



**Science Mission
Directorate**

Sun-Solar System Connection Roadmap

**Barbara Giles
APIO Directorate Lead for Roadmap #10**



NASA Strategic Goals

Goal 1 Implement a sustained and affordable human and robotic program to explore the solar system and beyond

Goal 2 Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations

Goal 3 Develop innovative technologies, knowledge, and infrastructure both to explore and to support decisions about the destinations for human exploration

Goal 4 Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests

Goal 5 Study the Earth system from space and develop new space-based and related capabilities for this purpose



Roadmap Objective

National Goal #5: Study the Earth system from space and develop new space-based and related capabilities for this purpose.

Roadmap Objective: Explore the Sun-Earth system to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that will be experienced by human explorers, and demonstrate technologies that can improve future operational Earth observation systems.



Essential Roadmap Elements

- Broad science and exploration goals, priorities, recommended activities or investigations, and a summary of anticipated discoveries and achievements
- Suggested implementation approach and mission sets
- High-level milestones, options, and decision points
- Key dependencies on and relationships to other Strategic Roadmaps
- Identification of required capabilities, facilities, human capital, and infrastructure

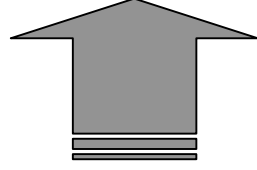


NRC Review

NRC will review the individual roadmaps as they near completion

- Clear and comprehensive support to the 2005 Agency Objectives, including the objectives of the Vision for Space Exploration and the 2003 NASA Vision and Mission statements? Significant gaps?
- Intrinsic merit of the derived objectives and merit of proposed implementing programs in the context of relevant NRC or other external advisory reports?
- Resilience with respect to changing technological capabilities and budgets and agility to take advantage of unforeseen opportunities?
- Important crosscutting opportunities not identified or adequately developed?
- Clear initial priorities and decision rules for making prioritization decisions as implementation proceeds?
- Realism with respect to necessary resources, technologies, and facilities? Presentation of roles and relationships of NASA centers, other federal partners, academia, industry, and international participants?
- Treatment of timelines, relationships between program elements, and schedule realism?

Current plan: The NRC and/or the NASA Advisory Council will review the Integrated Space Architecture when completed



Sun-Solar System Foundation Team Process:

- Subcommittee of Earth-Sun System Subcommittee
- Four meetings over ~9-months
- Community workshop
- External Chair assisted by Center co-chair
- 20 team members, community call for nominations
- GSFC/JPL engineering team for ~12 mission studies
- GSFC support team for logistics, production, graphics
- Product is Comprehensive Roadmap, to be reviewed by Earth-Sun System Subcommittee, ~100pp.
- Roadmap includes science, mission pathways, technology, applications, and EPO

Sun-Solar System APIO Committee Process:

- FACA committee appointed by APIO
- Three meetings over 4-5-months
- Three co-chairs, 14 team members
- Will review foundation team work, provide course corrections via "findings"
- Product is Strategic Roadmap, reviewed by Science Advisory Committee & National Academy, ~20 pp.
- Roadmap includes science, mission pathways, technology, applications, and EPO



SSSC APIO Committee Membership

NASA HQ Co-Chair: Al Diaz (Science Mission Directorate)

Center Co-chair: Franco Einaudi (GSFC)

External Co-chair: Timothy Killeen (National Center for Atmospheric Research)

Committee Members:

✓ A. Scott Denning (Colorado State University)

✓ Jeffrey Forbes (Univ of Colorado)

✓ Stephen Fuselier (Lockheed Martin)

✓ Don Hassler (Southwest Research Institute)

✓ Todd Hoeksema (Stanford Univ.)

✓ Craig Kletzing (Univ. Of Iowa)

Edward Lu (NASA/JSC)

✓ Vic Pizzo (NOAA)

✓ James Russell (Hampton University)

✓ James Slavin (GSFC)

✓ Michelle Thomsen (LANL)

Beth Wahl (SAIC)

Atmospheric Science Representative

Sun-Climate Representative

Ex Officio members:

✓ Donald Anderson (Science Mission Directorate)

✓ Dick Fisher (Science Mission Directorate)

✓ Rosamond Kinzler (American Museum of Natural History)

~~—Jennifer Trosper (Exploration Systems Mission Directorate)—~~

Mark Weyland (Space Radiation Analysis Group, JSC)

Michael Wargo (Exploration Systems Mission Directorate)

DOD Senior Representative

Systems Engineers:

John Azzolini (GSFC)

Tim Van Sant (GSFC)



Near-term Priorities

- Draft #1 of Comprehensive Roadmap by end of January
- Draft #2 of Comprehensive Roadmap by end of February
- Detailed planning for APIO committee meetings
- Draft #1 of Strategic Roadmap by end of February
- Detailed implementation of integration function
- Completion of mission studies



Challenges

- **Roadmap content**
 - Settle contents, style, and format
- **Flow of Comprehensive Roadmap into the Strategic Roadmap**
 - Implementation of programmatic and budgetary realities
- **Integration**
 - Detailed planning, promulgation, and implementation
- **NRC review**
 - Phasing of delivery and review schedules, implementation of suggestions



Remaining Schedule

February 10-11: SSSC APIO Committee, Washington DC

Late Feb/Early March: HQ will hold a series of half-day bilateral meetings with other US Government agencies to introduce roadmap concepts

February 28-March 2: Most likely date for first meeting of the new Earth-Sun Systems Subcommittee

March 8-10: SMD International Conference to introduce roadmaps to prospective foreign partners

March 15-16: SSSC APIO Committee, Washington DC

March 16: Joint sessions of SSSC APIO Committee with the APIO Committee for Roadmap #9
March 16-18: SSSC Foundation Team, Washington, DC --> dates TBD

March 30-April 1: first meeting of the new NASA Science Advisory Committee

April - May: Roadmap review by the National Academy

June/July: SSSC Foundation Team, TBD location --> Necessary meeting? Depends on review?

June/July: SSSC APIO Committee, TBD location



**Science Mission
Directorate**

Reference Information



Approach

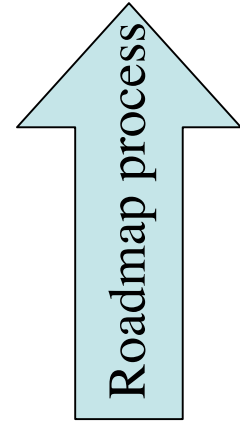
The environment is noisy and uncertain

The S³C approach:

- take care of current projects and programs
- concentrate on factual information
- assess impacts as far as can be determined
- be clear on intentions

Senior Review

ROSES



Identification of future goals and priorities



The Elements of Strategy

Classical Strategic Element

Vital Goal

Available Resource

Political Will

S³C Strategic Element

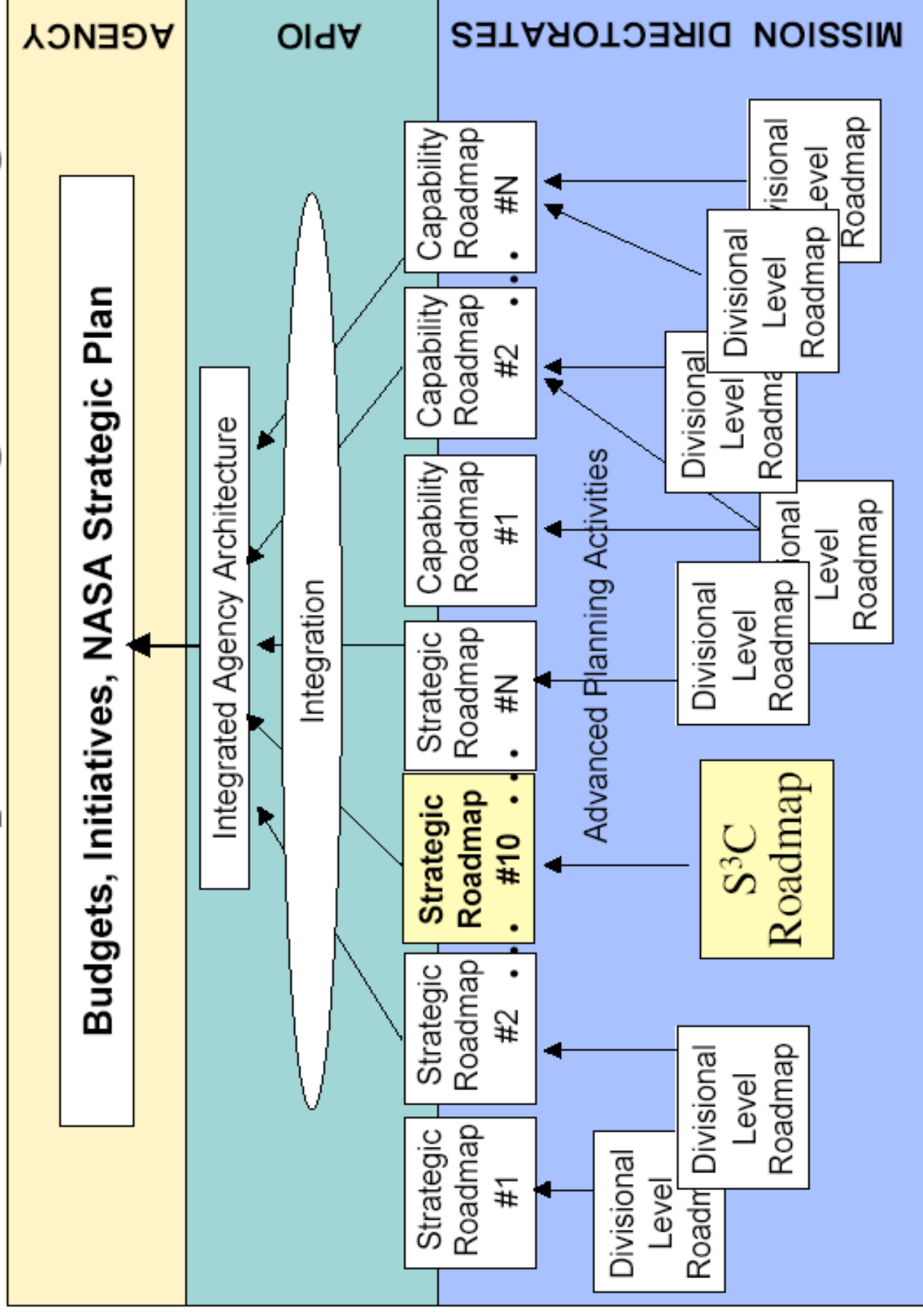
S³C Roadmap
NRC Decadal Study
NASA Strategic Plan

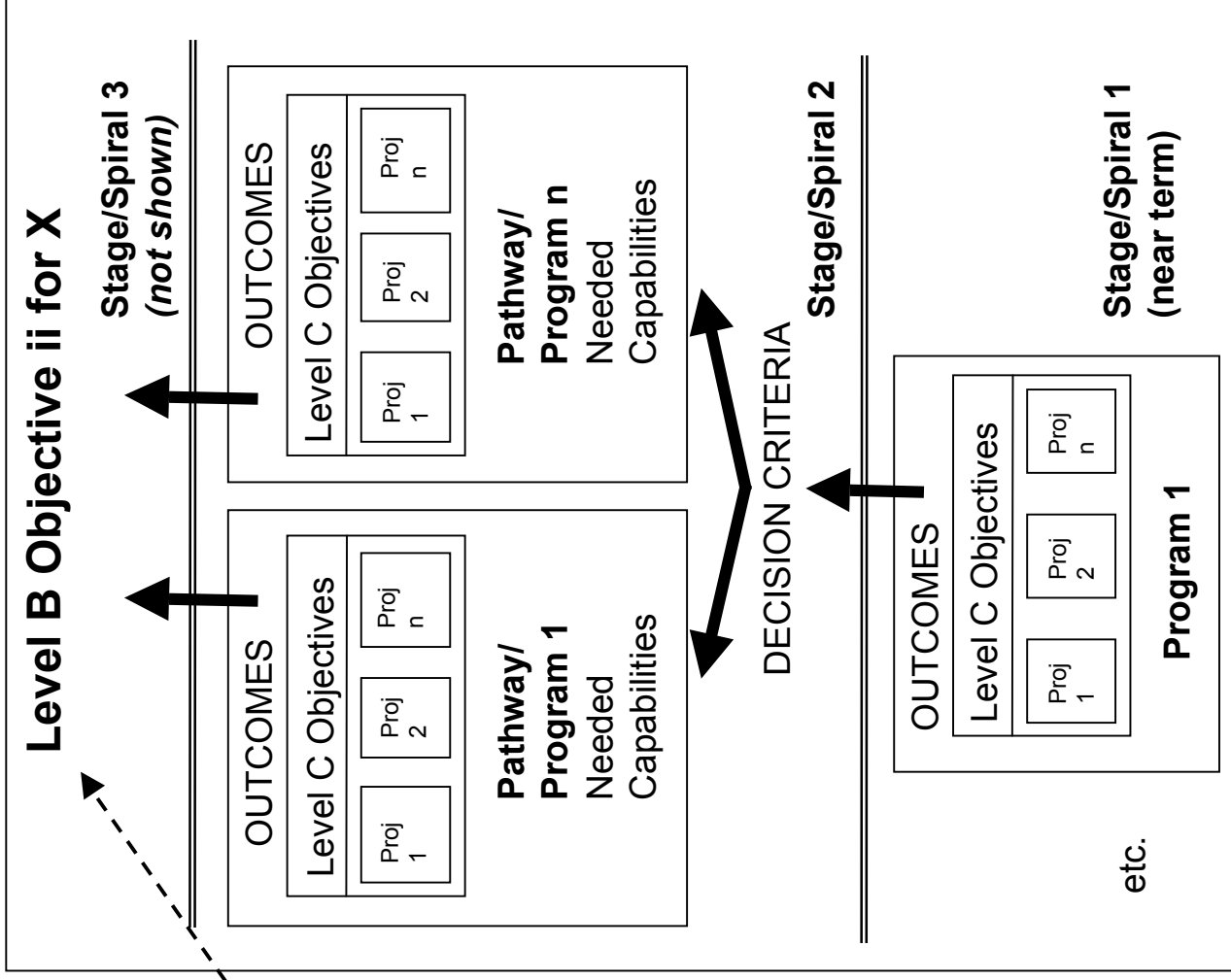
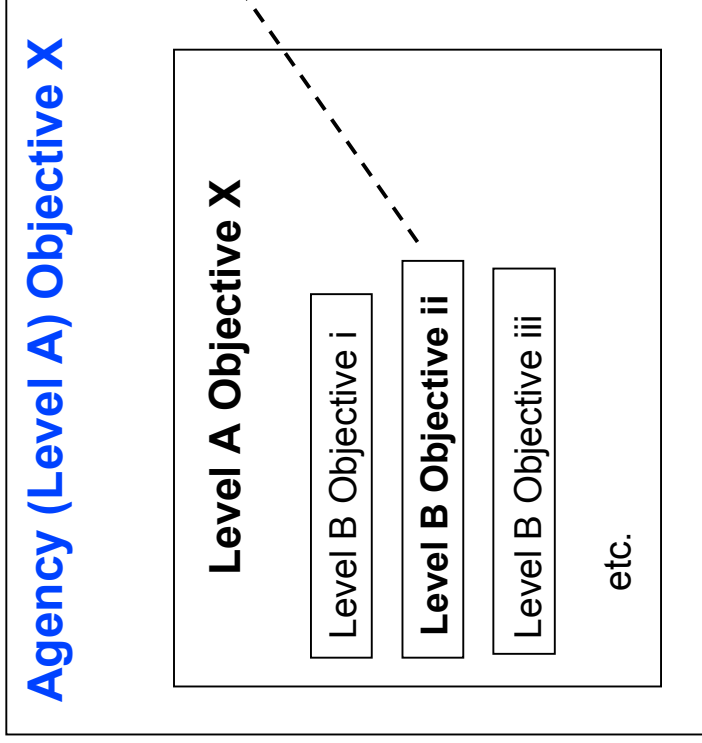
STP Mission Line,
LWS Program Mission Line, and
Explorer Program Line
[Flagship Mission Resource]

Support of the involved:
Scientific Community,
Agency,
Executive Branch, and
Congress

The SSSC Roadmap is one part of a larger, continuous process.

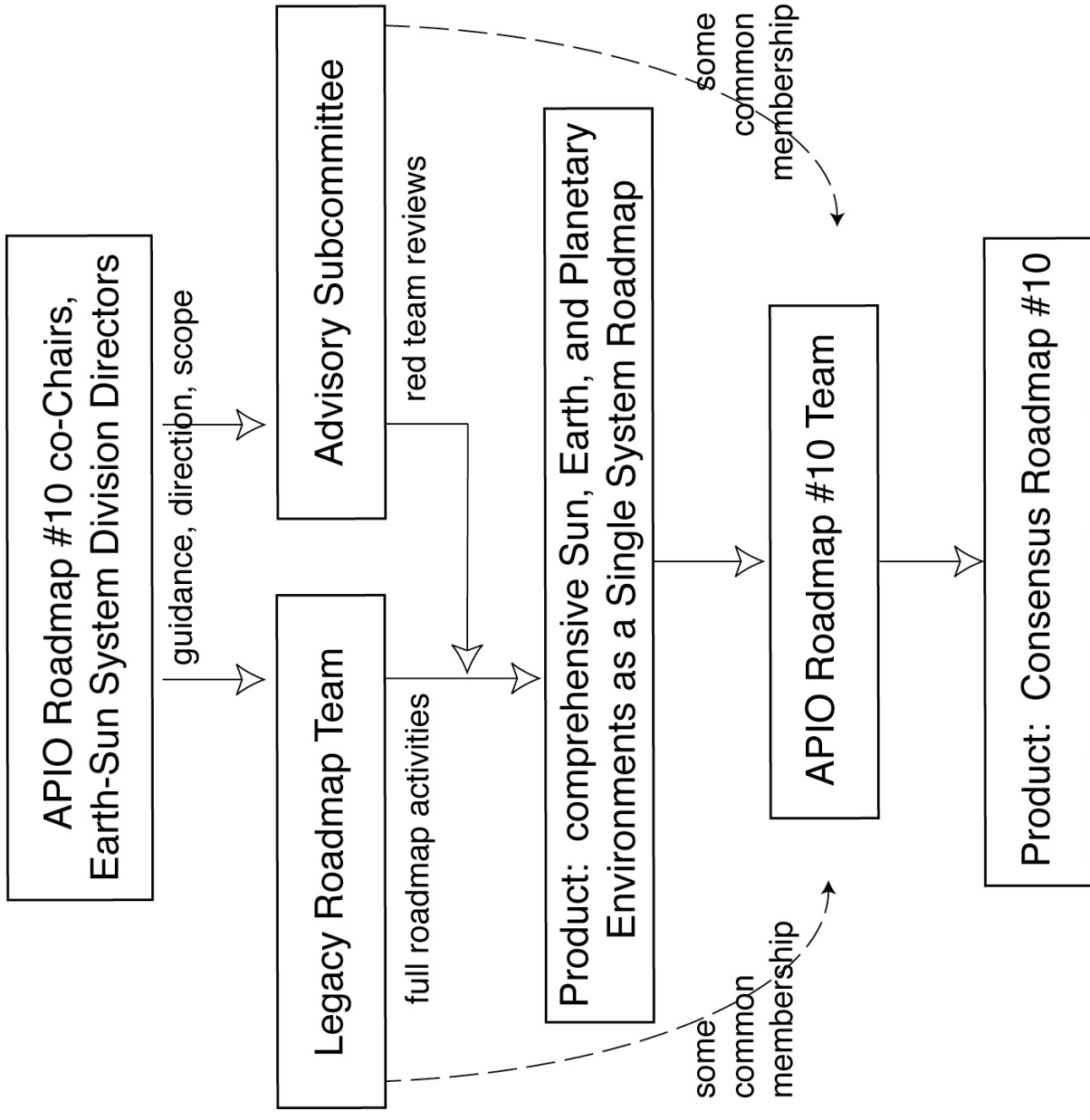
NASA's Updated Strategic Planning





Framework:
Objectives, Pathways,
Programs/Spirals,
Outcomes, and
Decision Criteria

Relationship of SSC Teams and committees





SSSC Foundation Team Membership

External Chair: Todd Hoeksema, Stanford University

Center Co-Chair: Thomas Moore, NASA/GSFC

Markus Aschwanden, Lockheed-Martin

Donald Anderson, NASA/HQ

Scott Bailey, University of Alaska

Thomas Bogdan, NCAR

Cynthia Cattell, University of Minnesota

Gregory Earle, Univ. of Texas at Dallas

Joseph Fennell, Aerospace Corp.

Jeffrey Forbes, University of Colorado

Glynn Germany, University of Alabama in Huntsville

Nat Gopalswamy, NASA/GSFC

Donald Hassler, Southwest Research Institute

Rosamond Kinzler, American Museum of Natural History

Craig Kletzing, University of Iowa

Barry LaBonte, JHU/Applied Physics Lab

Michael Liemohn, University of Michigan

Paulett Liewer, NASA/JPL

Neil Murphy, NASA/JPL

Edmond Roelof, JHU/Applied Physics Lab

James Russell, Hampton University

Leonard Strachan, Smithsonian Astro Observatory



Engineering Team for the Roadmap Committee

Mary DiJoseph GSFC

Tim VanSant GSFC

Ron Muller GFSC/QSS

Pete Cline GSFC

Regan Howard GSFC

Gregg Marr GSFC

Neil Murphy JPL

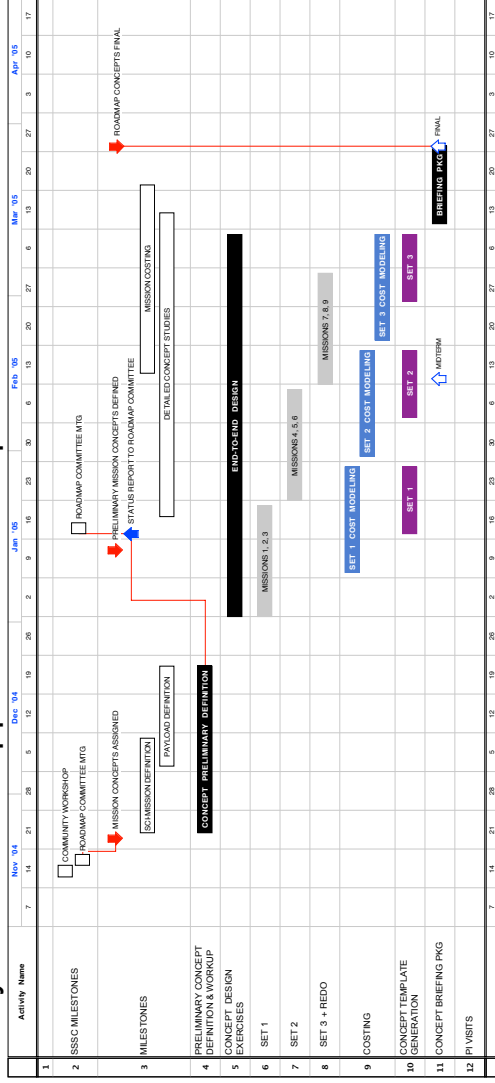
Juan Ayon JPL

Janine Daughters JPL



Engineering Team Support

Study schedules support the Roadmap schedule



Engineering team Goals

- Complete innovative mission conceptual designs proposed by mission advocates
- Support the SSSC Roadmap Committee via the mission advocates
- Ensure realistic mission cost estimates
- Identify and incorporate new enabling technologies

Mission Advocate's Role

- Critical to quality mission design
- Focal point for mission (and liason to Roadmap Committee)
- Frequent interaction with engineering team is essential
 - Ensures that the engineering team captures the science objectives correctly
 - Can create insights that result in innovative and creative alternative concepts

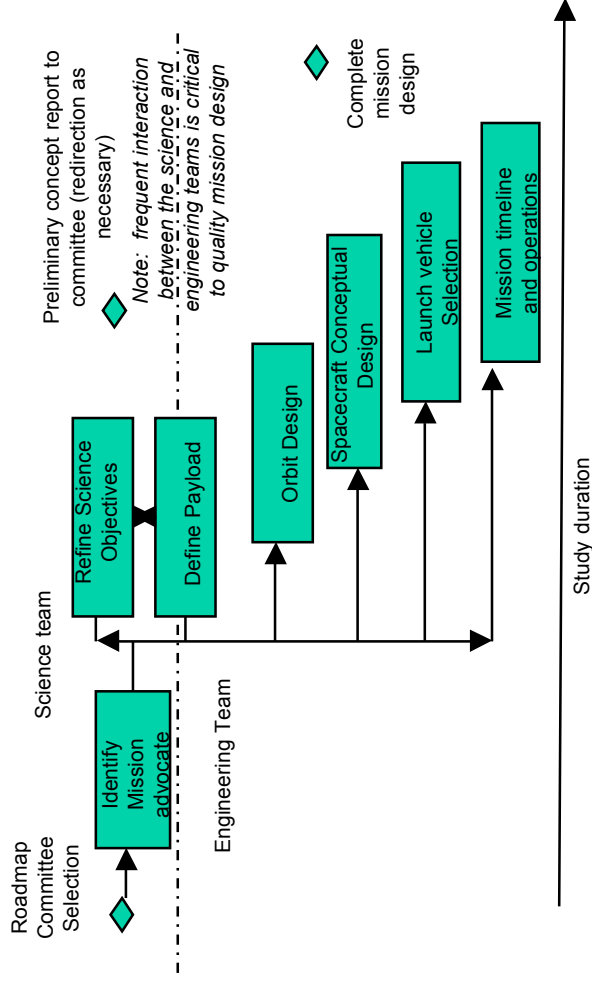
Technology Role

- Mission characteristics that drive technology and cost
 - High data rate instruments (drive power and communication)
 - Complex orbits requiring intensive real-time operations
 - Interplanetary orbits requiring nuclear power
 - Formation flying
- Technology enables missions
 - Advanced power, communications and propulsion technologies can enable missions not previously possible



Roadmap study process and outputs

Study process



Sample instrument summary

| Instrument | Mass (kg) | Power (w) | Data Rate (bps) |
|-------------------------|-------------|-------------|-----------------|
| Magnetometer | 0.6 | 5.0 | 431 |
| Plasma Composition | 2.6 | 3.0 | 1360 |
| Fast Plasma | 1.6 | 0.8 | 1071 |
| Energetic Particles | 0.9 | 1.3 | 521 |
| Cosmic Ray Telescope | 1.0 | 0.8 | 200 |
| WAVES | 2.5 | 2.3 | 579 |
| White Light Coronagraph | 10.0 | 6.5 | 1200 |
| Heliospheric Imager | 5.5 | 10.0 | 1192 |
| Doppler Magnetometer | 7.0 | 10.0 | 1200 |
| X-ray Spectrometer | 1.5 | 2.5 | 273 |
| TOTAL* | 33.2 | 42.2 | 8027 |

Other outputs

- Mission conceptual design
- Mission Quad charts
- Technical options, enhancements and significant trades
- Issues and cost drivers

| Missions Study Status | | 2000 RM Study | 2003 RM Study | Inter-RM | Vision Mission | SDT | Pre-Form | Formulat | Implement | Comments |
|---|--|---------------|---------------|----------|----------------|-----|----------|----------|-----------|--------------------------------------|
| Near-Intermediate | | | | | | | | | | |
| STP Missions | | | | | | | | | | |
| Solar-B | | | | | | | | | STP | |
| Solar-Terrestrial Relations Observatory (STEREO) | | | | | | | STP | | STP | AO Phase 1 Selection |
| Magnetospheric Multiscale (MMS) | | | | | | | | | | SDT Report |
| Geospace Electrodynamics Connections (GEC) | | | | | | STP | | | | Updated SDT In Process 2004 |
| Magnetospheric Constellation (MC) | | | | | | STP | | | | Report 10/03 |
| Tellmachus | | | RM | IRM | | | | | | Report 10/03 |
| Reconnection and Microscale (RAM) | | RM | RM | IRM | | | | | | Report 10/03 |
| Ionosphere Thermosphere Mesosphere Waves Coupler | | RM | RM | IRM | | | | | | Report 7/04 |
| Heliospheric Imager and Galactic Observer (HIGO) | | RM | RM | IRM | | | | | | |
| LWS Missions | | | | | | | | | | |
| Solar Dynamics Observatory (SDO) | | | | | | | | | LWS | (LWS) |
| Geospace Storm Probes | | | | | | | | | | |
| - Ionosphere Thermosphere Storm Probes | | | | | | | LWS | | | |
| - Radiation Belt Storm Probes | | | | | | | LWS | | | |
| Inner Heliosphere Sentinels (IHS) | | RM | RM | | | LWS | | | | SDT Initiated 2004 |
| Inner Magnetospheric Constellation (IMC) | | RM | RM | IRM | | | | | | Report 6/03 |
| Tropical ITM Coupler | | RM | RM | | | | | | | |
| Magnetic Transition Region Probe (MTRAP) | | | RM | IRM | | | | | | Report Due 10/04 |
| Solar Probe | | | | | | LWS | | | | JPL/APL Reports; STDT initiated 3/04 |
| Explorers | | | | | | | | | | |
| Coupled Ion Neutral Dynamics Investigation (CINDI) | | | | | | | | | EXP | |
| Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) | | | | | | | | | EXP | |
| Aeronomy of Ice in the Mesosphere (AIM) | | | | | | | | | EXP | |
| Time History of Events and Macroscale Interactions during Substorm (THEMIS) | | | | | | | | | EXP | |
| SSE/SEC Missions | | | | | | | | | | |
| Jupiter Polar Orbiter (JPO) | | RM | RM | | | | | | | New Frontiers Step 2- JUNO |
| Io Electrodynamics | | RM | Q | | | | | | | Planetary with Mag. Comp. |
| Titan Explorer | | | | | VM | | | | | Planetary with Mag. Comp. |
| Neptune Orbiter | | Q | Q | | VM(2) | | | | | variants studies at JPL |
| Mars Aeronomy Probe | | RM | Q | | | | | | | variants studies at JPL |
| Venus Aeronomy Probe | | RM | | | | | | | | |
| Long Term | | | | | | | | | | |
| STP Missions | | | | | | | | | | |
| Dayside Boundary Layer Constellation (DBC) | | RM | Q | | | | | | | |
| Magnetosphere-Ionosphere Observatory (MIO) | | | RM | | | | | | | |
| Particle Acceleration Solar Orbiter (PASO) | | RM | RM | | | | | | | |
| Auroral Multi-Scale (AMS) | | | RM | | | | | | | |
| Geospace System Response Imager (GSRI) | | RM | RM | | | | | | | |
| Solar Connection Observatory for Planetary Environments (SCOPE) | | | Q | | | | | | | |
| Solar Polar Imager | | RM | RM | IRM | VM | | | | | Report 2003 |
| LWS Missions | | | | | | | | | | |
| L1-Diamond | | | RM | IRM | | | | | | Report 10/04 |
| Solar Imaging Radio Array (SIRA) | | | Q | | | | | | | |
| Sun-Earth Energy Connector (SEEC) | | RM | | | | | | | | |
| Sun-Heliosphere-Earth Constellation | | | Q | | | | | | | |
| Other Missions | | | | | | | | | | |
| Bepi-Colombo | | | RM | | | | YES | YES | | ESA AO Issued 4/04 |
| Interstellar Probe | | RM | RM | | VM(2) | | | | | 2001-2 Reports |
| Solar Orbiter | | | Q | | | SDT | YES | | | ESA Mission Report Fall 2004 |
| Stellar Imager | | Q | Q | | VM | | | | | Vision Mission |

Notes:

Baseline = SEC 2003 Roadmap Appendix D Missions

Q = Mission Quad Sheet Only

RM = Roadmap Mission Team One Week Study

IRM = HQ Selected Inter-Roadmap Studies w/IMDC/Team X

VM = Vision Mission Under Study

SDT = Science Definition Team Conducted with Program Mission Studies

STP = Present Status in STP Program

LWS = Present Status in LWS Program



Status of new mission studies

| | HELIOSTORM | MARS DYNAMICS | MARS AERONOMY | SIRA | Doppler | Solar Wind Vanes | Space Physics Package |
|--|---|-------------------------|--------------------------|------------------------------|-----------------------------|------------------------|---------------------------|
| Science Leads | Tim Van Sant, Chris St. Cyr | Jeff Forbes/Jim Russell | Jim Slavin, Mike Liehmon | Nat Gopalswamy, Bob McDowell | Don Hassler, Paulett Liewer | Ed Roelof, Neil Murphy | Tom Moore, Craig Kletzing |
| Engineering Lead | Janine Daughters | Jim Chase | Juan Ayon | Regan Howard | PeteCline | Ron Muller | Michael Johnson |
| SCIENCE | | | | | | | |
| SCIENCE OBJECTIVES | Complete | Complete | Complete | Complete | Complete | | Complete |
| PAYLOAD | | | | | | | |
| Complement Identified | Complete | Complete | Complete | | Complete | | Complete |
| Instrument Characteristics | Partial | Partial | Very Partial | Complete | Complete | | Complete |
| Instrument Cost | Complete | Limited | Partial Strategy | | Complete | | Partial |
| DATA ACQUISITION SCENARIO | Complete | | | | | | |
| MISSION ANALYSIS | | | | | | | |
| INTERPLANETARY TRAJ | Solar Sail - Low Thrust | In Progress | In Progress | N/A | N/A | | N/A |
| LAUNCH WINDOW ANAL | Preliminary | In Progress | | Preliminary | | | |
| INTERPLANETARY TRAJ GEOMETRIC CHARACTS | Preliminary | In Progress | | N/A | N/A | | |
| ! V REQUIREMENTS | Preliminary | | | Complete | | | |
| OPERATIONAL ORBIT | Preliminary | In Progress | Preliminary Requirements | Complete | Preliminary | | |
| OPERATIONAL ORBIT GEOMETRIC CHARACTS | | In Progress | | Complete | Preliminary | | |
| FLIGHT SYSTEM | | | | | | | |
| MASS EQUIPMENT LIST | | | | Preliminary | | | |
| CONFIGURATION | | | | Preliminary | | | |
| S/S CONCEPTS | | | | Preliminary | | | |
| SYSTEM CONCEPT | Solar Sail Implementation Rt-Store, Global | | | Complete | Complete | | |
| MOS | | | | | | | |
| GROUND SYSTEM CONCEPT | | | | | | | |
| EIS STRATEGY | | | | | | | |
| COST | | | | | | | |
| FLIGHT SYSTEM | | | | | | | |
| MISSION | | | | | | | |
| TECH BRIEFING PACKAGE | | | | | | | |
| QUAD CHART | | | | | | | |
| PAYLOAD SUMMARY | | | | | | | |
| F/S CONCEPT BLOCK DIA. | | | | | | | |
| ISSUES AND COST DRIVERS | | | | | | | |
| TECH OPTIONS/ ENHANCEMENTS/ SIGNIFICANT TRADES | | | | | | | |
| COST BRIEFING PACKAGE | | | | | | | |
| COST SUMMARY | | | | | | | |
| PHASE SUMMARY | | | | | | | |

Current Schedule

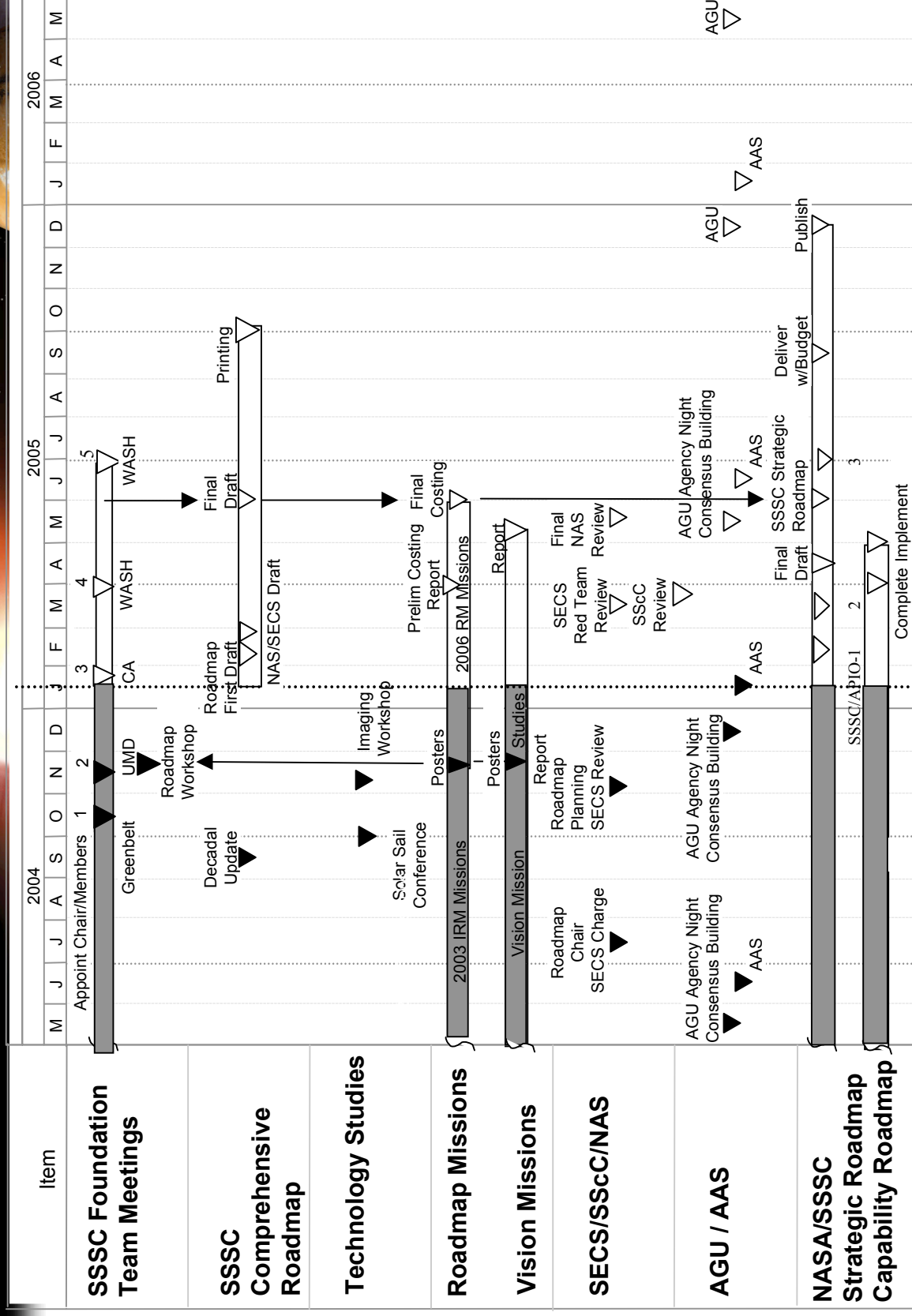
| Key Milestone | Target Date |
|--|----------------------|
| SPC approval of Strategic Roadmap development plan | August 11, 2004 |
| Co-chairs candidates approved by the Strategic Planning Council | September 3 |
| Co-Chairs signed up | October 8 |
| Complete team formation, assess existing material, finalize SRMP-B, begin work | December |
| Strategic Roadmap teams mid-term status review | February-March, 2005 |
| Roadmaps submitted for NRC review | April 15 |
| <i>NRC reviews received</i> | <i>June 15</i> |
| Roadmaps complete | July 31 |
| Integrated Strategic Architecture complete | October 1 |

11/2/2004



Roadmap Schedule

01/12/05

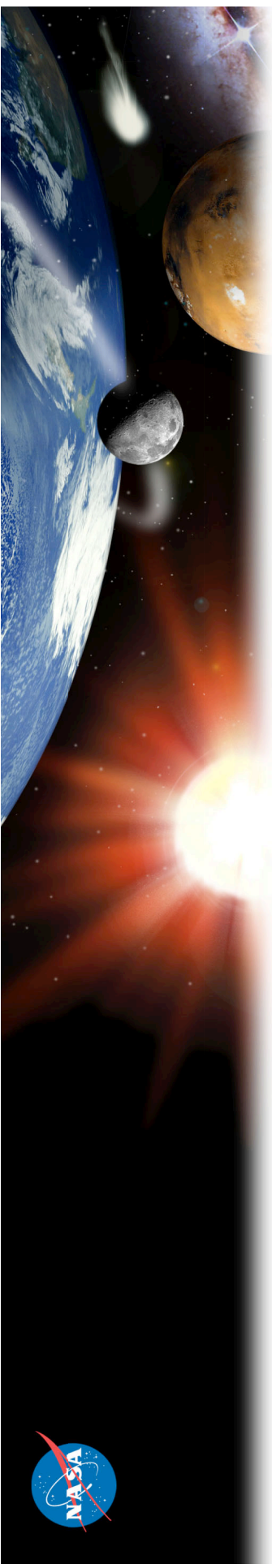


Provisional Roadmap Outline

1. Agency Objective Statement
2. Overview of Objectives, Stages, and Pathways Framework
3. Recommended Investigations, Missions, R&D Programs, etc., Aligned with Objectives and Stages/Pathways Framework
4. Summary of Key Program Milestones, Options, and Decision Points

APPENDIXES

1. National Policy Framework and External Constituencies
2. Required Capabilities Mapped to Stages/Pathways Decision Points
 - Technology
 - External Industrial and Academic Capacities
 - Agency Human Capital
 - Applicable Agency Infrastructure
 - Unique Requirements
 - 3. Unique Education and Outreach Opportunities
 - 4. Inter-Roadmap Dependencies
 - 5. External Partnerships
 - USG Agencies
 - International Partners
6. Bibliography of Key Agency Documents and NRC Documents



An Example of the Strategic Roadmap Concept for “Pathways”: The Mars Pathways Model



MEP—The Current Decade

Launch Year

OPERATIONAL



Mars Global Surveyor



ESA
Mars Express



Mars
Reconnaissance
Orbiter
(Italian SHARAD)

2005

2007



Mars Telesat

2009

...Next Decade

Explore the
Evolution of Mars

Mars
Odyssey



Search for
Evidence of Past Life

Science pathways
responsive to discovery

Search for Present Life

Mars
Exploration
Rovers



Completed Scout Mission

Phoenix



Mars Science
Laboratory



Explore
Hydrothermal
Habitats



Mars Potential Next-Decade Pathways

| Pathway | Lines of Scientific Inquiry |
|---|---|
| Search for Evidence of Past Life | <ul style="list-style-type: none">• Science from First Decade missions plus early next-decade missions confirms ancient Mars was wet and warm<ul style="list-style-type: none">• Locating and analyzing water-lain sedimentary rock is primary goal.• Pathway includes search for evidence of past life. |
| Explore Hydrothermal Habitats | <ul style="list-style-type: none">• Exploration in First Decade discovers hydrothermal deposits (active or fossil)<ul style="list-style-type: none">• Probability of hydrothermal regions being discovered is potentially high.• Hydrothermal habitats are focus of second decade of Mars exploration.• Potential for discovery of evidence of past and present life is greatly improved. |
| Search for Present Life | <ul style="list-style-type: none">• Commits to search for present life at sites determined to be modern habitats by First Decade missions<ul style="list-style-type: none">• Search for life at active hydrothermal deposits or polar margins.• Path would be taken only following a discovery that revolutionizes our understanding of the potential of Mars to harbor present life.• MSR with mobility is included as the most reliable, validatable means of detecting life. |
| Explore Evolution of Mars | <ul style="list-style-type: none">• Science of First Decade of Mars exploration does not find evidence of past or present liquid water environments<ul style="list-style-type: none">• Determine the loss mechanisms and sinks for water and CO₂ over time.• Determine why the terrestrial planets evolved differently, much more so than we had thought.• Determining whether the initial conditions on Venus, Earth and Mars were similar or very different. |





...and Potential Pathway Mission Sequences

| Pathway | 2009 | 2011 | 2013 | 2016 | 2018 | 2020 | Notes |
|----------------------------------|-------------------------------------|-------|-------------------------------|----------|--------------------------------------|------------|--|
| Search for Evidence of Past Life | MSL to Moderate Latitude | Scout | MSR | Scout | Astrobiology Field Lab or Deep Drill | Scout | Missions to high-probability past habitat. Mission in '18 influenced by MSL results. |
| Explore Hydrothermal Habitats | MSL to Hydrothermal Deposit | Scout | Astrobiology Field Laboratory | Scout | Deep Drill | Scout | All core missions sent to active or extinct hydrothermal deposits. |
| Search for Present Life | MSL to High Latitude or Active Vent | Scout | Scout | MSR | Scout | Deep Drill | Missions to modern habitat. Path has highest risk. |
| Explore Evolution of Mars | MSL to Moderate Latitude | Scout | MSR | Aeronomy | Network | Scout | Path rests on proof that Mars was never wet. |

| | | | | | | |
|--------------------------------------|--|----------------------|--|--------------|--|--------------|
| 2005 President's Budget Augmentation | | Scout & Mars Testbed | | Mars Testbed | | Mars Testbed |
|--------------------------------------|--|----------------------|--|--------------|--|--------------|



Note: The pathway followed will depend on knowledge and technologies developed this decade.

A horizontal banner featuring a collage of celestial bodies: a large orange sun on the left, a blue and white Earth with a ring in the center, and a large Jupiter on the right, all set against a starry space background.

NASA's Strategic Roadmaps

1. Lunar exploration (human & robotic)
2. Mars exploration (human & robotic)
3. Solar system exploration
4. Earth-like planets
5. Exploration transportation
6. ISS completion & utilization
7. Shuttle phase out & transition
8. Exploration of the Universe
9. Earth system & dynamics
10. Earth-Sun system
11. Air transportation system
12. Educate students & public
13. Nuclear missions

Note: Blue = SMD has primary responsibility

A banner image for NASA's Technology Roadmaps. It features a vibrant space scene with a large, glowing orange and yellow planet on the left, a blue and white Earth in the center, and a large, brown and white Jupiter on the right. The background is a deep blue space filled with stars and nebulae. The title "NASA's Technology Roadmaps" is written in large, white, sans-serif font across the center of the image.

NASA's Technology Roadmaps

- | | |
|---|--|
| 1. High-energy power & propulsion | 9. Autonomous systems & robotics |
| 2. In-space transportation | 10. Transformation spaceport/range |
| 3. Advanced telescopes & Observatories | 11. Scientific instruments/sensors |
| 4. Communication & navigation | 12. In-situ resource utilization |
| 5. Robotic access to planetary surfaces | 13. Advanced modeling/simulation/analysis |
| 6. Human planetary landing systems | 14. Systems engineering cost/risk analysis |
| 7. Human health & support systems | 15. Nanotechnology |
| 8. Human exploration systems & mobility | |

Note: **Blue** = SMD has primary responsibility



Strategic Roadmaps (page 1 of 2)

| Roadmap | Chairs (HQ Directorate, Center, External) | Coordinators APIO Directorate |
|---------------------------------------|--|--|
| Robotic and Human Lunar Exploration | Adm. (ret.) Craig Steidle (HQ/ESMD) and William Readdy (HQ/SOMD) Gen. (ret.) Jefferson Howell (JSC) Gen. (ret.) Tom Stafford | Frank Bauer (GSFC/HQ) Scott Wilson (ESMD) |
| Robotic and Human Exploration of Mars | Al Diaz (HQ/SMD) Dr. Charles Elachi (JPL) Tom Young (Lockheed Martin, ret.) | Judy Robey (HQ) Dr. Mike Meyer (SMD) |
| Solar System Exploration | Orlando Figueroa (HQ/SMD) Scott Hubbard (ARC) Dr. Jonathan Lunine (Uni. of Arizona) | Judy Robey (HQ) Dr. Carl Pilcher (SMD) |
| Search for Earth-Like Planets | Dr. Ghassem Asrar (HQ/SMD) Dr. Charles Beichman (JPL) Dr. Adam Burrows (Uni. of Arizona) | Dr. Rich Capps (JPL, ret.) Dr. Eric Smith (SMD) |
| Exploration Transportation System | Adm. (ret.) Craig Steidle (HQ/ESMD) Jim Kennedy (KSC) Gen. (ret.) Charles Bolden | Dr. Dana Gould (LaRC) Mark Borkowski (ESMD) |
| International Space Station | Mark Uhran (HQ/SOMD) Bob Cabana (JSC) Adm. (ret.) Tom Betterton | Stacey Edgington (HQ) Dr. Michele Gates (SOMD) |
| Space Shuttle | <i>Deferred*</i> | <i>Deferred*</i> |



Strategic Roadmaps (page 2 of 2)

| Roadmap | Chairs (HQ Directorate, Center, External) | Coordinators APIO Directorate |
|---|--|---|
| Universe Exploration | Dr. Anne Kinney (HQ/SMD) Dr. Nick White (GSFC) Dr. Kathy Flanagan (MIT) | Dr. Rich Capps (JPL, ret.) Dr. Mike Salamon (SMD) |
| Earth Science and Applications from Space | Orlando Figueroa (HQ/SMD) Dr. Diane Evans (JPL) Dr. Charles Kennel (UCSD/Scripps) | Gordon Johnston (SMD) |
| Sun-Solar System Connection | Al Diaz (HQ/SMD) Dr. Franco Einaudi (GSFC) Dr. Timothy Killeen (NCAR) | Dr. Azita Valinia (GSFC) Dr. Barbara Giles (SMD) |
| Aeronautical Technologies | Terry Hertz (HQ/ARMD) None (Center) James Jamieson (Boeing) | Vicki Regenie (DFRC/JPL) Yuri Gawdiak (ARMD) |
| Education | Dr. Adena Loston (HQ/Office of Education) Dr. Julian Earls (GRC) Dr. France Cordova (Uni. of California, Riverside) | Ashley Stockinger (HQ) Shelley Canright (Office of Education) |
| Nuclear Systems | Adm. (ret.) Craig Steidle (HQ/ESMD) Chris Scolese (GSFC) Dr. John Ahearn (Duke Uni.) | Dr. Perry Bankston (JPL) Jay Jenkins (ESMD) |



Capability Roadmaps (page 1 of 2)

| Capability | NASA chair | External chair | Directorate | Coordinators APIO |
|--|------------------------|---------------------------------------|--|---------------------------|
| High-Energy Power and Propulsion | Joe Nainiger (GRC) | Dr. Tom Hughes (Penn State Uni.) | Overall – Betsy Park Technical – RayTaylor (ESMD) | Dr. Perry Bankston (JPL) |
| In-Space Transportation | Paul McConaughy (MSFC) | Col. Joe Boyles (US Air Force SMC) | Overall – Betsy Park Technical – Gary Lyles (ESMD) | Tom Inman (MSFC) |
| Advanced Telescopes and Observatories | Lee Feinberg (GSFC) | Dr. Howard MacEwen (SRS Technologies) | Dr. Harley Thronson (SMD) | Dr. Dan Coulter (JPL) |
| Communication and Navigation | Bob Spearing (HQ/SOMD) | TBD | Tom Cremins and Dr. Michele Gates (SOMD) | Steve Mecherle (Innocept) |
| Robotic Access to Planetary Surfaces | Mark Adler (JPL) | Dr. Robert Braun (Georgia Tech) | Dr. Harley Thronson (SMD) | Carl Ruoff (JPL) |
| Human Planetary Landing Systems | Robert Manning (JPL) | Dr. Harrison Schmitt | Overall – Betsy Park Technical – Jennifer Trosper (ESMD) | Rob Mueller (KSC/JPL) |
| Human Health and Support Systems | Dennis Grounds (JSC) | Al Boehm (Ret, Hamilton-Sundstrand) | Overall – Betsy Park Technical –Dr. Gene Trinh (ESMD) | Dr. Jan Aikins (ARC/JPL) |
| Human Exploration Systems and Mobility | Chris Culbert (JSC) | Dr. Jeff Taylor (Uni. of Hawaii) | Overall – Betsy Park Technical – John Mankins (ESMD) | Tom Inman (MSFC) |



Capability Roadmaps (page 2 of 2)

| Capability | NASA chair | External chair | Directorate | Coordinators | APIO |
|---|---|---|--|--------------------------|------|
| Autonomous Systems and Robotics | Dr. Steve Zornetzer (ARC) | Doug Gage (Ret. DARPA) | Dr. Harley Thronson (SMD) | Dr. Jan Aikins (ARC/JPL) | |
| Transformational Spaceport/Range | Karen Poniatowski (HQ/SOMD) | Gen. (Ret.) Jimmy Morrell Col. Dennis Hilley (OSD) | Tom Cremins, Dr. Michele Gates (SOMD) | Darin Skelly (KSC) | |
| Scientific Instruments/Sensors | Rich Barney (GSFC) | Dr. Maria Zuber (MIT) | Dr. Harley Thronson (SMD) | Dr. Perry Bankston (JPL) | |
| In Situ Resource Utilization | Jerry Sanders (JSC) | Dr. Mike Duke (Colorado School of Mines) | Overall – Betsy Park Technical – John Mankins (ESMD) | Rob Mueller (KSC/JPL) | |
| Advanced Modeling, Simulation, Analysis | Dr. Erik Antonsson (JPL) | Dr. Tamas Gombosi (Uni. Of Michigan) | Dr. Harley Thronson (SMD) | Dr. Jan Aikins (ARC/JPL) | |
| Systems Engineering Cost/Risk Analysis | Steve Cavanaugh (LaRC) | Dr. Alan Wilhite (Georgia Institute of Technology) | Overall – Betsy Park Technical – VickyHwa (ESMD) | Vicki Regenie (DFRC/JPL) | |
| Nanotechnology | Dr. Murray Hirschbein (HQ/ARMD) and Dr. Minoo Dastoor (HQ/ESMD) | Dr. Dimitris Lagoudas (Texas A&M) | Dr. Harley Thronson (SMD) | Julie Crooke (GSFC/HQ) | |



Co-Chairs Responsibilities

- NASA co-chairs
 - Represent views of their organizations to the team
 - Assist with NASA internal support to activity
 - Provide Agency mission leadership for activity
- External co-chairs
 - Represent views of their stakeholders or constituents to the team
- Assist with identification and recruitment of team members
- Oversee work of roadmapping team
- Help develop and concur on final roadmap product
- Represent team and its products in public forums and within NASA



Shared Responsibilities of Directorate and APIO Coordinators

- Support team co-chairs and team membership in carrying out responsibilities
- Draft and revise material for final roadmap document
- Serve as Executive Secretaries to roadmap teams
 - Work with APIO meeting coordinator to task meeting contractor for meeting arrangements (arrange among selves how to divide up these tasks)



Specific Responsibilities of Directorate Coordinator

- Represent Directorate planning styles and legacy processes to team
- Survey and analyze applicability of legacy processes to roadmapping requirements; identify disjoints, gaps, and schedule problems
- Lead consolidation of legacy processes with requirements of roadmapping goals and processes, including problem solving
- Convey consequences of this consolidation process to managers of legacy processes and outside stakeholders and win support
- Help ensure consistent and clear communications with Directorates
- Ensure smooth flow of Directorate planning efforts and products into roadmapping activity
- Convey Directorate views and concerns to team on behalf of AA



Specific Responsibilities of APIO Coordinator

- Play active role in setting APIO standards and policies
- Convey APIO guidelines to roadmapping teams and legacy Directorate activities
- Provide status and feedback from teams and Directorates to APIO
- Help ensure inter-SRM team coordination on common issues, working with APIO integration functions
- Facilitate coordination between team and Capabilities Roadmap teams and processes
- Oversee roadmapping progress in terms of ultimate usability of products
- Arrange for APIO support in system engineering and affordability analysis areas
- Prepare weekly progress reports and represent SRM status and progress at weekly APIO telecons
- Work with APIO FACA Coordinator to manage FACA notice, posting, and reporting requirements
- Prepare materials for team representation to DRD meetings
- Coordinate with APIO Web Designer for roadmapping activity public web presence, including collecting and drafting needed information