## Part 1 Accumulation and Application of Knowledge Gained Through Basic Research: To Enhance Japan’s Research Capability

### Chapter 1 Basic Research to Discover New Knowledge

#### Section 1 Importance of Basic Research

- Number of Papers: Declining International Share and Stagnant Participation in Rising Research Areas
- Research Funds: Importance of Basic Research Funds to Support Basic Research
- Research Personnel: Decreasing Number of Newly Enrolled Doctoral Students
- Research Environment: International Comparison of Research Hours and the Number of Research Assistants

#### Chapter 2 Value That Basic Research Delivers to Society

- Realization of Blue LED that Opened the Era of LED
- Eradicating Parasitic Infections with a Substance Produced by Bacteria in Soil
- Development of the World’s Strongest Permanent Magnet Using Abundant Iron
- Rechargeable Lithium-Ion Battery That Contributed to the Spread of Portable Devices
- Possibility of Realizing New Regenerative Medicine by Somatic Cell Reprogramming (iPS cells)
- New Tool That Enables Precise Editing of Genome Information
- Discovery of Superconductivity and Its Application in Medical and Transportation Fields
- Particle Physics for Exploring the Origin of the Universe and Its Applications in Day-to-Day Settings

### Chapter 3 Technologies That Support and Drive Basic Research

- Detector That Opened a New Door to Physics (Photomultiplier Tube and Ultrapure Water)
- Essential Equipment for Optical Experiments (Diffraction Grating)
- Method to Make Proteins Glow While Keeping Subject Organisms Alive (GFP: Green Fluorescent Protein)
- Technique for Observing Intact Proteins (Cryogenic Electron Microscopy)
- Measurement Method That Dramatically Improved the Efficiency of X-Ray Crystallography (Crystalline Sponge Method)

### Chapter 4 Promoting Social Application of Research Results

- System-Related Efforts to Promote Social Application of Research Results
  - Law on the Revitalization of Science, Technology and Innovation Creation
  - Tax System
  - Strategic Use of International Intellectual Property and Standardization
  - Improvement of Research Capabilities and University Reform
- System-Related Initiatives to Promote Social Application of Research Results
  - Establishment of a System to Promote Open Innovation
  - Driving an Innovation System Tapping into Regional Strengths

### Chapter 5 Conclusion: Why the Accumulation and Application of Knowledge Gained Through Basic Research Are Important
## Part II Measures Implemented to Promote Science and Technology

### Chapter 1 Development of Science and Technology

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Science and Technology Basic Plan</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
<td>Council for Science, Technology and Innovation</td>
<td>50</td>
</tr>
<tr>
<td>2.1</td>
<td>Major Endeavors of CSTI in FY2018</td>
<td>52</td>
</tr>
<tr>
<td>2.2</td>
<td>Strategic Prioritization in the Science and Technology-related Budget</td>
<td>52</td>
</tr>
<tr>
<td>2.3</td>
<td>R&amp;D Evaluation of Projects of National Importance</td>
<td>56</td>
</tr>
<tr>
<td>2.4</td>
<td>Major Deliberations at Expert Panels</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>Integrated Innovation Strategy</td>
<td>57</td>
</tr>
<tr>
<td>4</td>
<td>Administrative Structure and Budget for Science, Technology and Innovation Policies</td>
<td>59</td>
</tr>
<tr>
<td>4.1</td>
<td>Administrative Structure for Science, Technology and Innovation Policies</td>
<td>59</td>
</tr>
<tr>
<td>4.2</td>
<td>Science and Technology Budgets</td>
<td>63</td>
</tr>
</tbody>
</table>

### Chapter 2 Acting to Create New Value for the Development of Future Industry and Social Transformation

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fostering R&amp;D and Human Resources that Boldly Challenge the Future</td>
<td>66</td>
</tr>
<tr>
<td>2</td>
<td>Realizing “Society 5.0”</td>
<td>66</td>
</tr>
<tr>
<td>2.1</td>
<td>Vision of Society 5.0</td>
<td>66</td>
</tr>
<tr>
<td>2.2</td>
<td>Undertakings necessary for the realization</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>Enhancing Competitiveness and Consolidating Fundamental Technologies in Society 5.0</td>
<td>67</td>
</tr>
<tr>
<td>3.1</td>
<td>Efforts necessary for enhancement of competitiveness</td>
<td>67</td>
</tr>
<tr>
<td>3.2</td>
<td>Strategic strengthening of infrastructure technology</td>
<td>68</td>
</tr>
</tbody>
</table>

### Chapter 3 Addressing Economic and Social Challenges

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sustainable Growth and Self-sustaining Regional Development</td>
<td>76</td>
</tr>
<tr>
<td>1.1</td>
<td>Ensuring stable energy, resources, and food</td>
<td>76</td>
</tr>
<tr>
<td>1.2</td>
<td>Achieving a sustainable society to handle hyper-aging, depopulation, etc.</td>
<td>91</td>
</tr>
<tr>
<td>1.3</td>
<td>Improving competitiveness in manufacturing and value creation</td>
<td>101</td>
</tr>
<tr>
<td>2</td>
<td>Ensure Safety and Security for Our Nation and its Citizens and a High-quality, Prosperous Way of Life</td>
<td>102</td>
</tr>
<tr>
<td>2.1</td>
<td>Addressing natural disaster</td>
<td>103</td>
</tr>
<tr>
<td>2.2</td>
<td>Ensuring food safety, living environments, and occupational health</td>
<td>111</td>
</tr>
<tr>
<td>2.3</td>
<td>Ensuring Cybersecurity</td>
<td>116</td>
</tr>
<tr>
<td>2.4</td>
<td>Addressing national security issues</td>
<td>117</td>
</tr>
<tr>
<td>3</td>
<td>Addressing Global Challenges and Contributing to Global Development</td>
<td>121</td>
</tr>
<tr>
<td>3.1</td>
<td>Addressing global climate change</td>
<td>121</td>
</tr>
<tr>
<td>3.2</td>
<td>Responding to biodiversity loss</td>
<td>126</td>
</tr>
<tr>
<td>4</td>
<td>Pioneering Strategically Important Frontiers</td>
<td>128</td>
</tr>
<tr>
<td>4.1</td>
<td>The promotion of oceanographic R&amp;D</td>
<td>128</td>
</tr>
<tr>
<td>4.2</td>
<td>Promotion of R&amp;D in space science</td>
<td>131</td>
</tr>
</tbody>
</table>
Chapter 4 Reinforcing the Fundamental Capability for STI ......................................................... 141

Section 1 Developing High-quality Human Resources ............................................................... 141
  1 Developing, securing and improving career prospects of human resources as intellectual professionals 141
  2 Promoting diversity and career mobility .............................................................................. 149

Section 2 Promoting Excellence in Knowledge Creation ......................................................... 155
  1 Promoting academic and basic research as a source of innovation ...................................... 155
  2 Strategic enhancement of common-platform technology, facilities, equipment, and information infrastructure supporting research and development activity .................................. 159
  3 Promotion of open science .................................................................................................. 171

Section 3 Strengthening Funding Reform .............................................................................. 173
  1 Fundamental funds reform ................................................................................................ 173
  2 Reform of public funds ..................................................................................................... 174
  3 Integrated promotion of the national university reform and the research funds reform ...... 177

Chapter 5 Establishing a Systemic Virtuous Cycle of Human Resources, Knowledge and Capital for Innovation ................................................................. 179

Section 1 Enhancing Mechanisms for Promoting Open-innovation ....................................... 179
  1 Enhancing systems of promotion in companies, universities, and public research institutes .... 179
  2 Inducing a virtuous cycle of human resources for innovation creation ................................ 186
  3 Creating “spaces for co-creation” to concentrate human resources, knowledge, and capital .. 186

Section 2 Enhancing the Creation of SMEs and Startup Companies to Tackle New Business Opportunities .................................................................................. 190
  1 Cultivating an entrepreneurial mentality ............................................................................ 191
  2 Promoting the creation of startup companies at universities ............................................. 191
  3 Creating environments conducive to new business ............................................................ 191
  4 Helping initial demand and endorsing the trustworthiness of new products and services .... 192

Section 3 Strategic Use of International Intellectual Property and Standardization ................ 192
  1 Promoting use of IP assets in innovation creation ............................................................ 192
  2 Accelerating strategic international standardization and enhancing related support systems .. 195

Section 4 Reviewing and Improving the Regulatory Environment for Innovation ................ 197
  1 Reviewing systems in accordance to new products, services, and business models ........ 197
  2 Improving IP systems in response to the tremendous development in ICT ................. 198

Section 5 Developing Innovation Systems that Contribute to “Regional Revitalization” ........ 198
  1 Revitalizing regional companies .................................................................................... 199
  2 Driving innovation systems that make use of local characteristics .................................. 200
  3 Promoting policies that encourage local initiative .......................................................... 202

Section 6 Cultivating Opportunities for Generating Innovation in Anticipation of Global Needs 203
  1 Promoting R&D that anticipates global needs ................................................................. 203
  2 Developing systems to promote inclusive innovation ..................................................... 204

Chapter 6 Deepening the Relationship between STI and Society ........................................... 205

Section 1 Promoting Co-creative STI ......................................................................................... 205
  1 Dialogue and collaboration with stakeholders ................................................................. 205
## Contents

2 Stakeholder initiatives for co-creation ......................................................... 205  
3 Scientific advice for policymaking .............................................................. 207  
4 Ethical, legal, and social initiatives ............................................................... 208  

### Section 2 Ensuring Research Integrity ......................................................... 209

### Chapter 7 Enhancing the Capacity to Promote Science, Technology and Innovation ................................................................. 211

#### Section 1 Reforming Universities and Enhancing their Function ................................................................. 211

1 University Reform .................................................................................. 211

#### Section 2 Reforming National R&D Agencies and Enhancing their Function ................................................................. 212

1 R&D Agency Reforms .............................................................................. 212

#### Section 3 Strategic International Implementation of STI Policies ......................................................................................... 213

1 Utilization of international frameworks .................................................. 213  
2 Utilization of international organizations ................................................ 216  
3 Utilization of research institutions .......................................................... 218  
4 Promotion of Strategic International Activities Related to Science Technology Innovation ........................................... 218  
5 Cooperation with Other Countries ............................................................ 219

#### Section 4 Pursuing Effective STI Policies and Enhancing the Chief Controller Function ......................................................... 222

1 Following up the Basic Plan .................................................................... 222  
2 National Guideline on the Method of Evaluation for Government R&D ........................................................................ 222  
3 Promoting Policies Supported by Objective Evidence ................................ 223  
4 Strengthening the Leadership Functions of the CSTI .................................. 224

#### Section 5 Ensuring R&D Investment for the Future ......................................... 224

**Scientific and Technological Achievements Which Contribute to Daily Life** ................................................................. 227
Figures & Tables

Part I

Table 1-1-1 Number of papers and number of adjusted top 10% papers by country/region: top 10 countries/regions ................................................................. 7
Figure 1-1-2 Major countries’ number of areas of participation and share of the number in the global total number of research areas ......................................................... 8
Figure 1-1-3 Changes in operating expense grants for national university corporations ........ 9
Figure 1-1-4 Changes in current expenditure grants for private universities, etc. ............ 9
Figure 1-1-5 Changes in operating expense grants for national R&D agencies .................. 9
Figure 1-1-6 Share of the higher education and government sectors in basic research funds .... 10
Figure 1-1-7 Changes in the departmental number of newly enrolled doctoral students .......... 11
Figure 1-1-8 Changes in the share of research hours spent by university and college faculty members .......................................................................................................................... 12
Figure 1-1-9 Changes in the share of hours spent on work activities by university and college faculty members by academic field .................................................................................... 13
Figure 1-1-10 Changes in the number of research assistants at universities, etc. in Japan .... 14
Figure 1-2-1 Mechanism of a lithium-ion battery ........................................................................ 20
Figure 1-2-2 Preparation of transplant retinal pigment epithelial cells using iPS cells ......... 21
Figure 1-2-3 Structure of CRISPR/Cas9 .................................................................................... 22
Figure 1-2-4 Internal imaging of a volcano on Satsuma Iōjima .................................................. 24
Figure 1-2-5 Image of the observed internal structure of King Khufu’s pyramid ............... 25
Figure 1-2-6 Comparison of X-ray, CT, and PET screenings ..................................................... 25
Figure 1-3-1 History of improvement of microscope resolution .................................................. 27
Figure 1-3-2 Overview of Super-Kamiokande ........................................................................... 28
Figure 1-3-3 Overview of IceCube ................................................................................................. 28
Figure 1-3-4 Scheme of chirp pulse amplification ..................................................................... 29
Figure 1-3-5 Sample cooling method .............................................................................................. 32
Figure 1-3-6 Method to obtain the 3D structure of a sample ....................................................... 32
Figure 1-3-7 Overview of the crystalline sponge method ............................................................... 34
Figure 1-4-1 Virtuous cycle of revitalization of science, technology and innovation ............. 35
Figure 1-4-2 Amount of R&D tax credits granted ................................................................. 38
Figure 1-4-3 Main venture businesses originated from universities, etc. ............................. 38
Figure 1-4-4 Overview of the FY2019 reform of the R&D tax credit system ......................... 39
Figure 1-4-5 Relaxation of the Requirements for the Approval of Exemption from Tax on Deemed Capital Gains Regarding Donations of Evaluated Assets to National University Agencies, Etc. . . . . . . ................................................................. 40

Part II

Table 2-1-1 List of CSTI members ............................................................................................ 51
Figure 2-1-2 Organizational chart of CSTI ............................................................................... 52
Table 2-1-3 Strategic Innovation Promotion Program (SIP) ...................................................... 54
Table 2-1-4 Second period of Strategic Innovation Promotion Program (SIP) ....................... 55
Table 2-1-5 Key projects for promotion of science and technology policies (FY2018) .......... 56
Contents

Figure 2-1-6 Integrated Innovation Strategy 2018 (Summary) ............................................................. 58
Table 2-1-7 Major decisions and reports from Council for Science and Technology (FY2018) .......................................................... 61
Figure 2-1-8 Organizational structure of the Science Council of Japan (SCJ) ...................................... 62
Table 2-1-9 Major proposals by the Science Council of Japan (SCJ) (FY2018) .................................... 63
Table 2-1-10 Changes in science and technology budgets .............................................................. 64
Table2-1-11 Science and technology budgets of each ministry/office/agency ............................. 65
Figure 2-2-1 Outline of service platform .......................................................................................... 67
Table 2-2-2 Major projects for realization of Society 5.0 (FY2018) ............................................... 75
Table 2-3-1 Major projects for stable supply of energy, resources and food (FY2018) ................ 90
Table 2-3-2 Major policies for the realization of sustainable society in response to super aging and population decline (FY2018) ................................................................. 101
Figure 2-3-3 Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) .... 104
Figure 2-3-4 Seafloor observation network for earthquakes and tsunamis along the Japan Trench (S-net) ........................................................................................................................... 104
Figure 2-3-5 Monitoring of Waves on Land and Seafloor (MOWLAS) ........................................ 105
Table 2-3-6 Major projects for recovery and reconstruction from the earthquake disaster (FY2018) .......................................................................................................................... 111
Figure 2-3-7 Monitoring system implementation by ministries in accordance with the Comprehensive Monitoring Strategy ................................................................. 112
Figure 2-3-8 Radioactive substances distribution map ................................................................. 113
Figure 2-3-9 Sample of Radiation measurement map ..................................................................... 114
Figure 2-3-10 Japan Environment and Children’s Study (JECS) ...................................................... 115
Table 2-3-11 Major policies to ensure food safety, living environment, occupational health, etc. (FY2018) .................................................................................................................. 116
Table 2-3-12 Major policies for cyber security (FY2018) ............................................................. 117
Figure 2-3-13 Outline of Innovative Science & Technology Initiative for Security .................... 118
Figure 2-3-14 Outline of the initiative for early practical use of rapidly progressing cutting-edge civil technologies ................................................................. 118
Figure 2-3-15 Outline of research for advancement of image analysis technology to address terrorism ................................................................. 119
Table 2-3-16 Major policies to address national security issues (FY2018) .................................. 119
Table 2-3-17 Major policies to address global climate change (FY2018) .................................... 126
Table 2-3-18 Points of the Implementation Plan of the Basic Plan on Space Policy (Revised in FY2018) .................................................................................................................. 132
Table 2-3-19 Major policies to open up frontiers important for national strategies (FY2018) .... 132
Figure 2-4-1 Ratio of full-time teachers aged 40 or younger in universities ................................ 140
Table 2-4-2 Breakdown of successful candidates of the Second-Step Professional Engineer Examination by Technical Discipline (FY2018) ............................................................. 144
Figure 2-4-3 The 8th Science Intercollegiate opening ceremony .............................................. 147
Figure 2-4-4 Participants in the International Student Contests in Science and Technology (FY 2018) .......................................................................................................................... 147
Figure 2-4-5 The 8th Japan High School Science Championship ............................................. 149
Figure 2-4-6 The 6th Japan Junior High School Science Championship ................................. 149
Figure 2-4-7 Percentage of female researchers by country .......................................................... 150
Columns

2-1 The first Science 20 in Japan ........................................... 59
2-2 Improvement of crop varieties using genome editing .......... 89
2-3 Safety technology to reduce aircraft accidents by “visualizing turbulence” .................................................. 99
2-4 Initiative for early practical application of rapidly progressing advanced civil
technologies ........................................................................................................ 120
2-5 Chikyu making an attempt at drilling of the source region of Nankai
megathrust earthquakes .................................................................................... 129
2-6 Team KUROSHIO’s attempt to win XPRIZE .................................. 130
2-7 HAYABUSA2 demonstrated Japan’s space science and exploration technologies 136
2-8 Successful return of a small recovery capsule from the International Space
Station ................................................................................................................... 138
2-9 From Space to Earth
Beyond quasi-zenith satellites and agriculture - Space technology used on the
ground ..................................................................................................................... 139
2-10 Successful photographing of black hole ......................................... 140
2-11 Establishment of Japan Open Innovation Prize .......................... 185

Scientific and Technological Achievements Which Contribute to Daily Life

① Haiku Composition by AIs: Can Machines Enjoy Poetry? ....................................................................................... 228
② AI Increases Office Work Efficiency: Document Summarization ................................................................. 229
③ Can AI Help People Become Music Composers?: Melody Composition Experience ......................................... 230
④ How Will We Treat AI/Robots that Appear to Possess Consciousness? ...................................................... 231
⑤ Robotic Alter Ego Enables Bedridden Patients to Participate in Society Virtually ............................................. 232
⑥ Electric Wheelchair that Makes Outings a Pleasure .............................................................................................. 233
⑦ Correcting Near- and Far-Sightedness with Retinal Projection Technology ......................................................... 234
⑧ Converting Unpleasant Memories into Pleasant Ones: Rewriting Memory-storing Cells through Neuronal Manipulation ........................................................................................................ 235
⑨ New “Benchmarks” for Doping Tests to Ensure Good Sportsmanship ............................................................. 236
⑩ Automated Safety Inspection of Concrete Infrastructure Using a High-powered Laser ........................................ 237
⑪ Processing Record-breaking Bagworm Silk into Industrial Fiber Materials ...................................................... 238
⑫ Tree Rings Unveil the Past and the Future: Integration of Paleoclimatology, History and Archaeology 239

Maps used in this white paper may not necessarily indicate Japanese territory comprehensively