Space Exploration Vision for the 21st century

Presentation to:
Great Midwestern Space Grant Region Biennial Meeting

Ronald J. Birk
Applied Sciences Program
NASA Science Mission Directorate
The NASA Vision
To improve life here,
To extend life to there,
To find life beyond.

The NASA Mission
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.
First Wave of Great Observatories and the next wave of Planetary Explorers are in Space

Cassini

Chandra

Hubble

Gravity Probe-B

Mars Rovers
Of the total forcing of the climate system, 40% is due to the direct effect of greenhouse gases and aerosols, and 60% is from feedback effects, such as increasing concentrations of water vapor as temperature rises.
How is the Earth changing and what are the consequences of life on Earth?

- How is the global Earth system changing?
- What are the primary forcings of the Earth system?
- How does the Earth system respond to natural and human-induced changes?
- What are the consequences of changes in the Earth system for human civilization?
- How well can we predict future changes in the Earth system?
Earth-Sun System Science

Sun-Earth Connection

Climate Variability and Change

Carbon Cycle and Ecosystems

Earth Surface and Interior

Atmospheric Composition

Weather

Water & Energy Cycle
Earth System Models
Integrating Knowledge, Capacity and Systems into Solutions

**Inputs**
- NASA and Research Partners

**Outputs**
- Planetary Models
  - Land
  - Oceans
  - Atmosphere
  - Solar

- Sun-Earth Observatories
  - Satellite
  - Airborne
  - In Situ

- Predictions/Forecasts
  - High-Performance Computing, Communication, and Visualization

- Standards and Interoperability

**Partnership Area**

**Decision-Support Tools**
- Assessments
- Decision-Support Systems
- Scenario Tools

**Outcomes**
- Partners with Decision-Support Tools

**Impacts**
- Value and benefits to citizens and society
  - Policy Decisions
  - Management Decisions
  - Exploration Decisions
Applications of National Priority

- Agricultural Efficiency
- Air Quality
- Aviation
- Carbon Management
- Coastal Management
- Disaster Management
- Ecological Forecasting
- Energy Management
- Homeland Security
- Invasive Species
- Public Health
- Water Management
Agriculture Efficiency

EOSDIS & DAACs

Tasking

EDOS: Mission Control

Societal Benefits

Downlink

Exploitation

Terra

CADRE: USDA Decision Support System for Global Crop Production Assessments

Jason

October 21-23, 2004
MODIS Rapid Response products provide timely looks at crop condition.

TOPEX and JASON-1 products provide lake level data in critical irrigated areas.

TRMM products provide better data on available water.

EOS products
- Productivity modeling (FAS)
- WAOB Estimates
- Policy/Resource Decisions
Change Detection: Landsat and MODIS

Landsat 7

August, 1993  August, 2002

Landsat

August, 2002

MODIS

April, 2003  August, 2003

Terra

Aqua

Landsat 7

MODIS

Turkey

Euphrates River

Tigris River

Araruk Reservoir

Harran Plains

Syria
2002 Yield Study in Central Iowa
Classification of Landsat Imagery for SMEX02 Study Site

Legends
Class Names
Alfalfa
Corn
Grass
Soybean
Tree
Urban
Water
Roads

Scale
Kilometers

Landsat 7
LAI simulation (250m) for Corn & Soybean

July 4

July 28

August 29

Legend:
- 0-2
- 2-3
- 3-4
- >4
- Non-Ag
Corn and Soybean Crop Yields, 2002

Corn (T/ha)
- Red: 8.65 - 11.45
- Yellow: 11.45 - 11.86
- Green: 11.86 - 12.39

Soybean (T/ha)
- Purple: 2.85 - 3.43
- Cyan: 3.43 - 3.56
- Blue: 3.56 - 3.76
Assimilation of TRMM rainfall location, intensity and vertical structure into hurricane forecast models leads to improvements in forecasts of future position.

**Hurricane Ivan Forecast, September 2005**

Reduced track errors can save money ($600K - $1M per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall.
Plume Dispersion Modeling with the NASA fvGCM
2002 Sep 21  01Z
Global Earth Observations for Society

Global Earth Observing System of Systems

From Observations to Users to Benefits
Global System for Earth Observation Integrating Orbital, Suborbital and In Situ Components

Vantage Points

Far-Space
- U/L2/HEO/GEO
- Sentinel satellites for continuous monitoring

Near-Space
- LEO/MEO
- Active & passive sensors for trends & process studies

Airborne
- Suborbital
- In situ measurement in research campaigns & validation of new remote sensors

Terrestrial
- Surface-Based Networks
- Ocean buoys, air samplers, strain detectors, ground validation sites

Capabilities

Deployable
- Information Systems
- Data management, data assimilation, modeling & synthesis

Permanent
- Permanent system
### Next Generation Missions

<table>
<thead>
<tr>
<th>Mission</th>
<th>Description</th>
<th>Candidate Future Missions</th>
<th>Candidate Future Missions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPOESS Preparatory Project</td>
<td>Global Precipitation Measurement</td>
<td>Orbiting Carbon Observatory</td>
<td>Blue Horizons</td>
</tr>
<tr>
<td>Landsat Data Continuity Mission</td>
<td>Aerosol Polarimeter Sensor</td>
<td>Aquarius</td>
<td>Restless Planet</td>
</tr>
<tr>
<td>Ocean Surface Topography Mission</td>
<td>Chemistry/Climate Mission</td>
<td>Hydros</td>
<td>Aiolos</td>
</tr>
</tbody>
</table>

**Next generation systematic measurement missions to extend/enhance the record of science-quality global change data**

**Exploratory**

Expeditionary research missions for new vantage points & sensor types
Turning Observations into Knowledge Products

**Downlink Speed**

- **Petabytes $10^{15}$**
  - Multi-platform, multiparameter, high spatial and temporal resolution, remote & in-situ sensing

- **Terabytes $10^{12}$**
  - Calibration, Transformation To Characterized Geophysical Parameters

- **Gigabytes $10^9$**
  - Interaction Between Modeling/Forecasting and Observation Systems

- **Megabytes $10^6$**
  - Interactive Dissemination and Predictions

**Advanced Sensors**

**Data Processing & Analysis**

**Information Synthesis**

**Access to Knowledge**
Connecting Geospatial, Communications and Computing Infrastructure

...to enable timely and affordable delivery of Earth Science data and information
Remote Sensing Technologies

- Multispectral
- Hyperspectral
- RADAR / SAR
- Thermal
- Atmospheric LIDAR
- Surface LIDAR
- Passive Microwave
- RADAR Altimetry
- Limb Sounding
- Microwave Ranging
- Irradiance/Photometry
- Scatterometry
Future Enabling Technologies

- Information Synthesis: Distributed, Reconfigurable, Autonomous
- Access to Knowledge: On-orbit Processing, Immersive Environments
  - Laser/Lidar technology to enable Earth system science measurements
  - Large Deployables to enable future weather/climate/natural hazards measurements
  - Intelligent Distributed Systems using optical communication, on-board reprogrammable processors, autonomous network control, data compression, high density storage
    - Information Knowledge Capture through 3-D Visualization, holographic memory and seamlessly linked models.
Inspiring the Next Generation of Earth Explorers
Characterizing, understanding & predicting the interactions among Earth’s continents, oceans, atmosphere, ice, and life

Evolution of a comprehensive, coordinated and sustained Earth observation system

Forging the partnerships required to sustain the system and its uses for scientific exploration and practical applications

Applying the knowledge, capacity and systems from Earth System Science to Exploration

Training the next generation of scientists, engineers, and decision-makers
## Space-based System of Systems

### MARS

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planet</td>
<td>Mars</td>
</tr>
<tr>
<td>AU</td>
<td>1.5</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>-87/-5</td>
</tr>
<tr>
<td>Equatorial Diameter (km)</td>
<td>6,794</td>
</tr>
<tr>
<td>Volume (Earth=1)</td>
<td>0.149</td>
</tr>
<tr>
<td>Mass (Earth=1)</td>
<td>0.107</td>
</tr>
<tr>
<td>Density (gm/cm³)</td>
<td>3.933</td>
</tr>
<tr>
<td>Orbit Velocity (in km/s)</td>
<td>24</td>
</tr>
<tr>
<td>Orbit Time (Earth Days)</td>
<td>686</td>
</tr>
<tr>
<td>Orbit Time (Earth Years)</td>
<td>1.88</td>
</tr>
<tr>
<td>Rotation Time (Earth Hours)</td>
<td>24.6</td>
</tr>
</tbody>
</table>

### MOONS

- Deimos
- Phobos

### SATELLITES

- Mars Express
- Opportunity/Spirit
- Mars Global Surveyor
- Mars 2001 Odyssey
- Satellites: 5
Astronomical Biosignatures are detected by photometric, spectral and temporal features that indicate life

The Mid-IR
- $O_3$ (sensitive indicator of $O_2$), $CH_4$ and $N_2O$ ($H_2O$ - habitability)

The visible (and NIR)
- $O_2$ (direct detection), $O_3$(UV), $CH_4$, chlorophyll and red-edge, $H_2O$