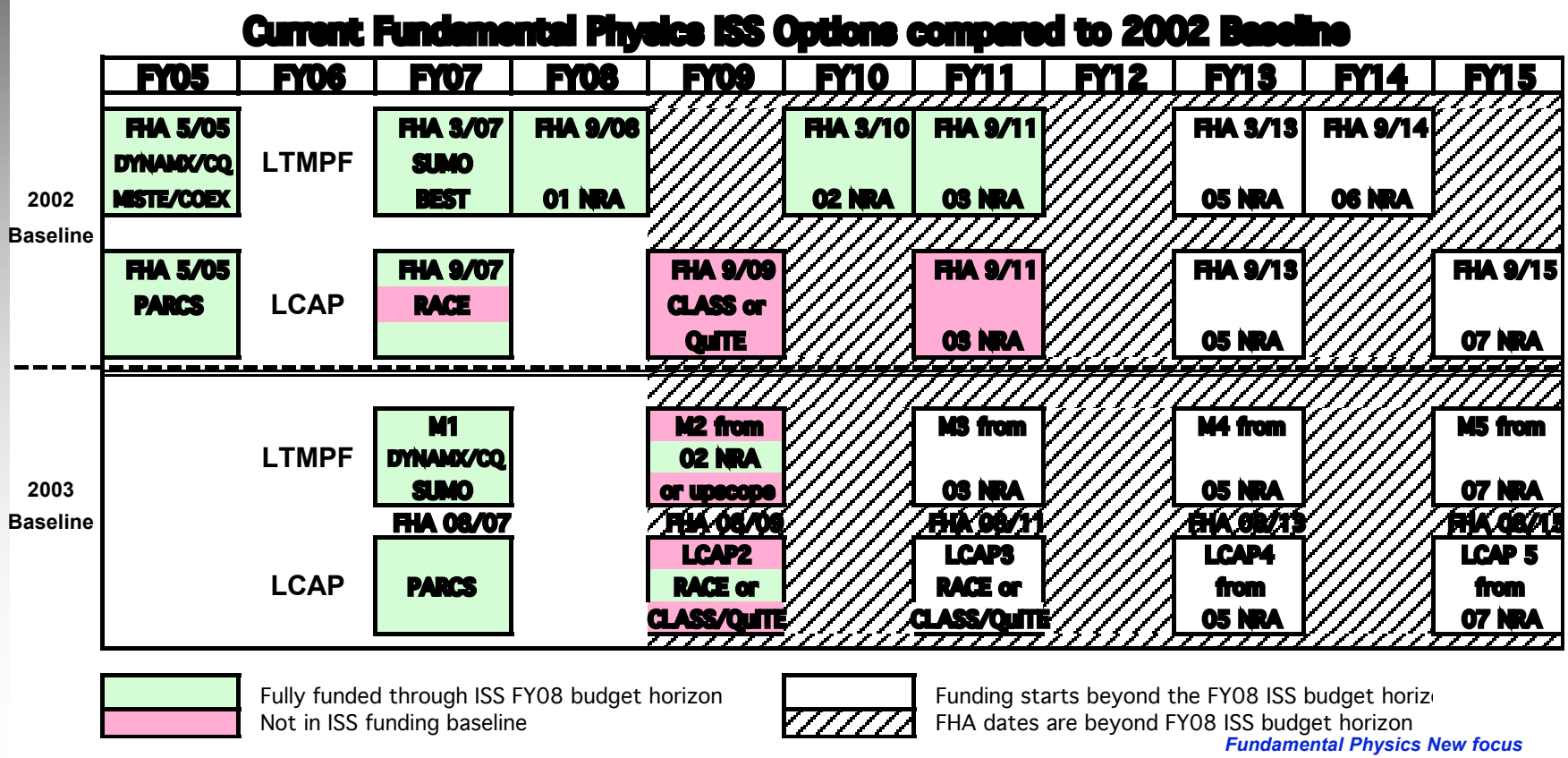
- *Recent NASA Changes*
- *Growing need for access to space for physicists*
- *Rationale for updating the Fundamental Physics in Space Roadmap*
- *Advocacy help from the community*
- *Conclusions*

Recent NASA Changes

- **REMAP**
  - **Increased budget pressure from Life Science disciplines**
- **Mary Kicza putting her spin on OBPR**
  - **ISS focus on human tended research**
  - **Increased importance of Strategic Research**
    - Enabling a safe human presence beyond LEO
  - **Free flyer initiative seeking a FY05 new start**
- **Societal relevance is still important**
- **To measure performance is still a requirement**
- **Columbia disaster**

Recent NASA Changes continued

- **JEM-EF delay has forced a slip of LTMPF and PARCS by 2+ years.**
  - **Budget arbitrarily reduced**
- **LTMPF–M1 re-programmed with SUMO instead of MISTE.**
  - **To maximize science return on first mission**
  - **Desire to link PARCS and SUMO clocks to further enhance science**



Growing need for access to space for physicists

- **Physics is standing at the threshold of major discovery.**
  - **Two of our foundational descriptions nature, quantum mechanics and general relativity, are incompatible with each other.**
  - **When scientists resolve this conflict, a different view of reality may emerge.**
- **Cosmological observations are providing additional clues that our understanding of reality is in need of modification.**
  - **Most of the energy content of the Universe resides in unknown dark matter and dark energy that may permeate all of space-time.**
- **Resolving the Quantum/gravitation conflict may also shed light on the cosmological unknowns.**
- **Today's availability of high-resolution technology and space access represents a unique opportunity for scientists to address these questions.**
- **Quiescent *sub-microgravity* freely flying research platforms would enhance the chances of major discovery substantially.**
  - **To be discussed on Tuesday afternoon**

Need for Roadmap

- 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
- Updated Roadmap:
  - Must incorporate <u>some</u> strategic research activities to be fully responsive to the current OBPR direction
  - Must capture the imagination of OBPR leadership, OMB, and Congress.
  - Must delineate OBPR from the "beyond Einstein" program in OSS
  - Must address relevancy to Society explicitly
- Status of the Roadmap development will be discussed after lunch today.
  - Seeking community inputs and endorsement
- Draft update targeted for June, final in August

In addition we must….

- **Continue to demonstrate research productivity to NASA**
  - **Significant events**
  - **Press releases**
- **Remember that our accomplishments are ultimately evaluated by the scientific community**
  - **Prestigious peer reviewed journals reaching a wide audience**
- **Continue reaching out to students and the general public**
- **Keep thinking about how your technology improvements might be applied to solve human space exploration issues.**
- **Keep thinking about how your technology improvements might be used for Earth applications to enhance national security or promote industrial prowess.**

Conclusions

- **Change continues in the NASA environment**
- **The need for access to space for physicists is growing if we are to fruitfully address today's challenging questions**
- **A new Roadmap is required to demonstrate the importance of our program to stakeholders**
  - Roadmap plans and activities to be discussed after lunch today
- **Our investigators must continue to advocate the benefits of our program:**
  - To NASA and Congress
  - To the scientific community
  - To students
  - To the general public
- **Our investigators must seek ways to use their advanced technology to support a human presence in space and to develop improved Earth applications**

Acknowledgement

The work described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

Updating the Fundamental Physics in Space Roadmap

April 14, 2003

Ulf Israelsson
Bill Klipstein
Don Strayer
Lute Maleki
Slava Turyshev
Talso Chui
Jet Propulsion Laboratory, California Institute of Technology

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	ISLES	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

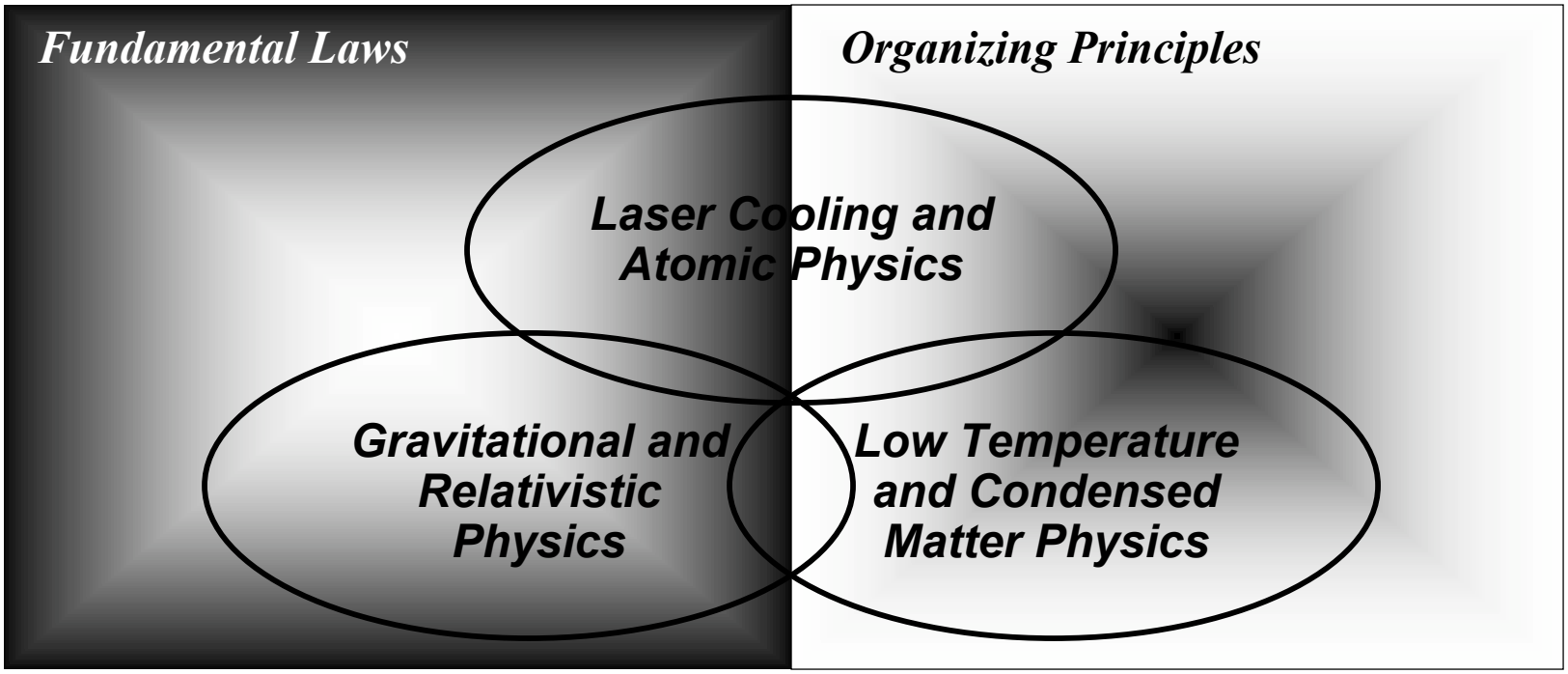
- ***Publications in refereed journals***
- ***Conferences and workshops***
- ***Colloquia and Seminars***
- ***WWW***

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

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?

4: What technology must we create to enable the next explorers to go beyond where we have been?

5: How can we educate and inspire the next generations to take the journey?

Fundamental Physics Outcomes

- 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.

- Expand human space exploration far beyond what is possible today.

- 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**

Acknowledgement

The work described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

The potential OBPR Free Flyer Platform and Fundamental Physics

April 15, 2003

Ulf Israelsson

Jet Propulsion Laboratory

California Institute of Technology

AGENDA

- *Overview of the Free Flyer augmentation request*
- *Importance from a fundamental physics perspective*
- *Summary*
- *Group Discussion*

OBPR FF Objectives versus NASA Goals

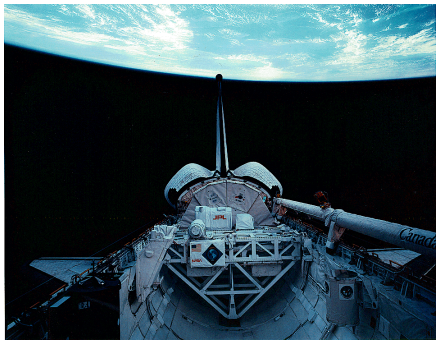
"Diversifying Research Platforms… While the Space Station will be the focus of biological and physical research, alternative space platforms are needed to fill gaps in research the Station cannot do."

OMB FY2003 President's Budget Request

FF Objectives	NASA Goals
Enable innovative Earth-based technologies through research discoveries beyond LEO with our partners	3. Create a secure world and improve the quality of life by investing in new technologies and collaborating with other agencies, industry, and academia
Enable important space research beyond what can be done on ISS	4. Explore fundamental principles of physics, chemistry, and biology
Understand life's response to increasing distances and durations beyond Earth.	9. Extend the duration & boundaries of human space flight
Increase access to space for broader science and technical community involvement and education.	6. Inspire and motivate students to pursue careers in science, technology, and mathematics
Inspire tomorrow's explorers to share in our journey of discovery	7. Engage the public in shaping and sharing the experience of exploration and discovery.

Expanding OBPR's research capabilities

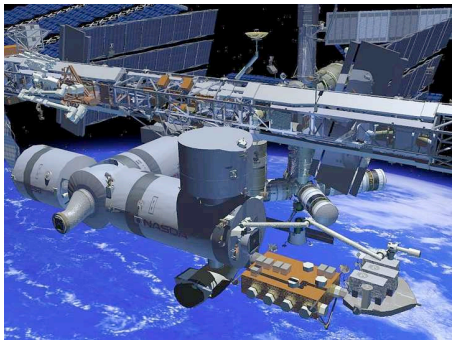
Space Shuttle
1985 - 2015



Key Capabilities

- Short Duration micro-gravity environment
- Crew tended
- Circular orbit
- 28 – 57 degree inclination
- 300 km altitude
- Return Capability

Space Station
2003 - 2015



Expanded Capabilities

- Long Duration micro-gravity environment

Free Flyer
2008 - 2025

Expanded Capabilities

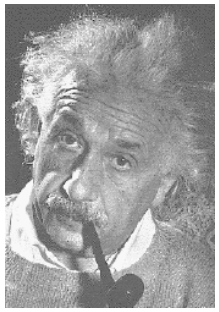
- Long Duration sub-micro-gravity environment
- Radiation environment beyond the Van Allen belts
- Use of very hazardous materials and techniques
- Expanded orbit selection
- Multiple spacecraft capability

1985 **2025**

Research Activities enabled by FF

- **Human Exploration**
  - Determine combined microgravity/radiation risks for human exploration.
  - Validate radiation protection strategies using in situ hardware.
  - Develop countermeasures for human exploration impediments beyond Low Earth Orbit.

- **Fundamental Research**
  - Understand combined microgravity/radiation effects in cells, living tissue, and animals.
  - Determine if cell radiation damage and repair are similar in space and on the ground.
  - Determine the validity of Einstein's theory of gravitation with many orders of magnitude better precision than possible on crew-tended vehicles.
  - Explore the nature of the quantum world with many orders of magnitude better precision than possible on crew-tended vehicles.



- **Technology and Research Partnerships**
  - Demonstrate potentially hazardous technologies and techniques before exposing them to crew.
  - Provide access to space for activities incompatible with crewed vehicles.

FF Implementation

- **Will be submitted as an Augmentation this year to be considered for a *FY05* new start.**
  - Outcome of the augmentation request will be known when the FY04 budget is approved.
- **Ames Research Center would be the lead center for the Free Flyer activity**
- **GSFC would support ARC with Spacecraft systems, launch vehicles, and Mission management**
- **JPL would be the lead for development of fundamental physics payloads.**
  - JPL will submit an approximate budget requirement to develop and fly one FP free flyer mission in mid-2010 and follow-on flights every 2 years thereafter.
- **JPL may also lead development of sample return hardware and drag-free technology hardware.**
- **Three classes of autonomous space craft envisioned**
  - Heavy class, sample return capability (500 – 2000 kg payload)
  - Medium class, one-way (100 – 500 kg payload)
  - Small class, one-way payload of opportunity (up to 100 kg payload)
- **A variety of Earth-orbits envisioned**
- **Payload solicitation mechanism not yet finalized (NRA versus AO)**

Why does Fundamental Physics need a Free flyer

- **Physics is standing at the threshold of major discovery.**
  - Two of our foundational descriptions nature, quantum mechanics and general relativity, are in conflict with each other.
  - When scientists resolve this conflict, a different view of reality may emerge.
- **Cosmological observations are providing additional clues that our understanding of reality is in need of modification.**
  - Most of the energy content of the Universe resides in unknown dark matter and dark energy that may permeate all of space-time.
- **Resolving the Quantum/gravitation conflict may also shed light on the cosmological unknowns.**
- **Today's availability of high-resolution technology and space access represents a unique opportunity for scientists to address these questions.**
- **Quiescent sub-microgravity freely flying research platforms would enhance the chances of major discovery substantially.**

Limitations of ISS Fundamental Physics Research

- **The Microgravity environment aboard the ISS limits the attainable precision in high-resolution physics experiments**
  - Sensitive gravitational physics experiments require a DC environment in the sub-micro-g range, or below. These experiments cannot be done on the ISS at all.
  - The DC environment limits how closely critical points can be approached.
  - The DC environment may limit studies of BE condensates.
  - The G-jitter environment heats low temperature samples and does not allow sensitive data to be collected.

- **The near circular orbit of the ISS does not allow variations in the gravitational potential as an experimental parameter**

- **ISS geometry complicates implementation of clock experiments requiring line of sight access between them**
  - A freely flying platform could accommodate multiple clocks linked together directly.

Example Free Flyer Mission - ISLES

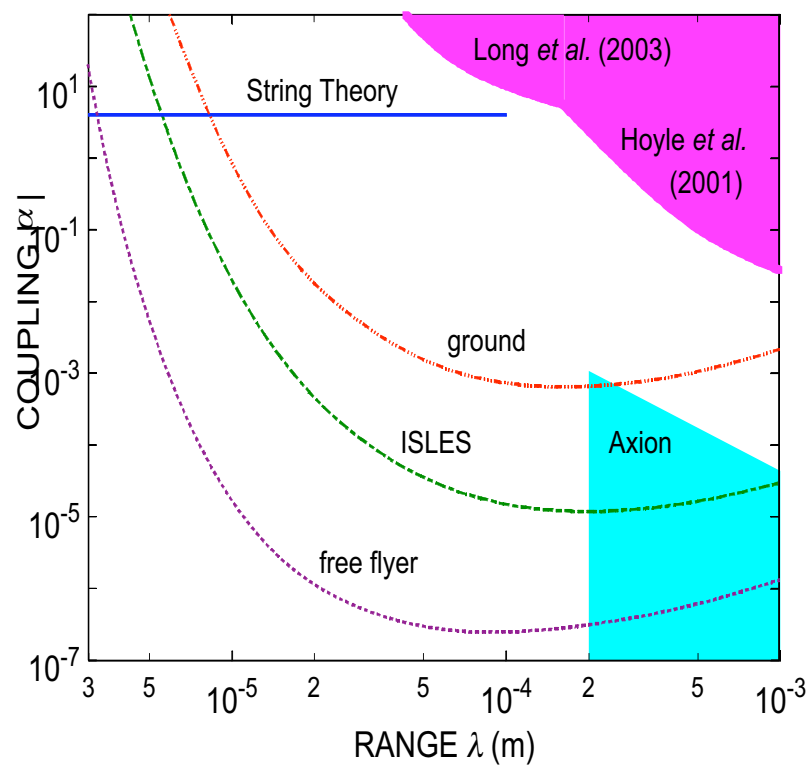
Experiment title: Inverse Square Law Experiment in Space (ISLES)

Principal Investigator: Ho-Jung Paik, University of Maryland

Experiment objective: To measure the 1/r^2 dependence of the force of gravity at 100 micro-meters a million times better than ground based experiments

Significance

- Newton's 1/r^2 law is a cornerstone of General Relativity
- Proposed extensions to the standard model of physics postulate the existence a lightweight axion particle.
- The axion is a candidate for the missing dark matter in the Universe.
- String theories aimed to unify the laws of physics predict a violation of the 1/r^2 dependence at short distances due to additional compacted dimensions.
- ISLES will verify or refute these fundamental fundamental predictions



Summary

- **The availability of the ISS is critical to developing and demonstrating a first generation of fundamental physics missions.**
- **A freely flying platform would enable the next generation of fundamental physics experiments with resolution not attainable on ISS**
  - Planned FP research on the ISS just beyond core complete can be used as pathfinder experiments
- **In many cases it may prove beneficial to design and operate experiments first on the ISS to prove out concepts and gain operational experience before committing to a free flyer development.**
- **A free flyer capability would enable candidate experiments that may shed light on some of the most vexing problems in physics today.**

Acknowledgement

The work described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

PROGRAM

2003 NASA/JPL WORKSHOP ON FUNDAMENTAL PHYSICS IN SPACE

Embassy Suites Hotel Mandalay Beach Resort
Oxnard, CA

April 14-16, 2003

NASA/JPL WORKSHOP ON FUNDAMENTAL PHYSICS IN SPACE
Monday
Embassy Ballrooms A & B

Time	Speaker	Title
8:30	Fred O'Callaghan, Manager, Astronomy & FP Program Office, JPL	Welcome
8:40	Eugene Trinh, Director, Physical Sciences Research, NASA HQs	Welcome from NASA HQs
8:50	Mark Lee, Fundamental Physics Enterprise Scientist, NASA HQs	Update on the Fundamental Physics Program
9:20	Ulf Israelsson, Discipline Scientist, Fundamental Physics, JPL	New Focus for Fundamental Physics Means New Plans
Break		
10:30	Melora Larson, JPL	Status of the Low Temperature Microgravity Physics Facility
10:50	Wolfgang Ketterle, MIT	Experiments with quantum-degenerate fermionic lithium atoms
11:20	Rob Duncan, University of New Mexico	Nonlinear Dynamics of the Superfluid Transition: What May We Learn On Orbit?
11:50	Lute Maleki, JPL	Experimental investigations of the electromagnetic vacuum: Can we weigh the vacuum?
12:20	Lunch	Patio near swimming pool

1:30	Ulf Israelsson, Discipline Scientist for Fundamental Physics, JPL	Group Discussion of a New Roadmap for Fundamental Physics
3:00	Kurt Gibble, Penn State University	Progress on RACE
3:20	Horst Meyer, Duke University	Characteristic Times in the Transient to Convection in a Very Compressible Fluid
3:40	Marty Barmatz, JPL	Theoretical Analysis of Thermodynamic Measurements Near a Liquid-Gas Critical Point
Break		
4:30-6:30	Poster Session & Reception	Harbor Room (upstairs)

NASA/JPL WORKSHOP ON FUNDAMENTAL PHYSICS IN SPACE
Tuesday
Embassy Ballrooms A & B

8:30	Harvey Gould, LBNL	Microgravity Electron Electric Dipole Moment Experiment with a Cold Atom Beam
8:50	Moses Chan, Penn State University	Measurement of critical adsorption of nitrogen near its liquid-vapor critical point
9:20	Lois Pollock, Cornell	Fundamental interactions in macromolecular folding
9:40	Ken Nordtvedt, Northwest Analysis	Earth as Source of Detailed STEP Signal
10:00	Break	
10:30	Efstratios Manousakis, Florida State University	Numerical studies of properties of confined helium
10:50	Neal Ashby, University of Colorado	Science Goals of the Primary Atomic Reference Clock in Space (PARCS) Experiment
11:20	Randy Hulet, Rice University	Fermion Superfluidity
11:40	Ho Jung Paik, University of Maryland	ISLES: Probing extra dimensions using a superconducting accelerometer
12	Lunch	

2:00	Ulf Israelsson, Discipline Scientist, Fundamental Physics, JPL	Group Discussion of Free-Flyer Satellites for Fundamental Physics
3:00	David Ceperley, University of Illinois	Superfluidity in a Doped Helium Droplet
3:20	John Lipa, Stanford University	Microwave Cavity Clocks On Space Station
3:40	Break	
4:00	Talso Chui, JPL	Fluctuations of the Phase Difference across an Array of Josephson Junctions in Superfluid He-4
4:20	Gary Williams, UCLA	Vortex Loops at the Superfluid Lambda Transition: An Exact Theory?
4:40	Al Sanders, University of Tennessee	Prospects for Measurement of (G-dot)/G at ~10^-14/yr
5:00	Slava Turyshev, JPL	LATOR: New mission concept to enable precision tests of relativity in space
Break		
7:30	Workshop Banquet	Speaker: Andrew Lange, Caltech Probing the First Nanosecond: The Next Step in Observations of the Cosmic Microwave Background

NASA/JPL WORKSHOP ON FUNDAMENTAL PHYSICS IN SPACE
Wednesday
Embassy Ballrooms A & B

8:40	Dave Brinza, JPL	Engineering Developments for the Primary Atomic Reference Clock in Space (PARCS) Experiment
9:00	Weijen Yao, Brown	Coalescence of Liquid Drops
9:20	Slava Turyshev, JPL	Improving the Accuracy of Lunar Laser Ranging Tests of Gravitational Theory: Modeling and Future Directions
9:40	Jason Ho, Ohio State	Fast Rotating Scalar and Multi-Component Bose Gases
10:00	Sergei Kopeiken, University of Missouri	General Relativistic Theory of the VLBI Time Delay in the Gravitational Field of Moving Bodies
10:20	Break	
10:50	Richard Lee, Caltech	Heat Capacity Measurements of the Self-Organised Superfluid Two-Phase State in Liquid He-4
11:10	Mike Gehm, Duke	Universal Dynamics of a Strongly-Interacting Fermi Gas
11:30	Jim Valles, Brown	Probing Gravitational Sensitivity in Biological Systems Using Magnetic Body Forces
11:50	Edward Fomalont, NRAO	Measurement of the Aberration of Gravity Using Jupiter's Motion
12:10	Dimitri Sergatskov, UNM	New propagating mode near the superfluid transition in He-4

NASA/JPL WORKSHOP ON FUNDAMENTAL PHYSICS IN SPACE
Poster Session 4:30-6:30 Monday Evening
Harbor Room (upstairs)

Alan Kostelecky Indiana University	Sensitive Tests of Lorentz Invariance
Scott Diddams, NIST-Boulder	Femtosecond Laser-based Optical Synthesizers
Enrico Lorenzini, Harvard-Smithsonian Observatory	Testing the Equivalence Principle in an Einstein Elevator: detector dynamics & gravity perturbations
Raymond Newell, University of Wisconsin-Madison	Evaporative cooling in a Holographic Atom Trap
Inseob Hahn, JPL	Measurements of the coexistence curve near the liquid-gas critical point of He-3
Moses H. W. Chan, Penn State University	Quartz microbalance study of 400 angstrom thick helium film near the lambda point
Hung Quach, JPL	Metglas for Low Temperature Transformer Core and EMI Filter
Konstanin Penanen, JPL	Thermally Driven Josephson Effect
David Lee, Cornell University	Magnetic Studies of Impurity Helium Solids
Joe Rudnick, UCLA	Progress in Developing a New Field-Theoretical Crossover Equation-of-State
Colin Green, UNM	Precise heater control with rf-biased Josephson junctions
Marty Barmatz, JPL	Progress in the Development of a New Field-Theoretical Crossover Equation-of-State
Fang Zhong, JPL	Measurement of Specific Heat Using a Gravity Cancellation Approach
Mark Weilert, JPL	A 2-D Piston Effect Solution for the Relaxation in the MISTE Cell
Ron Walsworth, Harvard-Smithsonian Observatory	Bound on Lorentz and CPT Violating Boost Effects for the Neutron
Melanie Kittle, University of Texas, Austin	New Experiment to Measure the Electron Electric Dipole Moment
Melora Larson, JPL	Experiments Along Coexistence near Tricriticality in ^{3}He-^{4}He Mixtures
Arito Nishimori, Stanford	A macroscopic realization of the weak interaction
Joel Nissan, Stanford	Specific Heat and Second Sound Measurements with the DYNAMIX Instrument

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