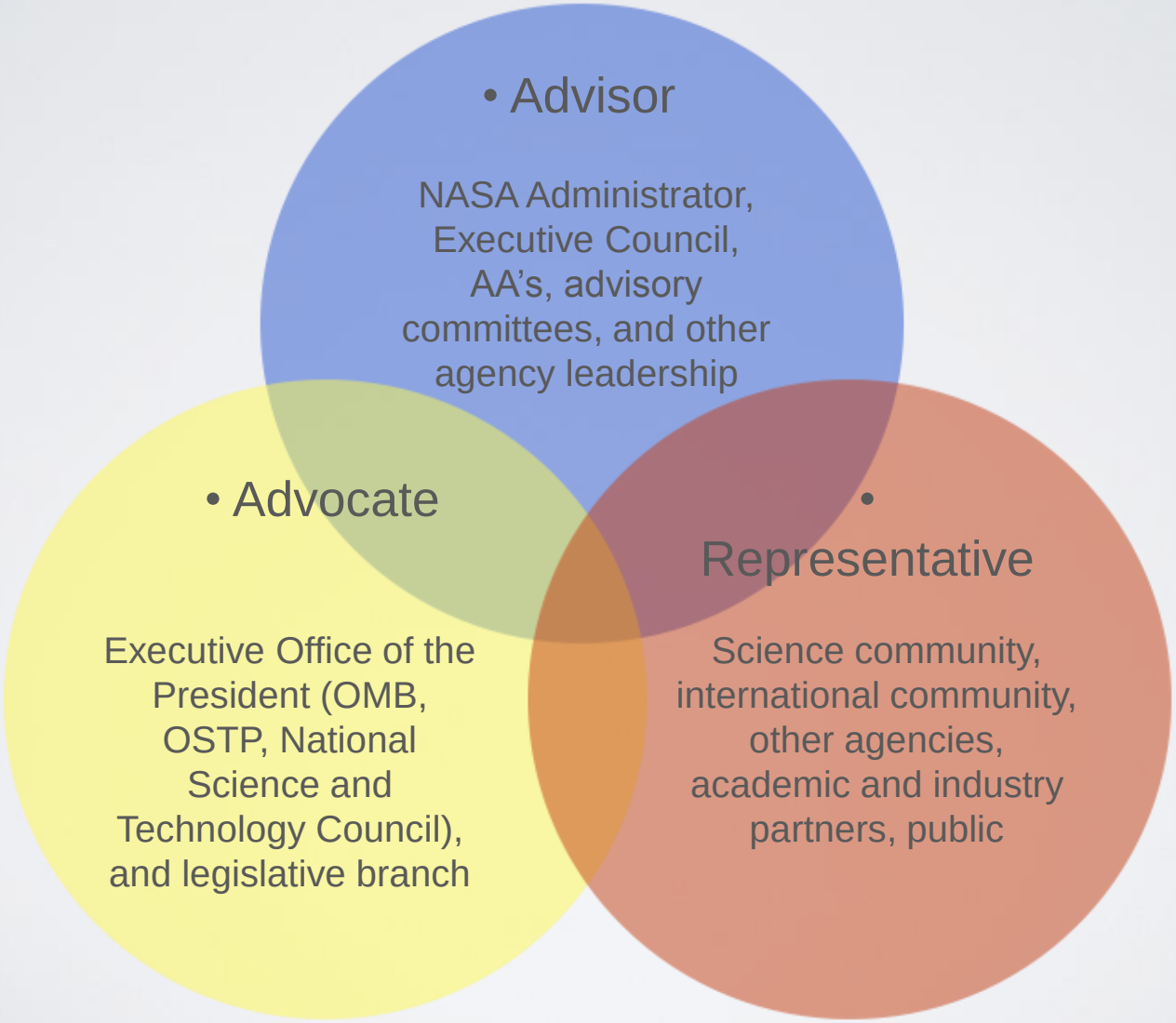
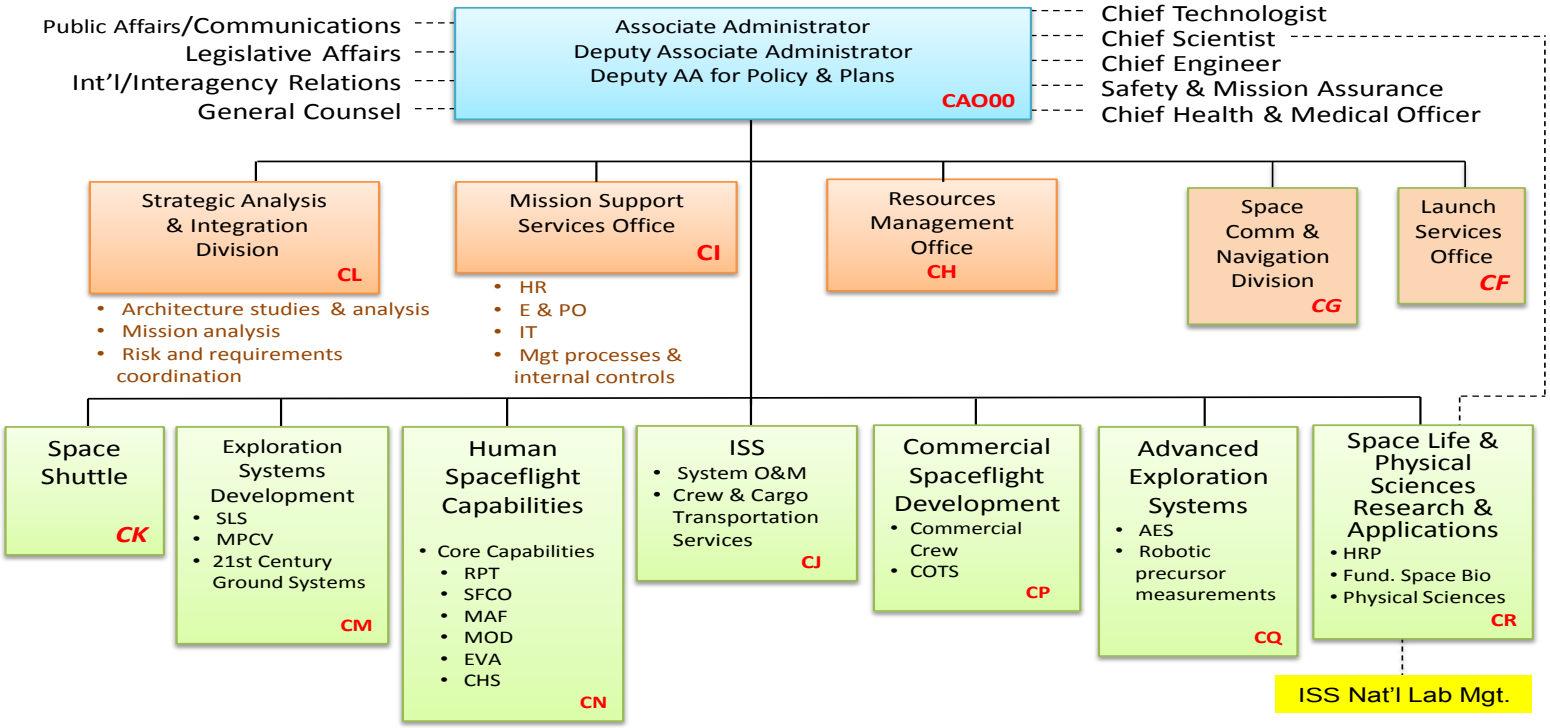
Briefing to the Committee on Biology and Physical Sciences in Space

Role of the Chief Scientist



Human Exploration and Operations Mission Directorate

Organizational Structure: Human Exploration and Operations Mission Directorate



Decadal Survey: Introduction

- The decadal survey was a comprehensive report that included over two hundred recommendations.
- The report identified 65 highest basic, applied, or translational priorities across fundamental space biology, physical sciences, technology, and human research using a set of eight prioritization criteria.
- It also included programmatic, education and outreach recommendations.
- The survey was unconstrained, meaning there were no budget, schedule, or destination boundaries.
- The survey did prioritize the recommendations as high, medium, low based on the criteria.
- In addition the report contained two bounding policies: human exploration and leading edge science.
- Each of these bounding policies identified a set of primary and secondary criteria.

Decadal Steering Committee Steps Taken to Develop Framework

- Using Bio/Phys relevant recommendations identified high, medium, low level of support in Table 13.3 for each bounding policy
- Using two bounding policies Human Exploration (Mars) Box 13.3 and Leading Edge Science Box 13.4
- Developed spreadsheet

Human Exploration beyond LEO

Recommendation	Criteria 1 priority	Criteria 2 priority	Criteria 3 priority	Criteria 5 priority
P1	M	L	L	H
P2	H	M	M	H
P3	H	H	H	H
AH3	H	M	H	H
AH4	M	M	M	H
AH5	H	M	H	H
AH8	H	M	H	H
AH10	H	H	H	H
AH12	M	M	M	M
AH14	M	L	M	M
AH15	M	L	M	M
AH16	M	M	M/L	H
CC8	M	M	H	H
CC9	M	M	L	M
CC10	M	M	M	M
AP1	H	H	H	H
AP2	M	H	H	H
AP3	M	M	H	H
AP5	L	L	M	L
AP6	H	M	L	H
AP7	M	N/A	N/A	M
AP8	H	M	L	M
AP9	N/A	N/A	L	L
AP10	L	H	H	M

Leading Edge Science

Recommendation	Criteria 4 priority	Criteria 5 priority	Criteria 8 priority	Criteria 6 priority	Criteria 7 priority
P1	H	H	M	M	H
P2	H	H	M	M	M
P3	L	H	M	M	M
AH3	M	H	H	H	M
AH4	M	H	H	H	M
AH5	M	H	H	H	M
AH8	M	H	M	M	M
AH10	H	H	M	H	M
AH12	M	M	M	L	H
AH14	M	M	M	M	M
AH15	M	M	M	M	M
AH16	H	H	M	L	H
CC8	L	H	L	L	L
CC9	L	M	L	L	L
CC10	L	M	M	M	L
AP1	M	H	H	L	H
AP2	M	H	H	M	H
AP3	L	H	L	N/A	L
AP5	H	L	M	M	H
AP6	L	H	M	L	H
AP7	H	M	H	H	H
AP8	H	M	H	H	N/A
AP9	H	L	H	H	H
AP10	M	M	M	H	L

Highest Priority Recommendations

Highest priority space biological and physical science exploration (Mars) and science recommendations based on bounding policies

Exploratio	Science
P3	P3
AP1	AP1
TSES2	TSES2
AH3	AH3
AH5	AH5
AP2	AP2
TSES14	TSES14
P2	P2
AP6	AP6
AP10	AP10
AP8	AP8
AH4	AH4
TSES1	AP7
CC8	P1
AP3	AH16
TSES6	AP9
AP4	AH8
	FP1
	FP2
	FP3
	AH12
	AH14
	AH15
	AP5

Recommendations that span exploration and science

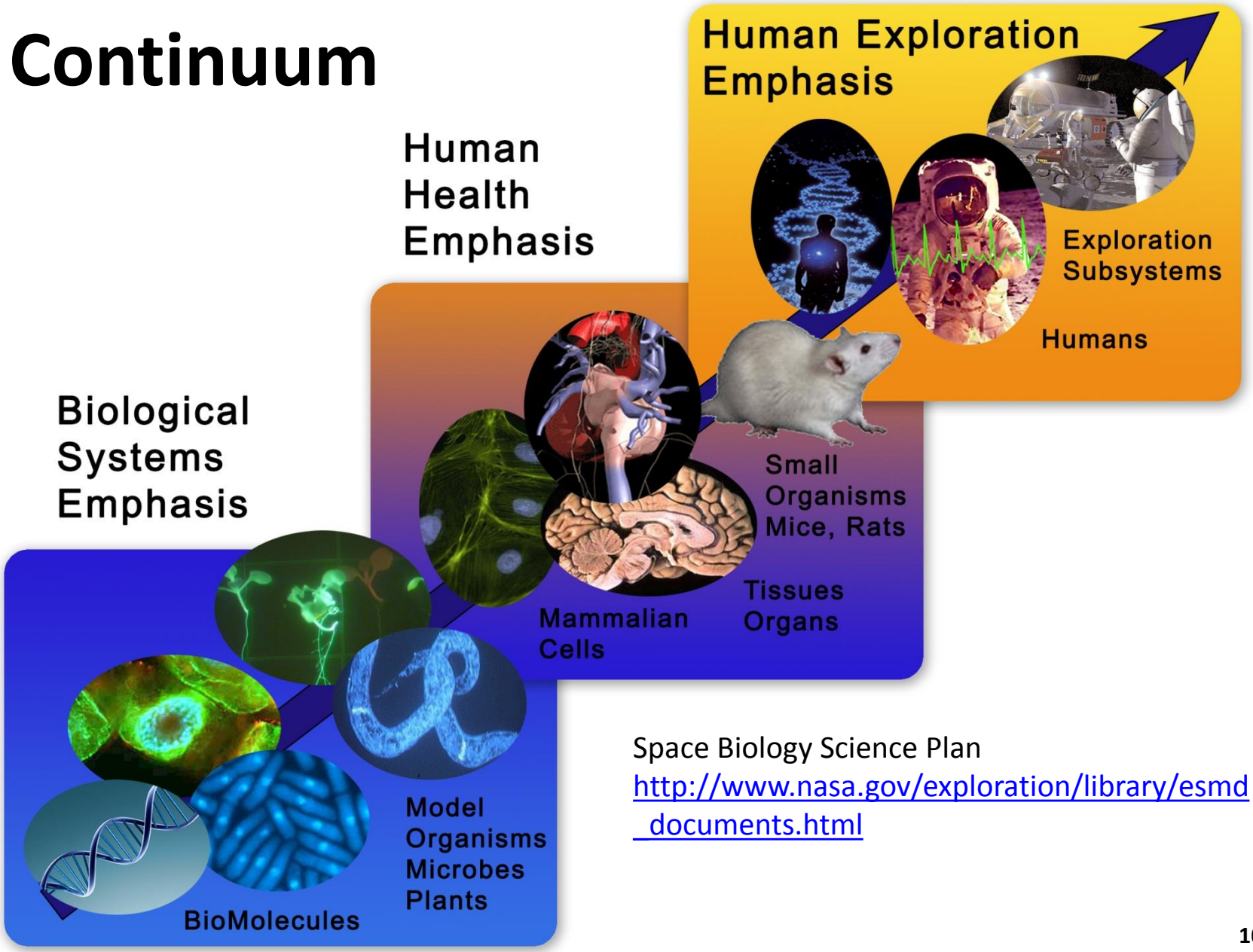
Recommendations unique to exploration

Recommendations unique to science

Was the Process Helpful? YES

- Provided a list of highest priority recommendations (helpful with limited budget), a jumping off point
- Identified areas to leverage that addressed both bounding policies
- Provided a basis to review space biology and physical sciences projects for gaps and/or overlaps in investments
- Identified areas of synergy in Human Research and Technology

Life Sciences: A Continuum

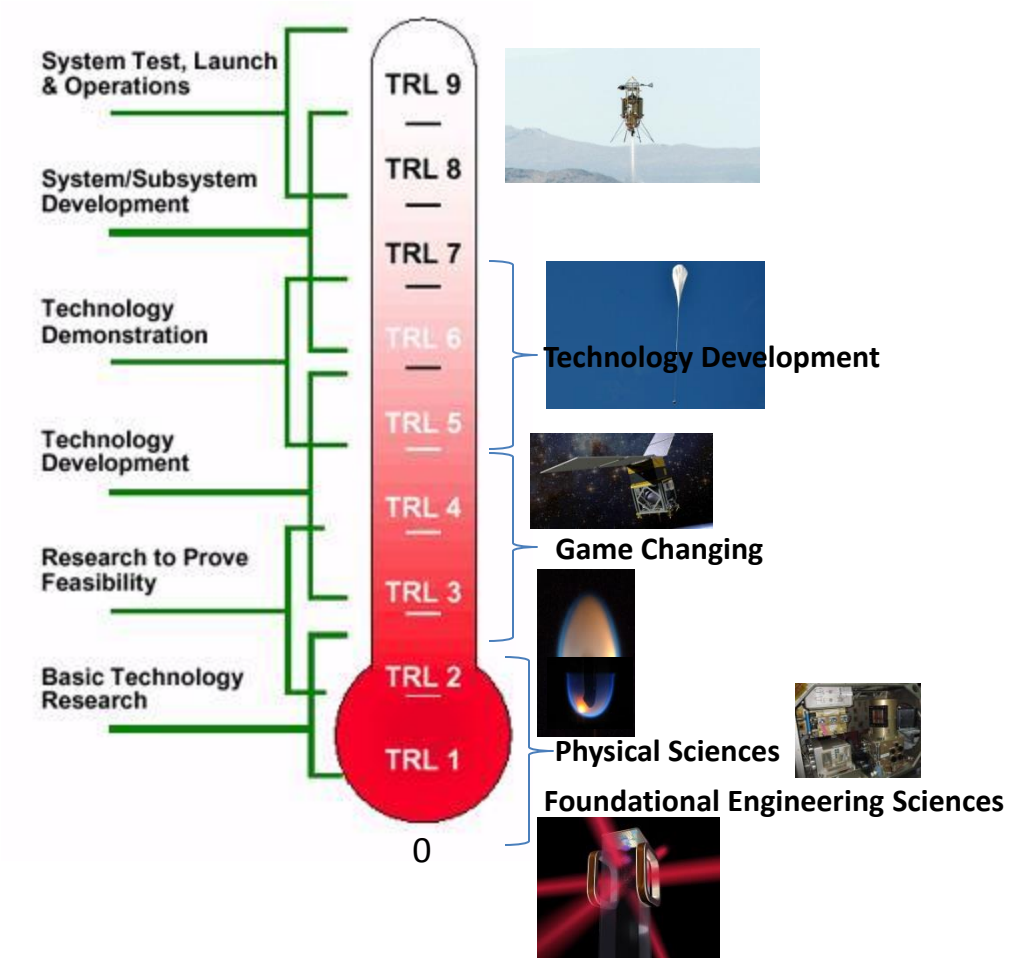


Space Biology Science Plan
http://www.nasa.gov/exploration/library/esmd_documents.html

Human Research Program

- HRP applied research is well documented and reviewed on a continuous basis by external evaluators. See: http://humanresearchroadmap.nasa.gov/
- **Examples of Human Research Linkages to Physical Sciences and Biology**
  FSB research in the areas of molecular & cellular, organism and developmental biology would provide basic foundational knowledge for HRP applied research aimed at risk mitigation.
  - Examples
    - mechanisms of immune function
    - fracture and wound healing
    - microbial virulence
    - neural vestibular function

The Technology Continuum



MAPPING

Physical Sciences Research to Space Technology Roadmaps

- TA02: In-Space Propulsion Systems*
  - Propellant Storage, Transfer & Gauging Liquid
    - Zero Boiloff: ZBOT > ZBOT-2 > ZBOT-3, (TSES – 2***)
    - Fluid Management: CFE > CFE-2, CCF, (AP2)
- TA03: Space Power & Energy Storage
  - Power Generation: FBCE (AP1)
- TA05: Communication and Navigation: ACES (FP -2)
- TA06: Human Health, Life Support and Habitation Systems
  - Environmental Control and Life Support Systems and Habitation Systems
    - Air Revitalization, and Water Recovery & Management: PBRE > PBRE-A** > PBRR** (TSES- 6)
      - Liquid-Gas Phase Separation: CFE-2, TFPSE (AP1)
    - Waste Management: SCWM > SCWM-2 > SCWO** (TSES-6)
  - Environmental Monitoring, Safety and Emergency Response
    - Fire Prevention, Detection and Suppression
      - Materials Flammability: BASS-2 > SoFIE > MWT-FS** (NASA STD 6001 Test 1) (AP6, TSES – 8)
- TA12: Materials, Structures, Mechanical Systems and Manufacturing: FAMIS, MVCS (AP10)
- TA14: Thermal Management Systems
  - Heat Pipes: CVB > CVB-2 > CVB-3** > HPE-L** (AP1)
  - Two-Phase Pumped Loop Systems: FBCE, MFHT, EHD (AP1, TSES - 1)

- *OCT Space Technology Roadmaps, 2010 (red/blue), Decadal Recommendations (Green)*
- *** proposed experiment, ***Decadal Survey Identifier*

Highest Recommendations Not in Priority Order

- ✓ AP3 – Dynamic granular material behavior and subsurface geotechnics to enable advanced human and robotic planetary surface and habitation
- ✓ AP4 – Development of fundamental-based strategies and methods for dust mitigation to enable advanced human and robotic exploration of planetary bodies
- ✓ AP6 – Fire safety research to improve methods for screening materials in terms of flammability and fire suppression in space environments
- ✓ AP7 – Combustion processes research, including reduced-gravity experiments with longer durations, larger scales, new fuels, and practical aerospace materials relevant to future missions
- ✓ AP8 – Numerical simulation of combustion research to develop and validate detailed single and multiphase numerical combustion models
- ✓ AP9 – Materials synthesis and processing and control of: microstructure and properties to improve the properties of existing and new materials
- ✓ AP10 – Design and develop advanced materials that meet new property requirements to enable human exploration at reduced cost using both current and novel materials
- ✓ TSES1 – Research should be conducted to address two-phase flow questions relative to thermal management
- ✓ TSES2 – Research should be conducted in support of zero-boiloff propellant storage and cryogenic fluid management. Physical sciences research includes advanced insulation, materials research, active cooling, multi-phase flows, and capillary effectiveness, as well as active and passive storage, fluid transfer, gauging, pressurization, pressure control, leak detection, and mixing destratification
- ✓ TSES6 – NASA should conduct research for the development and demonstration of closed-loop life support systems and supporting technologies. Fundamental research includes heat and mass transfer in porous media under microgravity conditions and understanding the effect of variable gravity on multi-phase flow systems
- ✓ TSES14 – Research is required to support the development and demonstration of space nuclear propulsion systems, including liquid-metal cooling under reduced gravity, thawing under reduced gravity, and system dynamics
- ✓ CC8 – Conduct animal studies to assess radiation risks from cancer, cataracts, cardiovascular disease, neurologic dysfunction, degenerative diseases, and acute toxicities such as fever, nausea, bone marrow suppression, and others

Highest Recommendations Not in Priority Order

- ✓ P1 – Establish a “microbial observatory” program on ISS to conduct long-term multi-generational studies of microbial population dynamics
- ✓ P2 – Establish a robust space flight program of research analyzing plant and microbial growth and physiological responses
- ✓ P3 – Develop a research program aimed at demonstrating the roles of microbial-plant systems in long-term life support systems
- ✓ AH3 – Bone loss studies of genetically altered mice exposed to weightlessness are strongly recommended
- ✓ AH5 – Conduct studies to identify underlying mechanisms regulating net skeletal muscle protein balance and protein turnover during states of unloading and recovery
- ✓ AH8 – Determine the basic mechanisms, adaptations, and clinical significance of changes in regional vascular/interstitial pressures (Starling forces) during long duration space missions
- ✓ AH12 – Determine the amount and site of the deposition of aerosols of different sizes in the lungs of humans and mammals in microgravity
- ✓ AH14 – To both address the mechanism(s) of the changes in the immune system and to develop measures to limit the changes, data from multiple “organ/system-based” studies need to be integrated
- ✓ AH15 – Perform mouse studies, including immunization and challenge, with immune samples acquired both prior to and immediately upon re-entry on the ISS to establish the biological relevance of the changes observed in the immune system. Parameters examined need to be aligned with those influenced by flight in humans
- ✓ AH16 – Studies should be conducted on transmission across generations of structural and functional changes induced by exposure to space during development. Ground-based studies should be conducted to develop specialized habitats to support reproducing and developing rodents in space
- ✓ FP1 – Research on complex fluids and soft matter
- ✓ FP2 – Understanding of the fundamental forces and symmetries of nature
- ✓ FP3 – Research related to physics and applications of quantum gases
- ✓ AP1 – Reduced-gravity multiphase flows, cryogenics and heat transfer database and modeling, including phase change heat transfer, pressure drop, and multiphase system stability
- ✓ AP2 – Interfacial flows and phenomena (including induced and spontaneous multiphase flows with or without phase change) relevant to storage and handling systems for cryogens and other liquids, life support systems, power generation, thermal control systems, and other important multiphase systems

Programmatic Recommendations and Status

Programmatic Issues –

Other recommendations in the decadal centered around management and program

- Regularly issued solicitations for NASA-sponsored life and physical sciences research
  - A regular and steady cadence of NRAs has been established for biology and physical sciences
- Transparent peer-review process for extramural and intramural research
  - Institute of Medicine reviewed the HRP process for selection of directed research; made recommendations. The entire process in online for public access.
  - Space biology and physical sciences conduct peer review in accordance with standard procedures
- Assembly of a Research Advisory Committee
  - Research subcommittee under the Human Exploration and Operations Advisory Committee has been formed
  - SSB Committee on Biology and Physical Sciences in Space formed

Other Recommendations and Status

- Long-term strategic plan to maximize research opportunities and initiatives
  - An integrated LPS strategic plan (science plan) will be developed in alignment with the decadal survey
- Improved central information networks to facilitate data sharing (OSTP policy will improve access)
  - Longitudinal data available on line
  - Human Research Roadmap online
  - Space Biology and Physical Sciences research listed in task book online
- Improved access of the scientific community to samples and data collected from astronauts via central networks
  - Data Sharing Policy released March 2012
- Foster interactions with the commercial flight providers that address research needs
  - Discussions underway identifying upmass and downmass
  - Biological specimen requirements in negotiation; first rodent transport to ISS Sep 21
- Leadership with scientific gravitas and well position in organizational structure
  - IPA recruited with experience in flight experiments and well respected in the community
- Strong leadership with authority over a dedicated research stream
  - ISS Research budget is dedicated to SLPSRA Division
- Positioning of leadership to allow conduct of necessary research programs as well as interactions, integration, and influence within the mission-planning elements
  - New division dedicated to Life and Physical Sciences Research established in the Human Exploration and Operations Directorate - Established a ‘seat” at the table

Life Sciences - CSC/TCAT Decision Memo

Summary: The Mission Support Council met on July 10, 2014 and evaluated a decision package on the disposition of the internal capability and corresponding workforce for Life Sciences Research at NASA. Life Sciences in this package only refers to the research into living systems and includes ground based laboratories and equipment to support that research. Disciplines of NASA life sciences include: space biology, human research, crew health and safety — all sponsored by HEOMD; and research using living systems within the Astrobiology and Planetary Protection Programs — sponsored by SMD.

The Mission Support Council made the decision after consultation by the recommender with the following stakeholders, and several others, based on the data and analyses provided.

- Affected Center Directors: ARC, GRC, JPL, JSC, KSC, LaRC
- Affected Mission Directors: HEOMD, SMD, STMD
- Affected Independent Technical Authorities: MSD, OCS, OCHMO, NMO

Decision: Based on this review, the Mission Support Council decided to:
Establish the Life Sciences Research Capability which includes the full range of life sciences research — from fundamental research to applied research. This decision does not include medical operations or human system integration into space flight planning under the banner of Life Sciences Research.

The Life Sciences Research Capability includes the Astrobiology and Planetary Protection research using living systems, sponsored by SMD, allowing for collaboration and advise across the Agency's life sciences efforts.

This decision is based on the new Capability Leadership Model (subject memo: Agency Technical Capability Leadership Plan: Institutionalizing TCAT Effort; April 24, 2014).

(Continued on next page.)

Concurrence this decision was reached in compliance with Mission Support Council procedures:

R. Keegan, ADA, Chair / AA MSD

R. Lightfoot, AA

B Robinson, CFO

concurred telephonically
T. Wilcutt, Chief S&MA

L. Sweet, CIO

Life Sciences - CSC/TCAT Decision Memo

Decision: Continued

Specific roles implementing the Life Sciences Research Capability are noted here:

- Advises Agency and ensures proper alignment across Missions and Centers consistent with Agency and capability advancement needs.
- Establishes plans/roadmaps to provide technical guidance to the Agency in the identification and prioritization of tasks necessary to enable discipline-level and system-level performance for future missions.
- Determine gap areas for advancement and strategic investment.
- Advises on capability sizing and strategic hiring, including contracting, across all Centers, so as to avoid Agency excess capacity, duplication in a capability area, or excessive contracting of intrinsic NASA technical capability areas.
- In coordination with existing programs, determine investments and divestments within capability scope, including advising Centers on assets, and coordinates with other capability areas so as not to duplicate scope between areas. Assess balance between intramural research and extramural research and potential new management models.
- Solicits innovative ideas from outside the capability area, related to such things as technical content, new approaches, workforce skills, asset use, and disposition.
- To maintain the linkage of life sciences research to overall human system risk mitigation.

This decision focuses on: a) enhancing communication among Life Science researchers; and b) providing advice to the affiliated program or project managers. However, tailoring of the roles of the Life Sciences Research Capability will be required, e.g., to figure out how best to coordinate the role of program investment decisions with programs (HRP, Fundamental Space Biology, etc.).

To enable the capability leadership roles and foster collaborative dialogs and knowledge exchange, the Life Sciences Research Capability will be led through the Office of Chief Scientist (OCS) as advised by the Office of the Chief Health and Medical Officer.

Summary

- January 2011 -HEO SLPS Division formed
- April 2011 -Decadal released
- July 2012 - Response to decadal
- Integrated plan in work
- Great progress to date

What Keeps me Awake at Night

- Budget
- SLPS participation with platforms other than ISS
- How does ISS commercialization play into the future of SLPS?
- SLPS post ISS – Need a forward plan

Backup

Experiment Acronyms

ACES	Atomic Clock Ensemble in Space
BASS	Burning and Suppression of Solids
CFE	Capillary Flow Experiment
CCF	Capillary Channel Flow
CVB	Constrained Vapor Bubble
EHD	ElectroHydroDynamic flow experiment
HPE-L	Heat Pipe Experiment - Loop
FAMIS	Formulation of Amorphous Metals in Space
FBCE	Flow Boiling and Condensation Experiment

MsFHT	Multiphase Flow And Heat Transfer Experiment
MVCS	Morphological study in Variable Cross Section
MWT-FS	Microgravity Wind Tunnel - Fire Safety
PBRE	Packed Bed Reactor Experiment
PBRE-A	Packed Bed Reactor Experiment - Applied
PBRR	Packed Bed Reaction Rate Experiment
SoFIE	Solid Fuel Ignition and Extinction
TPFSE	Two Phase Flow Separator Experiment
ZBOT	Zero Boil-off Tank Experiment