CONTENTS

Preface **v**

Policy **1**

SPACE-BASED RESEARCH IN FUNDAMENTAL PHYSICS AND QUANTUM TECHNOLOGIES
S. G. Turyshev, U. E. Israelsson, M. Shao, N. Yu, A. Kusenko, E. L. Wright, C. W. F. Everitt, M. Kasevich, J. A. Lipa, J. C. Mester, R. D. Reasenberg, R. L. Walsworth, N. Ashby, H. Gould and H. J. Paik 3

SPACE-BASED SCIENCE AND THE AMERICAN COMPETITIVENESS INITIATIVE
J. H. Marburger, III 51

FUNDAMENTAL PHYSICS AT NASA: TWO CRITICAL ISSUES AND FAIRBANK'S PRINCIPLE
C. W. F. Everitt 57

ADDRESSING THE CRISIS IN FUNDAMENTAL PHYSICS
C. W. Stubbs 71

LABORATORY EXPERIMENTS FOR FUNDAMENTAL PHYSICS IN SPACE
W. D. Phillips 77

FUNDAMENTAL PHYSICS ACTIVITIES IN THE HME DIRECTORATE OF THE EUROPEAN SPACE AGENCY
L. Cacciapuoti and O. Minster 81

LESSONS FROM INTRODUCING NEW SCIENTIFIC DISCIPLINES INTO EUROPEAN SPACE RESEARCH
M. C. E. Huber 91

NATIONAL SCIENCE FOUNDATION VISION IN PARTICLE AND NUCLEAR ASTROPHYSICS
R. N. Boyd 105

THE DEPARTMENT OF ENERGY HIGH ENERGY PHYSICS PROGRAM
K. Turner 113

Gravitational Theory **127**

DARK ENERGY, DARK MATTER AND GRAVITY
O. Bertolami 129

OBSERVABLE CONSEQUENCES OF STRONG COUPLING IN THEORIES WITH LARGE DISTANCE MODIFIED GRAVITY
G. Dvali 139

THEORY AND PHENOMENOLOGY OF DGP GRAVITY
C. Deffayet 149

TESTING STRONG MOND BEHAVIOR IN THE SOLAR SYSTEM
J. Magueijo and J. Bekenstein 161

CONSTRAINING TeVeS GRAVITY AS EFFECTIVE DARK MATTER AND DARK ENERGY
H. Zhao 181

COSMIC ACCELERATION AND MODIFIED GRAVITY
M. Trodden 191

A MODIFIED GRAVITY AND ITS CONSEQUENCES FOR THE SOLAR SYSTEM, ASTROPHYSICS AND COSMOLOGY
J. W. Moffat 201

LONG RANGE GRAVITY TESTS AND THE PIONEER ANOMALY
S. Reynaud and M.-T. Jaekel 217

Gravitational Experiment **233**

EXPERIMENTAL GRAVITY IN SPACE — HISTORY, TECHNIQUES AND PROSPECTS
R. W. Hellings 235

PROBING SPACE–TIME IN THE SOLAR SYSTEM: FROM CASSINI TO BepiColombo
L. Iess and S. Asmar 245

APOLLO: A NEW PUSH IN LUNAR LASER RANGING
T. W. Murphy, Jr, E. L. Michelson, A. E. Orin, E. G. Adelberger, C. D. Hoyle, H. E. Swanson, C. W. Stubbs and J. B. Battat 255

ASYNCHRONOUS LASER TRANSPONDERS: A NEW TOOL FOR IMPROVED FUNDAMENTAL PHYSICS EXPERIMENTS
J. J. Degnan 265

LASER RANGING FOR GRAVITATIONAL, LUNAR AND PLANETARY SCIENCE
S. M. Merkowitz, P. W. Dabney, J. C. Livas, J. F. McGarry, G. A. Neumann and T. W. Zagwodzki 279

SPACE-BASED TESTS OF GRAVITY WITH LASER RANGING
S. G. Turyshev and J. G. Williams 293

INVERSE-SQUARE LAW EXPERIMENT IN SPACE
H. J. Paik, V. A. Prieto and M. V. Moody 309

LASER ASTROMETRIC TEST OF RELATIVITY: SCIENCE, TECHNOLOGY AND MISSION DESIGN
S. G. Turyshev and M. Shao 319

LATOR: ITS SCIENCE PRODUCT AND ORBITAL CONSIDERATIONS
K. Nordtvedt 333

SATELLITE TEST OF THE EQUIVALENCE PRINCIPLE: OVERVIEW AND PROGRESS
J. J. Kolodziejczak and J. Mester 343

TESTING THE PRINCIPLE OF EQUIVALENCE IN AN EINSTEIN ELEVATOR
I. I. Shapiro, E. C. Lorenzini, J. Ashenberg, C. Bombardelli, P. N. Cheimets, V. Iafolla, D. M. Lucchesi, S. Nozzoli, F. Santoli and S. Glashow 355

A LABORATORY TEST OF THE EQUIVALENCE PRINCIPLE AS PROLOG TO A SPACEBORNE EXPERIMENT
R. D. Reasenberg and J. D. Phillips 373

EXPERIMENTAL VALIDATION OF A HIGH ACCURACY TEST OF THE EQUIVALENCE PRINCIPLE WITH THE SMALL SATELLITE "GALILEO GALILEI"
A. M. Nobili, G. L. Comandi, S. Doravari, F. Maccarrone, D. Bramanti and E. Polacco 387

PROBING GRAVITY IN NEO'S WITH HIGH-ACCURACY LASER-RANGED TEST MASSES
A. Bosco, C. Cantone, S. Dell'Agnello, G. O. Delle Monache, M. A. Franceschi, M. Garattini, T. Napolitano, I. Ciufolini, A. Agneni, F. Graziani, P. Ialongo, A. Lucantoni, A. Paolozzi, I. Peroni, G. Sindoni, G. Bellettini, R. Tauraso, E. C. Pavlis, D. G. Currie, D. P. Rubincam, D. A. Arnold, R. Matzner and V. J. Slabinski 399

MEASUREMENT OF THE GRAVITATIONAL CONSTANT USING THE ATTRACTION BETWEEN TWO FREELY FALLING DISCS: A PROPOSAL
L. Vitushkin, P. Wolf and A. Vitushkin 415

CONCEPT CONSIDERATIONS FOR A DEEP SPACE GRAVITY PROBE BASED ON LASER-CONTROLLED FREE-FLYING REFERENCE MASSES
U. A. Johann 425

PROPOSED OBSERVATIONS OF GRAVITATIONAL WAVES FROM THE EARLY UNIVERSE VIA "MILLIKAN OIL DROPS"
R. Y. Chiao 437

A ROBUST TEST OF GENERAL RELATIVITY IN SPACE
J. Graber 447

Physics Beyond the Standard Model **453**

DETECTING STERILE DARK MATTER IN SPACE
A. Kusenko 455

ELECTRON ELECTRIC DIPOLE MOMENT EXPERIMENT WITH SLOW ATOMS
H. Gould 467

TESTING RELATIVITY AT HIGH ENERGIES USING SPACEBORNE DETECTORS
F. W. Stecker 473

NAMBU–GOLDSTONE MODES IN GRAVITATIONAL THEORIES WITH SPONTANEOUS LORENTZ BREAKING
R. Bluhm 487

THE SEARCH FOR DARK MATTER FROM SPACE AND ON THE EARTH
D. B. Cline 495

NEW PHYSICS WITH 10^{20} eV NEUTRINOS AND ADVANTAGES OF SPACE-BASED OBSERVATION
T. J. Weiler 507

DETECTING LORENTZ INVARIANCE VIOLATIONS IN THE 10^{-20} RANGE
J. A. Lipa, S. Wang, J. Nissen, M. Kasevich and J. Mester 523

LIGHT SUPERCONDUCTING STRINGS IN THE GALAXY
F. Ferrer and T. Vachaspati 529

ADVANCED HYBRID SQUID MULTIPLEXER CONCEPT FOR THE NEXT GENERATION OF ASTRONOMICAL INSTRUMENTS
I. Hahn, P. Day, B. Bumble and H. G. Leduc 537

Atoms and Clocks **543**

NEW FORMS OF QUANTUM MATTER NEAR ABSOLUTE ZERO TEMPERATURE
W. Ketterle 545

ATOMIC QUANTUM SENSORS IN SPACE
T. van Zoest, T. Müller, T. Wendrich, M. Gilowski, E. M. Rasel, W. Ertmer, T. Könemann, C. Lämmerzahl, H. J. Dittus, A. Vogel, K. Bongs, K. Sengstock, W. Lewoczko-Adamczyk, A. Peters, T. Steinmetz, J. Reichel, G. Nandi, W. Schleich and R. Walser 553

COHERENT ATOM SOURCES FOR ATOM INTERFEROMETRY IN SPACE: THE ICE PROJECT
P. Bouyer 563

RUBIDIUM BOSE–EINSTEIN CONDENSATE UNDER MICROGRAVITY
A. Peters, W. Lewoczko-Adamczyk, T. van Zoest, E. Rasel, W. Ertmer, A. Vogel, S. Wildfang, G. Johannsen, K. Bongs, K. Sengstock, T. Steimnetz, J. Reichel, T. Könemann, W. Brinkmann, C. Lämmerzahl, H. J. Dittus, G. Nandi, W. P. Schleich and R. Walser 579

TIME, CLOCKS AND FUNDAMENTAL PHYSICS
C. Lämmerzahl and H. Dittus 587

PROBING RELATIVITY USING SPACE-BASED EXPERIMENTS
N. Russell 601

PRECISION MEASUREMENT BASED ON ULTRACOLD ATOMS AND COLD MOLECULES
J. Ye, S. Blatt, M. M. Boyd, S. M. Foreman, E. R. Hudson, T. Ido, B. Lev, A. D. Ludlow, B. C. Sawyer, B. Stuhl and T. Zelinsky 613

ATOMIC CLOCKS AND PRECISION MEASUREMENTS
K. Gibble 627

THE CLOCK MISSION OPTIS
H. Dittus and C. Lämmerzahl 631

ATOMIC CLOCK ENSEMBLE IN SPACE: AN UPDATE
C. Salomon, L. Cacciapuoti and N. Dimarcq 643

SpaceTime: PROBING FOR 21ST CENTURY PHYSICS WITH CLOCKS NEAR THE SUN
L. Maleki and J. Prestage 657

OPTICAL CLOCKS AND FREQUENCY METROLOGY FOR SPACE
H. Klein 669

ON ARTIFICIAL BLACK HOLES
U. Leonhardt and T. G. Philbin 673

Cosmology and Dark Energy **683**

DARK ENERGY TASK FORCE: FINDINGS AND RECOMMENDATIONS
R. N. Cahn 685

CMB POLARIZATION: THE NEXT DECADE
B. Winstein 697

NATURAL INFLATION: STATUS AFTER WMAP THREE-YEAR DATA
K. Freese, W. H. Kinney and C. Savage 707

IS DARK ENERGY ABNORMALLY WEIGHTING?
J.-M. Alimi and A. Füzfa 721

COHERENT ACCELERATION OF MATERIAL WAVE PACKETS
F. Saif and P. Meystre 727

GRAVITOELECTROMAGNETISM AND DARK ENERGY IN SUPERCONDUCTORS
C. J. de Matos 733

Author Index 741

Subject Index 745