The following information is a compilation of science objectives intended to form a basis for the development of a family of Design Reference Architectures applicable to Earth's Neighborhood. These objectives are arranged in logical groups but there is no intentional implication of relative importance or priorities. Reference sources are listed at the document end.

SCIENCE OBJECTIVES FOR SPACE SCIENCE RESEARCH

UNDERSTAND THE STRUCTURE OF THE UNIVERSE; FROM ITS EARLIEST BEGINNINGS TO ITS ULTIMATE FATE

- Identify dark matter and learn how it shapes galaxies and systems of galaxies
- Determine the size, shape, age, and energy content of the Universe

EXPLORE THE ULTIMATE LIMITS OF GRAVITY AND ENERGY IN THE UNIVERSE

- Discover the sources of gamma ray bursts and high-energy cosmic rays
- Test the general theory of relativity near black holes and in the early universe, and search for new physical laws using the universe as a laboratory
- Reveal the nature of cosmic jets and relativistic flows

LEARN HOW GALAXIES, STARS, AND PLANETS FORM, INTERACT, AND EVOLVE

- Observe the formation of galaxies and determine the role of gravity in this process
- Establish how the evolution of a galaxy and the life cycle of stars influence the chemical composition of material available for making stars, planets, and living organisms
- Observe the formation of planetary systems and characterize their properties
- Use the exotic space environments within our Solar System as natural science laboratories and cross the outer boundaries of the Solar System to explore the nearby environment of our galaxy

UNDERSTAND THE FORMATION AND EVOLUTION OF THE SOLAR SYSTEM AND THE EARTH WITHIN IT

- Inventory and characterize the remnants of the original material from which the Solar System formed
- Learn why the planets in our Solar System are so different from each other
- Learn how the Solar System evolves
- Investigate the composition, evolution, and resources of planets, the Earth's moon, and small bodies
- The geologic context of the lunar samples is only locally known, and it is clear from incomplete remote-sensing data that the samples do not represent the variety of lithologies constituting the lunar crust. Without a more thorough investigation, theories of the origin and early evolution of the Earth-Moon system remain poorly constrained.
- The Moon provides a unique and relatively accessible window into the solar system at 1 AU. Much can be learned about impact processes from the synoptic view afforded by analyses from lunar orbit. Because the lunar surface remains largely unaltered by weathering, the moon is a natural laboratory for studies of impact basins and craters and for investigations of the character and scale of materials shocked, melted, and mixed with surrounding lithologies.
- Establishing the ages of particular craters in the last few billion years to calibrate the record of relative crater density is necessary to properly understand the influencing of cratering in Earth's history. If this lunar record is established in sufficient detail, then possible periodicities of inner solar system cratering could be detected.

- Analysis of evidence of the flux and composition of solar wind and solar flares—present and past—preserved in lunar regolith has yielded novel insights into the long term evolution of the Sun. Future studies could make useful progress in this area by utilizing specific lunar surface samples carefully selected on the basis of well-defined exposure ages.
- The Moon's Aitken Basin, which is located in the South Pole, is the largest impact on the Moon. Samples from this region can provide data on Earth-Moon cataclysms and, since the lower crust and upper mantle is exposed, provide samples that date to the formation of the Moon itself.

UNDERSTAND OUR CHANGING SUN AND ITS EFFECTS THROUGHOUT THE SOLAR SYSTEM

- Understand the origins of long- and short-term solar variability
- Understand the effects of solar variability on the solar atmosphere and heliosphere
- Understand the space environment of Earth and other planets
- Develop the knowledge to improve space weather forecasting

LOOK FOR SIGNS OF LIFE IN OTHER PLANETARY SYSTEMS

- Discover planetary systems of other stars and their physical characteristics
- Search for worlds that could or do harbor life

PROBE THE ORIGIN AND EVOLUTION OF LIFE ON EARTH AND DETERMINE IF LIFE EXISTS ELSEWHERE IN OUR SOLAR SYSTEM

- Investigate the early origin and evolution of life on Earth, and explore the limits of life in terrestrial environments that might provide analogues for conditions on other worlds
- Determine the general principles governing the organization of matter into living systems and the conditions required for the emergence and maintenance of life
- Chart the distribution of life-sustaining environments within our Solar System, and search for evidence of past and present life
- Identify plausible signatures of life on other worlds

CHART OUR DESTINY IN THE SOLAR SYSTEM

- Understand forces and processes, such as impacts, that affect habitability of Earth
- Develop the capability to predict space weather
- Find extraterrestrial resources and assess the sustainability of Solar System locales for future human exploration
- Astronomy for determining trajectories of near-earth asteroids and long period comets.

VALIDATE NEW TECHNOLOGIES IN SPACE

SCIENCE OBJECTIVES FOR EARTH SCIENCE RESEARCH

HOW IS THE GLOBAL EARTH SYSTEM CHANGING?

- How are global precipitation, evaporation, and the cycling of water changing?
- How is the global ocean circulation varying on interannual, decadal, and longer time scales?
- How are global ecosystems changing?
- How is stratospheric ozone changing, as the abundance of ozone-destroying chemicals decrease and new substitutes increase?
- What changes are occurring in the mass of the Earth's ice cover?
- What are the motions of the Earth and the Earth's interior, and what information can be inferred about Earth's internal processes?

WHAT ARE THE PRIMARY FORCINGS OF THE EARTH SYSTEM?

- What trends in atmospheric constituents and solar radiation are driving global climate?
- What changes are occurring in global land cover and land use, and what are their causes?
- How is the Earth's surface being transformed and how can such information be used to predict future changes?

HOW DOES THE EARTH SYSTEM RESPOND TO NATURAL AND HUMAN-INDUCED CHANGES?

- What are the effects of clouds and surface hydrologic processes on Earth's climate?
- How do ecosystems respond to and affect global environmental change and the carbon cycle?
- How can climate variations induce change in the global ocean circulation?
- How do stratospheric trace constituents respond to change in climate and atmospheric composition?
- How is global sea level affected by climate change?
- What are the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality?

WHAT ARE THE CONSEQUENCES OF CHANGE IN THE EARTH SYSTEM FOR HUMAN CIVILIZATION?

- How are variations in local weather, precipitation, and water resources related to global climate variation?
- What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity?
- What are the consequences of climate and sea level changes and increased human activities on coastal regions?

HOW WELL CAN WE PREDICT FUTURE CHANGES TO THE EARTH SYSTEM?

- How can weather forecast duration and reliability be improved by new space-based observations, data assimilation, and modeling?
- How well can transient climate variations be understood and predicted?
- How well can long-term climatic trends be assessed or predicted?
- How well can future atmospheric chemical impacts on ozone and climate be predicted?
- How well can cycling of carbon through the Earth system be modeled, and how reliable are predictions of future atmospheric concentrations of carbon dioxide and methane?

SCIENCE OBJECTIVES FOR BIOLOGICAL & PHYSICAL RESEARCH

GRAVITATIONAL IMPACT ON BIOLOGICAL SYSTEMS

- Achieve an understanding of the role of gravity in chemical, biological, and physical processes
- Detrimental effects of reduced gravity and transitions in gravitational force on all body systems (especially the cardiovascular and pulmonary systems) and on bones, muscles, and mineral metabolism, together with possible countermeasures;
- Vestibular function and human sensor/motor performance;
- Effects of the microgravity, and fractional gravity environment on human immunological functions;
- Long-term effects of microgravity and fractional gravity on plant growth;
- The fractional gravity environment of the Moon and of space vehicles in transit offers a unique opportunity to study the effects of prolonged exposure to fractional gravity levels on

living systems. Similarly, space missions lasting as long as 2 to 3 years will provide an unusual opportunity to study human behavior under uniquely stressful conditions (confinement with no immediate possibility of escape).
- Gravity effects on cellular genomics and mechanisms

RADIATION EFFECTS

- Flux of cosmic-ray particles, their energy spectra, and the extent to which their flux is modulated by the solar cycle;
- Frequency and severity of solar flares;
- Long- and short-term effects of ionizing radiation on human tissue;
- Radiation environment inside proposed space vehicles;
- Effectiveness of different types of radiation shielding and their associated penalties (e.g., spacecraft mass);

PSYCHO-SOCIAL ASPECTS

- Psychosocial aspects of long-duration confinement with no escape possible and their effects on crew function; and
- Microgravity science and technology relating to long-duration space flight.
- Identify mechanisms of health risk and potential physiological and psychological problems to humans living and working in space.

LIFE SUPPORT

- Conduct research in analog test beds and on orbit to enhance medical care for human space flight
- Understand the effects of long-duration space flight (e.g., radiation).

OTHER BIOLOGICAL AND PHYSICAL SCIENCE ISSUES

- Biological aspects of the possible existence of extra-terrestrial organisms and means to prevent the back contamination of Earth.
- Feasibility of closed-loop life support systems;
- Interplanetary micrometeoroid flux and its time dependence;
- Investigate chemical, biological, and physical processes in the space environment.
- Atomic physics investigations probing relativity and new forms of matter
- Multigenerational studies of organisms
- Expand our understanding of molecular structures, cells, biological processes, etc.

References:

"Scientific Prerequisites for the Human Exploration of Space," Committee on Human Exploration Space Studies Board, National Research Council, National Academy Press, 1993.

"Scientific Opportunities in the Human Exploration of Space," Committee on Human Exploration Space Studies Board, National Research Council, National Academy Press, 1994.

"Setting a Course for Space Exploration in the 21st Century" Report of the NASA Exploration Team June 1999 through December 2000

Biological & Physical Research Enterprise Strategic Plan

Space Science Enterprise Strategic Plan

Space exploration, human space exploration in particular, has often been strongly shaped by U.S. geopolitical interests. In turn, space cooperation has reflected and followed those interests.Â Those interests include security, commerce, science, and international leadership, or any combination thereof. The next steps beyond low-Earth orbit will require cooperation among international partners for both practical and political reasons.Â The United States Government should encourage and support research and development for new technologies to enable lower cost commercial activities in space. 1. Space Science Enterprise 2. Earth Science Enterprise (ESE) 3. Biological and Physical Research Enterprise (BPR) 4. Human Exploration and Development of Space Enterprise (HEDS) 5. Aerospace Technology Enterprise (AST). IV. Future Opportunities for Collaboration.Â The National Aeronautics and Space Administration (NASA) is a Federal research and engineering agency that accomplishes most of its space, aeronautics, science, and technology programs through nine Field Centers and the Jet Propulsion Laboratory, which is a Federally Funded Research and Development Center.