

National Aeronautics and Space Administration

**NASA ADVISORY COMMITTEE [NAC]
ASTROPHYSICS SUBCOMMITTEE**

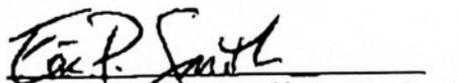
September 14-15, 2006

**L'Enfant Plaza Hotel
Washington, D.C.**

MEETING REPORT



David Spergel, chair



Eric P. Smith, executive secretary

Report prepared by
Mark Bernstein, Consultant
INFONETIC
October 20, 2006

NAC Astrophysics Subcommittee
Washington, DC
L'Enfant Plaza Hotel
Quorum Room

September 14-15, 2006

Agenda

Thursday, September 14:

9:00 a.m.	Science Plan Update	M. Salamon
9:30 a.m.	Science Plan Discussion	D. Spergel
10:45 a.m.	Coffee	
11:00 a.m.	GLAST Update	S. Ritz
11:30 a.m.	JWST Update	P. Sabelhaus
Noon	Science Talk Lunch	M. Markevitch
1:00 p.m.	Division Update	R. Howard
2:00 p.m.	Division Update Discussion	All
2:45 p.m.	SMD EPO Status	M.-Y. Wei
3:30 p.m.	Coffee	
3:45 p.m.	Committee Discussion	All
5:30 p.m.	Adjourn	

Friday, September 15:

8:30 a.m.	Public Comment	
9:00 a.m.	STScI Astrophysics/Moon	M. Livio
9:30 a.m.	Lunar Science Workshop Update	TBD
10:00 a.m.	Lunar Science Discussion	D. Spergel
10:30 a.m.	Coffee	
10:45 a.m.	Lunar Science Discussion [continued]	
11:30 a.m.	HST/SM4 Update	P. Burch/D. Leckrone
Noon	Lunch	
1:00 p.m.	Kepler Update	P. Marcum
1:30 p.m.	International Missions	R. Howard
2:00 p.m.	Balloon & Rocket Programs	V. Jones
2:30 p.m.	Discussion/letter writing	
4:00 p.m.	Adjourn	

INDEX

Update to Science Plan – Michael Salamon	4
GLAST Update – Steve Ritz	7
JWST Update – Phil Sabelhaus	8
Astrophysics Division Update – Richard Howard	9
Status of SMD EPO – Ming-Ying Wei	12
Subcommittee Discussion: Science Plan	14
Public Session	16
STScI Astrophysics/Moon – Mario Livio	16
Lunar Science Workshop Update – Brad Jolliff	18
Hubble Telescope – David Leckrone/Preston Burch	20
Subcommittee Discussion: Recommendations	21
Kepler Update – Pam Marcum	23
International Collaboration – Richard Howard	23
Balloon and Rocket Programs – W. Vernon Jones	25
Subcommittee Discussion: Recommendations	25

Appendices:

Appendix A: Membership, NAC Astrophysics Subcommittee

Appendix B: Meeting attendees

Thursday, September 14, 2006:

Meeting convened at 9 a.m.

Opening the meeting, Eric Smith, executive secretary, noted that as it was a FACA [Federal Advisory Committee Act] session, audience members must be called upon prior to speaking.

* * *

Presentation:

'Update to Science Plan'
Michael Salamon
Astrophysics Division

Michael Salamon reported that Science Plan Version 3.5 had been recently completed. Version 4.0 was due October 6. Version 3.5 listed JWST [James Webb Space Telescope] as the highest priority; HST [Hubble Space Telescope] SM-4 was second. The 'big news' was the reinstatement of SOFIA [Stratospheric Observatory for Infrared Astronomy]; the SIM [Space Interferometry Mission] text and launch date were unchanged. Asked about funding, Salamon reported that SIM was funded in the House of Representatives version, but not in the Senate version. While what would happen after FY'07 was unclear, the current plan kept options open. Salamon noted addition of Section 7.4.3, 'The Discovery Program,' and smaller changes. He reported that NAC [NASA Advisory Committee] had requested information on anticipated 10-year outcomes; Version 3.5 did not as yet include this.

David Spergel suggested discussion begin with high-level comments. Spergel noted that the NAC Science Committee would have a new chair and three new members at its October 10-11 meeting; he believed it would welcome the subcommittee's general assessment of how things stood. Second, he noted a September 19 meeting with Mary Cleave, associate administrator, SMD [Science Mission Directorate] and division directors to secure their approval of Table 2.2.d. Spergel reported that he had been briefing the Science Committee on the subcommittee's thinking.

Robert Kennicutt welcomed SOFIA's return; otherwise, nothing would fly in 2013. He added that Japan and ESA [European Science Agency] had multiple missions in this period. Michael Salamon reminded the group that launch dates were moving targets. The Explorer program was discussed, with two such missions anticipated in the next decade. Michael Salamon said this assumed that half of all Explorer missions were astrophysics; half, heliophysics. Responding to Eric Smith's question, Salamon said the Science Plan's timeline included missions entering formulation by 2016; the second and third Beyond Einstein missions were not included, which complicated discussion of the 10-year outcomes.

Eric Smith noted the low astrophysics launch rate for this and the subsequent decade. Michael Salamon reported that the timeline as presented was consistent with the budget. Belinda Wilkes noted that ST7 was not on the timeline; Salamon said it should probably be included. Wilkes noted ST7s scheduled launch date of 2015; did the budget profile reflect this? Salamon said not; he had no budget information beyond 2013. Wilkes said the ordering of the Beyond Einstein #2 and #3 did not follow the decadal survey's sequence; Salamon acknowledged this, but

said missions that far off were speculative. Wilkes said stating them 'in black and white' made them appear definite.

On mission sequence, Kathryn Flanagan noted that, of five pending missions, only one possible ordering did not conflict with the National Academy priorities list. Otherwise, the second Beyond Einstein would fly after TPF [Terrestrial Planet Finder], which involved doing a lower ranked mission first. Table 2.2.d, she noted, specified the launch date of TPF relative to the Einsteins. Salamon observed that the dates for TPF – beginning in 2016; launching in 2018 – were an error that had been corrected.

Kathy Flanagan noted that, of the five proposals being competed for first place, only three were receiving mission money: she thought this an unfair competition. Michael Salamon agreed, noting JDEM [Joint Dark Energy Mission] would receive concept study support. Christopher McKee said pushing the SOFIA launch date to 2010 was 'a disaster;' he believed the subcommittee should press to speed it up. Craig Hogan said while the chart under review gave scheduling information, it would not indicate to Congress where major expenditures would occur: could a 'three-dimensional' chart be created showing funding requirements? Salamon termed this an interesting suggestion. Richard Howard noted that the President's Vision on Space Exploration supported the search for earthlike worlds with progressively larger aperture telescopes: should this statement be incorporated? Salamon asked Howard to review and comment on the pertinent paragraph.

Neil Cornish said the plan included 'ghost missions;' a 'reality check' was required. He recommended a clearer statement of what would be done in the next decade. Salamon said the only missions listed on the chart that were not on the timeline were three of the five remaining Beyond Einstein missions. Responding to a question, Salamon said the chart was consistent with a level budget. Cornish questioned including missions whose initial development might be 'sneaked in' just before 2016. Salamon said that development money was currently going to LISA [Laser Interferometer Space Antenna], CON-X [Constellation-X] and JDEM [Joint Dark Energy Mission]; the plan, at present, was to provide technological support to these missions, if only at 'starvation levels.'

Robert Kennicutt asked if the development funding was in place to allow the 2010 decadal survey to set reasonable priorities. At present, Michael Salamon said, Con-X and LISA funding were suffering, but technology support for them would be ramped up. Belinda Wilkes suggested that Table 2.2.d and the budget statement were not consistent, and should be made so. Salamon restated that the two were consistent as presented.

David Spergel summarized points raised thus far; including: concern about the launch rate; the launch order of TPF and concern for its implementation; the SOFIA launch date; the rate of Explorer missions; and the need to link the President's statement to the subcommittee's plan. He added that the document should emphasize that many exciting possibilities existed, but due to resource limits only two of the five missions could be implemented. He added that the astrophysics community needed to know whether SIM was in the program.

Michael Salamon said discussions of the President's Vision Statement included considerable emphasis of possible lunar science, including ideas not vetted by the astrophysics community or by the National Academy: what should be said about them? Alan Dressler [by speakerphone] suggested saying these were things a continued lunar presence could support. David Spergel did not wish the subcommittee to endorse ideas that had not been thoroughly discussed. The NAC wished to know astrophysics' role on the moon and with the President's Vision for Space Exploration. Michael Cherry said budget uncertainties made discussion of the

decadal survey problematic; cost questions on lunar ideas were vaguer still: this should temper their discussion. An audience member called attention to two 'guiding documents:' the Space Act and the President's Vision for Space Exploration. He thought it likely senior White House personnel would ask how the subcommittee planned to implement these. Salamon suggested including a section to address that point. Kathryn Flanagan endorsed this approach. Salamon posted the relevant science plan passage, noted that it did not have language from the Vision Statement, and added that it should.

David Spergel noted that the NAC was seeking the subcommittee's recommendation on two matters: the lunar program and JWST. He invited further discussion. Asked about the Beyond Einstein competition, Spergel said NRC [National Research Council] was currently looking for membership; this was being fast-tracked. The competition, Michael Salamon said, would choose the first mission, but not prioritize further; that would come in the decadal survey. Kathy Flanagan said delaying selection of the second Beyond Einstein until after the decadal survey presented problems; perhaps the subcommittee should request that the competition make the second choice. Asked if sufficient budget information existed to do this, Flanagan said that unless the later Beyond Einstein missions were adequately costed this year, the National Academy could not rank them in any case. Michael Salamon said sufficient time did not exist for the JDEM concept studies, particularly on cost v. science return. Christopher McKee said the current plan of allowing the decadal survey to do the next prioritization was the correct one. Eric Smith said detailed cost studies could occur only when detailed proposals were completed. Alan Dressler questioned the value of cost estimates made by people promoting the project in question. McKee agreed; the subcommittee should push NASA personnel on their estimates. The quality of an estimate, he added, reflected the level of program investment at the time of the estimate; generally, estimates should be made once 10 percent of program costs were incurred. Often, estimates were made well before that. Dressler suggested all estimating be done by a single entity.

Neil Cornish observed that review of the three JDEM proposals was charged to include technical readiness, but readiness of what? The projects entailed various components with widely differing states of readiness. Michael Salamon noted that one goal of JDEM concept studies was to see what science could be produced for \$600 million, as opposed to \$1.2 billion; it was not clear how that question stood. Marc Allen [NASA headquarters] noted that the November Space Studies meeting tentatively planned to consider how decadal surveys could be improved; costing was likely to be included. He noted a general question of how to address costing when there was disparate information on missions.

Christopher McKee noted Science Plan discussion of R&A [Research & Analysis]. This had been dramatically reduced; it would be useful to learn plans for its future. David Spergel said that the balance within R&A should be reviewed prior to the next decadal survey; this would educate other parts of NASA by calling attention to the range of compelling things being considered. He noted that UWG [Universe Working Group] was considering this. Michael Cherry reported that UWG, at its April meeting, had departed from usual procedure to discuss the general importance of R&A. In April, the astrophysics subcommittee had requested UWG for suggestions on year-to-year levels of R&A funding. Spergel welcomed UWG's thoughts on whether R&A funding should receive a Senior Review.

Discussion returned to the Science Plan. David Spergel noted the conflicting recommendation for TPF: the National Academy ranked it third; the Vision Statement ranked it higher. This needed discussion. Craig Hogan noted that SIM remained a question. Spergel agreed it needed discussion.

* * *

Presentation:

'GLAST Update' [Gamma-ray Large Area Space Telescope]

Steve Ritz

Project Scientist

Steve Ritz said GLAST was a five-year mission [with a ten-year goal], with launch set for October–November 2007. GLAST would permit viewing of 20 percent of the sky with a 30x improvement in sensitivity. GLAST would undertake a broad menu of science: systems with super-massive black holes; gamma-ray bursts; pulsars; solar physics; origin of cosmic rays; probing the era of galaxy formation; solving the mystery of high-energy unidentified sources, etc.

Ritz said the project's overall contingency had been exhausted; several milestones must be reached before full contingency requirements could be determined. On September 25, the project would go to headquarters for re-baselining. He noted that, after the first year, the observation plan would be driven by peer-reviewed guest observer proposals; no data would be proprietary. He reported that a GLAST fellows program, three selected annually for three years, would begin in 2007. He reported that GLAST data would be such a leap forward that the project was keen to encourage new thinking on its use. He noted the first international GLAST symposium, Stanford University in 2007: <http://glast.gsfc.nasa.gov/science/symposium/2007/>.

Discussion:

Christopher McKee noted decadal survey language that new missions should incorporate theory challenges: what was GLAST doing in this regard? Ritz said the selection of the IDS's reflected this; further, a number of theorists were affiliated scientists on the LAT [Large Area Telescope]. McKee said he believed GLAST could afford important opportunities for persons doing theory work. Craig Hogan asked about science funding from the DoE [Department of Energy]. Steve Ritz said the particle physics community did not have an open investigator program; participation for DoE-funded and GLAST scientists would primarily come through cooperation in the instrument teams. He did not have FTEs on the numbers engaged. DoE had contributed \$40 million toward the construction of the LAT. Overall funding was about one-half from NASA; GLAST was a NASA-led effort.

Steve Ritz noted that beginning in the second year, the observatory could be pointed, e.g. at particular flaring objects. The standards for successful pointing proposals were being determined; perhaps 20 percent of available time would be reserved for these. Robert Kennicutt urged that training on proposal submission be offered to those outside the community; such training should begin well before the submission deadlines. Ritz welcomed this suggestion. Lucy Forston noted the representation from the ground-based community; were further formal relationships being developed. Steve Ritz said not at the mission level. Forston noted that for the first year ground based observatories enjoyed a special status. Ritz commented that the place for interaction was in selection of the first year's list; if serendipitous sightings merited attention, these could be added without bumping anything else.

* * *

Presentation:

'JWST Update' [James Webb Space Telescope]

Phil Sabelhaus
Project Manager

Phil Sabelhaus defined JWST as a deployable infrared telescope with a 6.5 meter diameter segmented adjustable primary mirror. It is a cryogenic telescope with instruments for infrared performance. The five-year mission [with a ten-year goal] is scheduled to launch June 2013. He identified the 18 mirrors involved as JWST's critical path; each takes four years for production and assembly. Assembly is currently occurring at two sites. Sabelhaus reported current JWST projected pending at \$90-\$100 million a year, for both mission operations and science operations after launch. He noted that the NIRSPEC microshutter engineering unit had failed their acoustic test; the light-shields around the microshutters were being redesigned and he expected the problem would be solved by December.

Discussion:

David Spergel asked if Phil Sabelhaus believed JWST's budget 'mountain' would descend soon. Sabelhaus said he did, noting that project contingency levels were high and considerable money remained to be allocated. Christopher McKee asked about provision in JWST for theory challenges? John Mather said there was no specific provision. Eric Smith noted that when money was identified in a budget specifically for theory challenges, the funding tended to get removed. He suggested theory challenges might need a better way to fit within the program for them to withstand budget pressure.

Phil Sabelhaus was asked why JWST was seeking to advance its PDR [Preliminary Design Review] from March 2008 to September 2007. Sabelhaus said the earlier date would force closure on various project objectives; further, it would constitute a 'good faith commitment' to the broader community that JWST would adhere to its funding level. Craig Hogan asked how the JWST budget was split between NASA and other sources; Sabelhaus termed this 'a little fuzzy,' but that 20 percent of the budget total was for NASA activities and personnel.

Responding to Alan Dressler, Phil Sabelhaus said a half-scale test of the sunshield was scheduled for August-September 2009; the sunshield would be deployed in a chamber: while this would not duplicate the gravity of space, temperature conditions would be similar.

Neil Cornish suggested the budget 'mountain' was peaking much earlier before launch than was common: if, as often happened, the 'mountain' moved, the impact on other NASA science would be enormous. Sabelhaus replied that, because the CDRs [Critical design Reviews] for most major JWST items preceded that peak, he regarded the budget curve as fairly typical. Alan Dressler [speakerphone] said he believed JWST had low reserves; what was the consequence if risks materialized over the next year? Sabelhaus said the project had been managed successfully through low reserves for 2006, and had a plan for 2007. Headquarters had addressed this question for 2008 and 2009; the review team had expressed satisfaction with the reserves level. Additionally, he noted the program had eight months of funded program reserves.

Robert Kennicutt asked if Sabelhaus could rule out major 'slips' while JWST was near peak expenditure. Sabelhaus said he could; because of technology investments, any slips would occur in later, less expensive years. He identified two concerns in those years: first, that JWST would take more time; second, that project

employment would not decline. Available contingencies could address either or both. In his experience, Sabelhaus said missions were likelier to take longer than to require more money in a given year; he noted that the budget for JWST's final three years contained 60 percent for contingencies.

Alan Dressler said it was 'vital' that JWST's components be tested and integrated. Sabelhaus agreed; that was why the project was building mirrors in parallel with multiple machines at the manufacturing sites; this was consciously undertaken so all hardware would be completed, allowing integration to follow. Dressler asked if ISIM testing would be delayed until all project instruments were completed. Sabelhaus said almost all testing could be done so long as the NIRcam was available; if the NIRcam was unavailable, the project had surrogates it could use.

* * *

Presentation:

'Astrophysics Division Update'
Rick Howard
Acting Director, Astrophysics Division

Richard Howard reported the following as having occurred since July 2006.

SOFIA had been reinstated; management of the science and of the aircraft is being moved to Dryden: the primary focus was now on getting the aircraft flying and tested. Christopher McKee asked why the first SOFIA science mission had been postponed. Howard replied that SOFIA had a history of cost over-runs; there was a need to get 'our arms around' the program. Further, the original plan of 30+ test flights of 8-10 hours each was not realistic given that the airplane had not flown in six years and was undergoing major remodeling; a schedule of 100 shorter flights was more likely. He suggested flights might start before all instruments and operational capabilities were in place, with instrument capability completed in stages. Michael Cherry asked how this altered schedule affected budget; Howard said the near-term estimates were no different from those of April 2006. He wished to optimize science community involvement to produce the best scientific return on the substantial sums involved.

Additional topics:

Kepler had completed its replan continuation review; launch had been delayed five months until November. The project's budget needed adjustment: funds had been pulled in FY'05; additional funds were needed for FY'07. This was being discussed with OMB [Office of Management and Budget]; he hoped it would be resolved within ten days.

The Astrophysics Division Directorship was being advertised. Applications would be accepted for two months. He expected the position to be filled prior to selection of the new associate administrator for Science Mission Directorate.

The GLAST LAT had successfully completed its thermal vac and next goes to Spectrum Astro in Arizona.

The WISE [Widefield Infrared Survey Explorer] team and PI [Principal Investigator] had been given a budget profile and program direction.

SPITZER went into safehold in August 19; nineteen days of science had been lost, but this will be picked up. For uncertain reasons, the on-board circuitry had switched from A side to B side; after review, the decision was to stay on B side. There is no reason to believe anything is wrong on the A side.

On JDEM, three concept studies were selected on August 9 for two-year study; in early August, NASA and DoE had made the requested joint report on JDEM to Congress.

Beyond Einstein: the NAC was reviewing all five Beyond Einstein elements to determine, from a science and readiness perspective, which should go first.

Exo-Planet Task Force: NSF, NASA and the NAC chairman are in discussion on its charter and requirements for launching. The task force will be ground-based, space-based and international in scope.

Discussion:

On the Beyond Einstein review, Craig Hogan noted that NAC generally assessed science, not readiness. Richard Howard said while this was true, NAC also considered questions of cost and mission. He expressed concern with an 'apples and oranges' review: LISA and CON-X, had received considerable support, the others had not; maturity levels varied. Tom Greene [speakerphone] asked whether discussions on the refocusing of Navigator would await the report of the Exo-Planet Task Force. Howard said that the task force's report was a year away; he did not intend to wait. The rebalancing of Navigator was in progress.

Richard Howard noted it was NASA Administrator Michael Griffin's view that FY'07 funds for SOFIA would come from SIM; this had the effect of pushing SIM into the future. [He noted House of Representatives approval of SIM funding at the President's requested level.]

Robert Kennicutt said JWST had 'a very aggressive funding profile;' any slip would have serious implications for other NASA ventures. Richard Howard said the figures presented by JWST had been presented to Congress; considerable discussion ensued on their realism. Until the NAR [Non-Advocate Review] in March 2008, the agency would make no solid decision on funds required and launch date. Responding to Kennicutt's question, Howard said he believed JWST could be held to its funding peak.

On Beyond Einstein, Michael Cherry said assessment of the probes would be difficult, as these had received little funding thus far. Richard Howard agreed; the division needed to do what was possible on science and mission design and 'bracket' the cost and readiness issues for each. Howard said the ranking had two purposes: first, to provide NASA with input on priorities; second, to provide input to the decadal survey. The review should be provided with all possible options; the review would prioritize the science, not the mission – NASA and DoE would jointly resolve mission selection. Responding to Kathryn Flanagan, Howard said that whatever Dark Energy mission was selected, it would be competed, though probably not as a PI mission. Flanagan asked the effect on Beyond Einstein if a probe or Great Observatory went first; Howard said that question was too far off. Robert Kennicutt commented that the best way to measure Dark Energy was separate from whether

the way selected was worth the \$1.2 billion it would entail: would NRC assess the full Beyond Einstein suite? Eric Smith said he believed so. Michael Salamon said the questions required that a global view be taken. Howard said while the assessment was pre-decadal, it would be input into the decadal survey.

Christopher McKee asked if the relationship between SOFIA and SIM could be clarified at the subcommittee's next session; Richard Howard said that awaited Congressional budget action. David Spergel identified three outcomes for SIM: that it gets built; that it gets cancelled, or 'worst,' that it continued without getting built. Howard said SIM had the technology development and maturity to move forward; funding to do so did not exist. The question was: what funding should be maintained until a decision was reached. McKee suggested the next subcommittee meeting be delayed until Congress had produced a budget.

Dennis Ebbets [audience] noted that both the House and Senate FY'07 funding bills provided DoE with money for JDEM and instructions to proceed: was there a NASA response to this? Paul Hertz noted it was not NASA's position to comment on DoE.

David Spergel asked Richard Howard for a 'fever chart' on astrophysics activities. Howard said GLAST was 'yellow;' JWST was 'green;' and the Hubble servicing mission was 'green.' SIM, 'obviously,' was 'red.' TPF was 'green.' Beyond Einstein was also 'red.' KEK was 'red, and has got only redder.' Kepler was 'yellow;' WISE was 'green.'

On SOFIA, Martin Harwitt [audience] termed it 'fairly remarkable' that the aircraft required another four years to be fully operational: was the problem the work required or funding? Richard Howard said both were at issue; the original schedule had been completely unrealistic. The first priority was getting the aircraft up and flying; to do this, some instrument work would be deferred. He noted the SOFIA involved the largest modification ever made to a Boeing 747. Responding to Harwitt, Howard said a second opinion, sought from an Independent Review Team that included Boeing's chief test pilot, concluded the 2008 date was not feasible. The 2011 date also reflected adding scheduled reserves to the timeline; that deadline might be brought forward a year.

Considerable discussion followed on whether the ordering in the Science Plan and the decadal survey were consistent. Michael Devirian [audience] made reference to a January 2004 Vision for Space Exploration document stating as a goal: 'to conduct advanced telescope searches for earthlike planets and habitable environments around other stars;' this, he thought, figured into the decadal survey statement on sequencing. Asked to comment on the 'differing priorities' established by the President and National Academy, Richard Howard said the President's statement did not establish the priority of missions to accomplish that science. Richard Howard was asked how a 2018 launch date for TPF could be reconciled with its current zero budget. Howard said, first, he did not plan to keep that budget at zero; second, significant progress had been made in technologies related to TPF. He believed TPF's launch date could be reached even if funding did not begin until 2012.

Responding to Neil Cornish, Richard Howard said the division was 'absolutely engaged' in coordination with ESA [European Science Agency] on missions where a partnership was involved.

Responding to Craig Hagan, Eric Smith said that with the termination of the Strategic Roadmaps, the division would return to making three-year rolling plans.

Responding to Lucy Forston, Greg Williams [audience] said the chief purposes of the Science Plan were, first, to respond to the Congressional authorization package, identifying the important science questions, the missions, the priorities, and the rationales for those priorities; and, second, to respond to the NASA strategic plan with a strategic document at the enterprise level. Robert Kennicutt suggested

that, given the lengthy discussion the mission sequence language had prompted, some 'wobble words' be inserted on the notional nature of plans for the second decade.

* * *

Presentation:

'Status of SMD EPO' [Education and Public Outreach]

Ming-Ying Wei

Ming-Ying presented the 'NASA Education Strategic Coordination Framework.' The strategic framework was to inspire, engage, educate and employ [workforce issues]. She noted that NASA has educational activities at the elementary and second level, with higher education, and with the general public. She reported that for some while, NASA education activities had not been well-regarded by OMB. Work had been done with OMB to identify outcomes: one key outcome was the development of a competitive workforce, which required attracting students to and retaining them in the STEM [science, technology, engineering, mathematics] disciplines. She presented plans for EPO's reorganization.

Discussion:

Lucy Forston noted that, as presented, the four division support groups were organizational in nature, lacking programmatic budgets. Currently, the Universe Forum had programmatic funds, allowing it to cross-cut various missions. Producing the CD 'Beyond the Solar System' would have been difficult had its creators been obligated to go from mission to mission. Larry Cooper [audience; SMD EPO] said the idea was to separate programmatic activities from their supporting activities; nothing prevented cross-divisional activities. Paul Hertz commented that, currently, no real evaluation of the forums was possible. While acknowledging this, Forston cautioned against 'throwing the baby out with the bath water.' Hertz added that determining what infrastructure should integrate and coordinate the directorates required careful thought; a distinction was needed between programmatic ideas and those who facilitated them. Ming-Ying Wei said that absent cross-mission competitive opportunities, there was no way for individuals to collaborate.

Student collaboration was discussed. David Spergel reported that college students worked in his program following their freshman year; the intent was to 'bridge' their interest through their junior years. Lucy Forston reported the one-half of female freshman science students left the field before becoming juniors; further, that while the research post-freshman year students did might have little scientific value, it was of great value to the student. Ming-Ying Wei said this was an important point. Neil Cornish suggested that science education was an activity well-suited to undergraduates.

Larry Cooper noted that NASA education programs funded student internships. Craig Hogan asked how the NASA Space Grant program tied to this; Cooper said EPO encouraged participation; Space Grants were an excellent leverage for other funds. EPO presented workshops on how to write successful proposals; failed applicants were invited to sit in on review panels to better understand the requirements. Ming-Ying Wei said the Space Grant program was being transformed; some program aspects would be changed.

Discussion ensued on student participation in missions. Ming-Ying Wei noted that the Discovery AO [announcement of opportunity] had previously had a baseline

policy of 1.0 to 2.0 percent for EPO, mission costs less launch costs. The new policy was 0.25 to 0.50 percent, though this could be raised to 1.0 to 2.0 percent if the proposal included student collaboration; the proviso was that such participation could not be in critical path activities. She reported her impression that such involvement was a good thing, particularly in earth science. She noted that collaboration involved students at all levels, with the proviso that it involve age-appropriate activities.

Lucy Forston said not all missions had appropriate collaborative possibilities; she expressed concern that 'everyone was being forced' into a single approach. Paul Hertz said it was an opportunity; not a forcing. To date, he added, few AO proposals had included student collaboration. A key EPO objective was to keep the most qualified students in the pipeline; student participation in spacecraft would contribute to that. Forston said she had objection if the AO language stated that a cap would be available for 'pipeline' work; however, she did object if the expenditure had to be mission specific and specifically related to undergraduate and graduate students. Ming-Ying Wei said the language did not specify graduate or undergraduate, only that it must be a valuable contribution. Hertz said the language could be reviewed as perhaps overly restrictive. He said programmatic constraints would always exist: when funding was designated specifically for educational purposes, it was often taken away. Kathryn Flanagan said that boosting EPO expenditure to 1.0 to 2.0 percent to involve students had the effect of directing the program in that direction.

Discussion ensued on fellowships. Ming-Ying Wei described the pending launch of NASA Earth and Space Science Fellowships. In the past, the NASA Graduate Student Researchers Program had had 60 students, 20 students selected a year for three years. The Earth System Science Fellowship Program had about 150 slots. Robert Kennicutt asked if outcome statistics existed for student participants. Wei responded that the heliophysics branch tracked this informally; all were gainfully employed. Elsewhere, a majority were working in government research or academia. No effort had been made to track fellowship recipients' career paths against those for research apprentices to professors.

Queried by Michael Cherry, Ming-Ying Wei said each division would decide how many fellowships to offer. Richard Howard said astrophysics would maintain its previous level: nine positions through the R&A budget and three from division reserves; four each year for three years. Robert Kennicutt suggested that 'a lot of hours were being burned' in overhead to operate a small program: four slots were not as good as fifteen, but perhaps it was not as good as none. Christopher McKee expressed opposition to taking R&A funds to expand this program.

Discussed ensued on general EPO activities. Christopher McKee said he believed NASA public outreach funds spent on Hubble were extremely valuable; persons present would likely support that expenditure over transferring those funds to R&A. Was there, however, a process for assessing whether funds should go to science or EPO. Ming-Ying Wei said no detailed examination had been made. Kathryn Flanagan said an EPO expenditure of 0.33 to 0.50 percent might be insufficient; however, that did not mean it should be raised. She directed an EPO program; however, EPO might not be the proper priority at a time when scientists were being let go: perhaps the astrophysics fellowship program could no longer be sustained. Flanagan said it might be unfair to train a new instrumentalist when job prospects were bleak. Fred Lo warned against assuming that people being trained could only do one thing; a decade ago, he added, it was asserted there were too many astronomers: now, astronomers were in demand because their training was useful in other fields. David Spergel expressed agreement with Lo. Craig Hogan said NASA must inform the public to maintain public support for NASA activities; EPO was needed to do that.

Robert Kennicutt said NASA was living off 'the coattails' of the enormous public awareness of Hubble. He noted that when he was in China, and needed to explain what an astronomer was, all he needed to say was Hubble. Kathryn Flanagan noted that JWST would start just as Hubble was winding down.

Lucy Forston suggested discussion was needed of the strategic impact of EPO, but that this discussion was not occurring. Given the Science Plan's deadline, was it possible to complete a reasonable strategy at this time? Ming-Ying Wei suggested more space was needed if such a strategy was to be presented. Forston asked if the subcommittee should make such a recommendation. David Spergel asked if there would be value to creating an EPO working group that spanned the four science groups. Wei said she would welcome the opportunity. Michael Cherry said a number of philosophical questions were involved: while a full review would be valuable, he did not think it was needed for the Science Plan. Forston said the Science Plan provided an important audience. David Spergel commented that if he as a reviewer encountered a \$70 million expenditure, he would want to be able to learn the return on the outlay. Wei said she believed some additional work was required for the EPO section of the science plan.

* * *

Subcommittee Discussion: Science Plan

David Spergel commended the GLAST report, but said he had no specific recommendation.

On JWST, David Spergel said he believed the community would be more comfortable if the PDR [Preliminary Design Review] and the NAR were held sooner. Neil Cornish said completion would raise confidence in the project's budget projections. Spergel said he believed the NAC would welcome a JWST recommendation. Robert Kennicutt asked if JWST was under threat; if so, perhaps the subcommittee should state its support. Spergel noted that JWST was the largest current program; Jack Schmitt [chairman, NAC] wanted to see its cost overruns halted and reversed.

Kathryn Flanagan asked how JWST's costs aligned with other Great Observatories; she noted that \$90 million a year was planned for JWST operations. Spergel said that was not out of line given mission size; operation costs were generally five to ten percent of the total. Alan Dressler said he doubted the subcommittee was in a position to address the issue. Spergel said he did not wish to make a JWST recommendation, as the subcommittee had not reviewed its operations. [It was noted that the subject of lean operations for Hubble could be addressed at the following day's Hubble presentation.] Clarifying, Spergel said the subcommittee's recommendations were addressed to the NAC Science Committee; adding that communication was both formal and informal.

David Spergel asked if the subcommittee endorsed creating an EPO working group that would cross all subcommittees. Lucy Forston volunteered to take part. Further, she urged that the AO language on extra EPO expenditures be changed to be more welcoming of student collaboration; Spergel asked her to draft a recommendation.

Christopher McKee noted Richard Howard's comment that Navigator was 'a shambles'; he sought further information on this. Eric Smith said that at its next meeting, the subcommittee would likely hear reports on Navigator and Beyond Einstein. At Kathy Flanagan's suggestion, David Spergel said someone from the National Academy's Beyond Einstein assessment could report on its work.

John Mather urged that the language of the Vision for Space Exploration be reflected in the Science Plan; Christopher McKee termed this 'extremely important.' David Spergel suggested that something be written on that.

Craig Hogan termed SIM 'the elephant in the room.' David Spergel cited two issues: the science plan draft did not recognize the budget implications; and, the plan was written as if SIM was in the budget, which it was not. Neil Cornish urged 'truth in advertising,' with SIM and with the ten-year achievement section. Alan Dressler said it was not the group's wishing to do SOFIA *or* SIM; rather, it was a question of timeline. Responding to Robert Kennicutt, Spergel provided background on the SIM decision: at their last meeting, Administrator Michael Griffin had announced that SIM was being downgraded to technology development status. Kennicutt said the question should not wait until the decadal survey; could the subcommittee play a role? Spergel said the SIM decision might involve a trade – possibly, if SIM was restored, SOFIA was killed. He thought it best to start that discussion now. Alan Dressler suggested the decadal process was being taken too literally; perhaps it should be stated that dates approaching 2020 were notional. Craig Hagan said the issue was one of making good programmatic decisions now. Dressler said that priorities had not as yet been changed; the group was not empowered to drop or re-order missions. Dressler added that he did not believe the Administrator would welcome the subcommittee's advice; these were not the subcommittee's choices. The committee's lists did not represent choices; they were to 'do everything until it ran out of time and money.'

David Spergel said that science related to SIM had changed considerably; did this push it up or down the list? Robert Kennicutt said the subcommittee should urge that a decision, either way, be made. Spergel said that keeping SIM on 'life support' would cost \$100 million a year; was Congress saying it was worth being kept on life support, but not worth completing. Neil Cornish said the subcommittee had endorsed the Administrator's decision; at that time, however, the sum discussed was considerably less. Spergel, clarifying, said the House had not appropriated an additional \$100 million for SIM; it had directed how \$100 million in existing funds be spent. Marc Allen said if SIM's budget was scaled out, it would be 'demoted' from being a mission in progress to being a pre-phase A mission; Spergel said the Science Plan described SIM as a Phase B mission on hold. Eric Smith suggested that the strongest recommendation the subcommittee could make was that the status of SIM in the Science Plan be made consistent with the division's budget projections. Spergel welcomed that; secondly, he suggested an assessment of SIM's scientific value: he noted that the subcommittee was not constituted to do this. Christopher McKee said that a 'science per dollar' analysis might not produce a clear answer; if the subcommittee was reopening the SIM v. SOFIA question, it might appear to be constantly changing its position. Allen commented that Administrator Griffin's letter made clear that the subcommittee was just one source of advice. Spergel noted that the subcommittee did not object at the time to the SIM decision: the NAC had asked if objections would be forthcoming; he had replied that sentiment was not that strong. Robert Kennicutt said that, as 'steward for the community,' the subcommittee should create a process for scientific input. Spergel said he wished to have the scientific community involved.

Belinda Wilkes noted that for the plan to be consistent with itself, it needed to be consistent with the budget, which was unknown. Should the subcommittee recommend that the Science Plan be made consistent with the budget? Eric Smith said the circumstance was further complicated by the fact that the pertinent wording referred not to funds appropriated, but funds authorized; these came from separate Congressional committees. What was known, he added, was the Science Plan was consistent with the President's February 2006 budget request. Michael Cherry said

the speed of change made consistency impossible; the Science Plan went beyond the budget, in part because one of its purposes was to be a wish list.

The Thursday session adjourned at 6 p.m.

* * *

Thursday, September 15:

Meeting convened at 8:30 a.m.

Public Session:

Eric Smith invited public comments.

Michael Devirian [NASA JPL] read a statement that the characterization of the Navigator program as 'a shambles' was 'unfortunate and inaccurate.' He said Navigator had clear objectives and plans for moving forward; SIM, though it faced an uncertain future, had passed eight milestone checks and with funding could launch as early as 2012. He believed both SIM and TPF would move forward aggressively, preparing for the next decadal survey. He noted the subcommittee had yet to request a presentation on SIM science. Responding to a question, Devirian said the Administrator's decision to place SIM after JWST had been primarily budget-driven. David Spergel said the subcommittee would seek briefings on Navigator and Beyond Einstein [SIM included] at its next meeting; he believed SIM should either be strongly endorsed or cancelled.

Dennis Ebbets, Ball Aerospace, reported that those who built hardware had been challenged by the Administrator to extend robotic ability to deploy, assemble and repair in space. An ad hoc group was addressing this; he wished to gain recognition for its ideas; for example, the combined human/ robotic servicing of space assets, or space-based testing of things that could not be tested on earth. The former might offer inexpensive means to extend the lifetimes of high value assets. He said he would welcome the opportunity to brief the subcommittee. Responding to a question, Ebbets said this work was aimed at missions beyond those now in the science plan; if requested, he could supply figures on the financial tradeoffs involved.

* * *

Presentation:

STScI Astrophysics/Moon [Space Telescope Science Instrument]

Mario Livio

Space Telescope Science Institute

Mario Livio described the November 28-30, 2006 meeting at Space Telescope on astrophysics as it might be enabled by the return to the moon. The focus, he said, would be on both the possibilities of science done following return to the lunar surface and possibilities enabled by the fact of that return. Meeting planners accepted the possibility that lunar return would not prove enabling. The program's framework would include: looking at radio astronomy observations [in particular, the red-shift universe]; issues of Dark Energy; questions of large-scale structure; the

possibility of ultraviolet or infrared activities; high-energy cosmic rays and 'some blue sky' thinking. The astrophysics topics to be addressed included: first, the accelerating universe and Dark Energy; second, extra-solar planets [and the question of life on other planets]; and, third, the outer solar system.

Discussion:

Responding to Alan Dressler, Mario Livio said a poster session was planned and time for informal discussion scheduled. Craig Hogan asked how the science topics listed were related to return to the moon; Livio said in some obvious ways, e.g. given that the far side of the moon was very radio quiet, could it become a site for radio telescopes? Were there lunar possibilities for liquid mirror telescopes; could larger ones be built there? Alan Dressler commented that given how little was known about possible lunar infrastructure, such topics were difficult to discuss. Eric Smith commented that the meeting's lead-off speaker, Scott Horowitz [associate administrator, EMSD] would provide infrastructure information. Neil Tyson [audience] noted the agenda did not address costs; many things, he added, could be done better in space, but might cost 100 times as much done that way. Even if lunar infrastructure enabled astrophysics, he added, it did not necessarily follow that the moon was the proper site. Livio said conference planners viewed their task as developing science input for ensuing conferences: one, the week following his, at Johnson Space Center; the second was the February 2007 workshop. Livio added that he hoped to be invited to present his meeting's findings at the February session. David Spergel said Livio's session would be good for the science community.

Neil Tyson commented that NAC chair Jack Schmitt was very interested in engaging the astrophysics community with the return to the moon. He said that lunar exploration would proceed with or without astrophysics, but astrophysics involvement would produce a better package to take to Congress; given the large share of NASA resources engaged with lunar exploration, the science groups should wish to be involved. Alan Dressler said he objected to being asked to 'come up with ideas' just to go along with something else. Tyson suggested the subcommittee might need a new paradigm: lunar presence might offer such a paradigm and perhaps it would take a new generation of astronomers to think through its possibilities. Dressler said the key constraint was that astrophysics was largely a photon-limited domain; little that would happen early on the moon related to that.

David Spergel said he was unclear what 'the Vision' meant and what it would enable. He noted that lunar presence would create an infrastructure: Hubble and the Space Station were not really developed for science; they were part of the Vision for Space Exploration, c. 1960. Nonetheless, he was not sure what was being asked when Administrator Griffin asked about astrophysics' role. Craig Hogan said the subcommittee tended to fixate on telescopes; the committee had recently adopted the fundamental physics goal of testing gravity: this could be uniquely lunar. James Green [audience] pointed out that Hubble did not fit into a shuttle bay by coincidence; the shuttle had been altered to accommodate Hubble. Astrophysics had failed, he believed, on the space station by not pressing to have it altered to its needs. Astrophysics needed to have its needs incorporated into lunar exploration.

* * *

Presentation

'Lunar Science Workshop Update'
Brad Jolliff [by speakerphone]

NAC Science Committee member

Brad Jolliff reported that the workshop was set for February 26-March 1, consisting of a four-day subcommittee jamboree, followed by a day for synthesizing. Site was Tempe, Arizona. The plenary sessions would hold 250. Presentations would be made only by subcommittee members and invited guests; the workshop would open with an overview by ESMD and SMD personnel. The general idea was to put the various constituencies in interaction with each other to promote understanding of what groups were doing, how those activities fit the architecture; and how that architecture might need to be changed to accommodate the science. He noted a possible mid-week field trip to an observatory.

Discussion:

Responding to Heidi Hammel, Brad Jolliff said he hoped to provide participants with 'a good statement' about the draft architecture and its timeline prior to the gathering; minimally, a white paper would be available. Dave McKay [Heliophysics Subcommittee member; audience] asked if a poster session was scheduled. Jolliff identified two venues for contributions: 3-5 minute presentations to the plenary sessions, and evening poster sessions. McKay urged holding the field trip at the workshop's beginning or end, so participants could treat it as optional. Jolliff said he would canvass opinion on that. Asked to detail the plenary session, Jolliff said there may be a day-long plenary on day one, with each subcommittee having 1.5 to 2.0 hours to make a presentation. It was noted that John Mather and Alan Dressler were the astrophysics subcommittee's representatives on workshop planning. Jolliff accepted the suggestion that Mario Livio make a presentation on lunar science.

Asked the meeting's purpose and likely deliverables, Brad Jolliff said the primary purpose was to help the NAC make good recommendations on lunar architecture, beginning early spring, 2007. He hoped to gather together all parties -- SMD, ESMD, the subcommittees and the analysis groups -- to develop an architecture all can support. David Spergel said the subcommittee would discuss lunar issues further at its February 2007 meeting; he hoped it could at that time be briefed on outcomes of the November 2006 lunar meeting. Jolliff said he anticipated having a two-page white paper for each presentation; he hoped these could be compiled so November attendees could see them in advance.

Christopher McKee said the November workshop would encourage a wide variety of ideas; how would these be vetted? Some evaluation would be beneficial. Brad Jolliff responded that the February 2007 workshop would be, first, an opportunity to present as wide a variety of ideas as possible and, second, an opportunity for the subcommittees to state what they saw as most important. David Spergel suggested that, at the November Space Telescope meeting, people who had ideas could be asked to write white papers for submission to the subcommittee by early February 2007, for discussion rather than formal endorsement. Jolliff welcomed the suggestion.

Kathryn Flanagan noted that, during the Strategic Roadmap Process, members of the community had been asked to submit white papers; she urged any request be advertised in the AAS [American Astronomical Society] so the community had that opportunity. Jolliff suggested such papers take into account early information about the architecture, allowing for a more integrated process. An audience member of the heliophysics subcommittee said they had formed a sub-panel to canvass the community for ideas in the form of white papers; this was not a formal NASA call for white papers, but more grassroots. Robert Kennicutt suggested that someone outside NASA establish a website where papers could be posted.

David Spergel said he favored a broad invitation; Kathryn Flanagan said that, absent such an invitation, people might make future claims that the process had not been open. Jolliff acknowledged that point.

Christopher McKee said if the workshop was to enable the NAC to make recommendations on lunar architecture, it would be better if the astrophysics subcommittee did not present 'a stack of great ideas,' but could proceed from information on the key architectural items needed. Craig Hogan said discussion needed to address cost issues: not only what can be done, but how can it be done cost effectively. McKee asked if coordination was occurring with the Space Science Board; David Spergel said the subcommittee would soon be in receipt of its interim report. McKee termed that input important. Discussion clarified that Dressler and Mather were the subcommittee's representatives in planning; all subcommittee members were welcome to attend. Further, as the session was defined as a subcommittee meeting, NASA would pay the costs of attendance.

David Spergel suggested that subcommittee hold its next meeting the Sunday-Monday before the workshop's opening, which assumed foregoing the Monday field trip. Lisa May [NASA; audience] commented that this required consulting the FACA [Federal Advisory Committee Act]. Spergel noted the subcommittee would have further agenda items; by February 2007 it would be in receipt of NASA FY'07 budget information. Jolliff said scheduling questions demanded quick resolution.

Brad Jolliff noted that while he would welcome it if Space Studies Board [SSB] and those drafting the lunar architecture came to the same conclusions, it was not the intention to push things in that direction. SSB would look closely at 'what is the key science?' - Less closely at the constraints the architecture might impose. The NAC, however, would definitely look at the architecture in terms of constraints. David McKay [audience] said the heliophysics subcommittee had the following concern: if resources were 'zero sum,' then any new idea might simply steal resources from that already planned: that view could inhibit development of new ideas. Jolliff noted this was 'a very real concern' that crossed the subcommittees. David Spergel commented that astrophysics had had a well-laid model; then, the phenomenon of Dark Energy appeared, and everything changed. In consequence, the subcommittee was balancing new missions aimed at Dark Energy with already agreed upon missions for other purposes. It was, he said, the nature of the field that new things would arise and challenge existing things.

Heidi Hammel asked why SSD's only science recommendation was that SSD fund scientific exploitation of lunar precursor and exploration programs; presumably, that money would have to come from other funded programs. Eric Smith commented that Administrator Griffin had recently stated that if science needed a change or augmentation in the lunar architecture, science would have to pay the cost of changing it. Lucy Forston said Dark Energy was a science-based change; lunar architecture was not science based. David Spergel said the subcommittee was driven by two things: first, new science questions; second, technological advances that changed the range of opportunity: lunar infrastructure was the latter. Forston said if the group did not embrace new lunar possibilities, opportunities would be lost.

Christopher McKee recalled that the space shuttle had been adjusted to accommodate Hubble. Now, it appeared that if the subcommittee presented visionary ideas requiring alteration in architecture, the 'bean counters' might charge the program hundreds of millions of dollars. As that, if true, would inhibit all ideas, it needed to be clarified. He noted that had SMD been charged for the shuttle's modification, Hubble would not have happened. Eric Smith said he thought it was 'early enough in the game' that architectural changes could be made without great costs. Neil Tyson urged people not to assume a 'zero sum game;' expensive projects

can create the interest needed to draw in the funds they required. David Spergel said it was a difficult calculation: while Hubble created great excitement and drawn in resources, costs were associated with its servicing missions. He was not certain a 'zero sum game' was involved. Kathryn Flanagan said Administrator Griffin had charged the subcommittee to take a 'zero sum' approach. She expressed two concerns: first, that science would be baselined without a National Academy review; second, that the division would be assessed infrastructure costs. She believed these fears were real fears.

* * *

Presentation:

Hubble Space Telescope [HST]
David Leckrone, HST Senior Project Scientist
Preston Burch, HST Program Manager

David Leckrone said his two key messages were: Hubble continues to be vital to science and the community; and, the pending Servicing Mission #4 [SM4] would leave Hubble in its best condition ever. SM4 would, among other things, make Hubble the most sensitive space-based ultra-violet spectrograph ever.

Preston Burch presented on program status, HST spacecraft health and science and life predictions, SM4 preparations and status and HST budget. He expected the go-ahead for SM4 in the next month. Responding to a question, Burch said the flight was not yet manifested; six to eight missions would come first. Burch noted that previous servicing missions had been at three year intervals; the six-year interval preceding SM4 had made keeping the team together a challenge. The program believed Hubble servicing was needed by the first half of 2008; all pre-launch work would be completed by January 2008. Burch described SM4's components, adding that the mission was 'full' both in hardware and the requested quantity of EVA time. The most complicated repair was that of STIS [Space Telescope Imaging Spectrograph] [STIS], which had experienced two failures; this might require a day of astronaut time.

Responding to a question, Burch said STIS and COS [Cosmic Origins Spectrograph] were designed to be complementary. Burch said that given the status of Hubble's gyroscopes and science instruments, servicing should not be delayed beyond 2008. He termed Hubble as being much more capable than at its 1990 launch; SM4 should produce five additional years of highly productive science. On budget, Burch addressed two points: why did development funding continue past SM4, and, why did Hubble cost so much to operate. Future development line costs included those associated with closing out 20 years of servicing/development work [necessary to take Hubble out of orbit] and computer maintenance. Burch said approximately 100 persons would be engaged on the MOSES [Mission Operations Systems and Engineering Software] contract immediately after SM4. Responding to a question, Burch said he did not know the parallel number for JWST operations following its launch. He suggested that Hubble was 'infinitely more complex' to operate.

Discussion:

Christopher McKee noted the decadal survey language on lean operations and asked how Burch's plan related to this. Burch said that all goals for Hubble had not been achieved. McKee asked what expenditures beyond FY'11 were for things other than

lean operations; Burch identified the development closeout and facilities consolidation. Responding to Kathryn Flanagan, Burch said work on Hubble's return mission would likely begin in ten years. He added there were no plans to an SM5.

Robert Kennicutt noted that annual budgets of \$120-\$160 million were directed at maintaining optimal performance and preparing for de-orbit; there was a cost-benefit question: what was the minimum required to keep Hubble operating? Burch said the cost of Hubble's first observation was huge; the cost of the nth observation was very low: dollars per science was not a linear function. A 'bottom line' figure for operations would be speculative, he said; however, Hubble would 'crash and burn' if it didn't get its full request. Hubble servicing could currently be done fairly inexpensively.

Responding to Michael Cherry, Burch said re-entry work involved developing a propulsion model and flying it to Hubble, with a ground team to operate it. Craig Hogan noted that, with eventual battery failure, Hubble would tumble back to earth: could it still be retrieved from space orbit in 2025? Burch said he believed so. David Spergel asked about Hubble's life expectancy: Burch said SM4 should provide five years of science and two years of archival research. Spergel said the 'good news' was that Hubble might last longer; the bad news was 'we have to pay for it.' If, in 2013, a fully operational Hubble was turned off, there would be considerable 'discussion' of this. Burch said operations costs could be lowered if more risk was accepted; Hubble cost considerably less now because of servicing missions and advances made in on-ground operation and on-board computers. Responding to a question, Burch detailed STIS repair; among other things, it involved an astronaut unfastening 111 screws; this had been 'dry run' on ground and under water. He noted that STIS repair was the lowest priority of the SM4 mission.

Heidi Hammel said there was a good argument to service Hubble by mid-2008; delivery date of needed parts was late 2007: did this concern Burch? Burch said the major critical path was the Wide Field Camera #3; about 1.5 months of slack existed. Launch date was driven by the shuttle program; HST would be ready when the shuttle was ready. Henry Ferguson [Space Telescope Science Institute; audience] said SM4 would create 'an almost new observatory': he thought it unwise to move to lean operations shortly after a capabilities increase. David Spergel said he wished a process that would, first, determine that 2013 was the appropriate stop date and, second, define lean operations.

* * *

Subcommittee: Additional Discussion and Recommendations:

David Spergel welcomed comments on the Hubble presentation. Christopher McKee suggested the program be aware that in 5-to-10 years, robotic servicing might offer less expensive approaches. Further, he believed lean operations should not be considered for the first years after SM4. On costs, he suggested that if Hubble was placed in Senior Review, it would have incentives to show how science per dollar could be optimized. Richard Howard said the Great Observatories were not currently a part of Senior Review; should something analogous be created for them? Robert Kennicutt asked whether HST would prefer \$150 million annually for four-five years, or a longer lifetime based on lesser annual expenditures: Hubble should embrace that question and enter the decadal survey with ideas of its own. Howard said Space Telescope Science Institute planned to support the transitioning from Hubble to JWST; that did not clarify Hubble's role after 2013. Spergel said a process was needed to resolve the question: the mission's science benefit decayed with time; costs remained the same: at some point, those lines crossed. Neil Cornish said that

as the Great Observatories offered extended operation, they were almost like a new mission: perhaps they should be subject to Senior Review. Howard said the identified budget and tradeoffs associated with the Senior Review process did not exist for Great Observatories. Hammel said the planetary division should be consulted; it had faced similar issues, e.g., should Galileo become an extended mission, or should it be crashed.

Discussion ensued on the meaning of 'extended mission' for Hubble, which was designed to be serviced. Alan Dressler said Hubble's original termination date was 2005; only recently had extended life been discussed. David Leckrone said SM4 had been in the program design since 1996. An audience member suggested that when Hubble's termination was pending, Congress and the public would weigh in on the question. Kathryn Flanagan said tradeoffs needed to be addressed: she believed Great Observatories should operate so long as they were 'giving science worth the bucks.' Spergel commented that Hubble was likely to appear less attractive with each subsequent review.

David Spergel recapitulated the subcommittee's recommendations thus far:

On JWST: to support advancing the PDR review from March 2008 to September 2007.

On EPO: to create a cross-divisional working group to assist EPO operations; to resolve the AO language question.

On Science Plan: to link its language more closely with that of the President's Vision for Space Exploration. Further, to express concern that the Science Plan was not consistent with the NASA budget.

Christopher McKee said the SOFIA priority was to initiate science operations as soon as possible. The question, he said, was if the plan presented was the fastest way to achieve this. Richard Howard noted the recommendation that responsibility for the aircraft be moved from Ames to Dryden; he believed Dryden was 'very aware' of what was needed. He affirmed the importance of an early start.

David Spergel noted the 'ambiguity on SIM'; adding that on this the scientific community could be helpful to NASA. The science v. budget question needed to be addressed.

* * *

Presentation
'Kepler Update'
Pam Marcum
Program Scientist

Pam Marcum said Kepler would detect hundreds of earth-size and larger planets, ground-based work would rule out false positives. Key questions were: are terrestrial planets common or rare? What are their sizes and distances? How often to they fall in the habitable zone? What is their dependence on stellar properties?

Discussion:

In discussion, the habitable zone was defined as the temperature range in which water was liquid. Responding to a question, Pam Marcum said that the call for proposals would be issued one or two months before launch; observations would start seven to eight months after launch. The program would offer assistance on proposal preparation: an office would be established at Ames along with a website and help desk.

Robert Kennicutt said discovery of perhaps 100 habitable planets would create extraordinary public interest, raising the question: How can this discovery be followed up? Eric Smith said JWST would assist with this. Jennifer Wiseman [NASA; audience] said most, perhaps all, of the planets discovered would be too distant to permit follow-up; the hope was that at least one would be within range. Pam Marcum said the project was optimistic that considerable follow-up information would be obtainable. Alan Dressler said he believed the mission's key was finding earth-like planets; the investigation of those planets was beyond its capabilities. This drew the comment that some of the stars and planets would be brighter than the minimum and might yield some information.

David Spergel asked what kept project leaders 'up at night'? Pam Marcum said that successful completion of the focal plane assembly would be a relief. Mike Moore [NASA Kepler Program Executive] said the assembly was 'incredibly complex:' he indicated that the prime contractor's execution to date was a management challenge. Heidi Hammel asked whether any lessons from 8x8 ground-based arrays were relevant to Kepler; Moore said generally not: ground-based installations could be 'tinkered with' to improve performance. Moore reported as important the design feature that if a detector ceased to function, only the immediate portion of the array was lost; the project's minimum requirements could be met if 30 percent of the view field was lost. He noted, as a vulnerability, that if the high-gain signal chain failed, downloading of data would be greatly slowed.

* * *

Presentation

'International Collaboration'

Richard Howard

Acting Director, Astrophysics Division

Richard Howard reported that an ESA [European Space Agency] AO [Announcement of Opportunity] would come as early as November 2006: should NASA be involved with it? ESA planned to select three large and three medium concepts for study; as this process identified possible U.S. involvements, they would be discussed. NASA, he added, should not write a 'blank check' for things outside its mission schedule. More generally, he noted that only two mechanisms currently existed for international cooperation: agency-to-agency strategic discussion and Missions of Opportunity; the latter, however, were progressively less frequent. Responding to Kathryn Flanagan, Howard said the methods of international collaboration were open to discussion.

Questioned by Fred Lo, Richard Howard said ESA's strategic vision was well-aligned with NASA in astrophysics; less so in planetary science. Asked by Lo to compare priorities, Howard said ESA placed its manned program at a much lower priority than did NASA. Robert Kennicutt asked how U.S. scientists might be involved in ESA's selection process. Howard said timing was favorable: ESA would select the smaller missions first, though not before May 2007; the larger would not be down-selected until 2009. He anticipated discussion on the first set.

Questioned by Craig Hogan, Howard said plans existed for ESA participation in Beyond Einstein, driven by international recognition that both sides had solid expertise. His biggest concern for Beyond Einstein was that if LISA was selected first, the current approach to LISA involved splitting the workload in ways he regarded as unworkable: a serious effort was required to determine what the U.S. and ESA should do. He believed that until LISA Pathfinder was done, no one on either side would commit to building LISA. Eric Smith sought clarification: was the task that technologies must reach a certain level, or was it that the technologies must be finished and launched with the data analyzed. Howard said every project posed that question: he believed that if LISA Pathfinder failed, ESA would wish to make a second attempt.

Neil Cornish commented some Europeans believed One Degree of Freedom had demonstrated some of what they wished from Pathfinder; further, had they been able to do this five years ago, Pathfinder would not have been approved. Howard said One Degree of Freedom was not Pathfinder. Kathryn Flanagan asked if LISA was not chosen to go first, would that in any way threaten ST7; Howard said no. Howard added that all the missions had sound reasons for being pursued; he hoped Pathfinder would launch within several years.

John Mather asked about collaboration with Japan. Richard Howard said that Mary Cleave [associate administrator, SMD] had been to Japan the previous week. In general, he believed collaborative efforts needed to 'bubble up' from the scientist-to-scientist level, until sufficient momentum was created. Robert Kennicutt commented on the need for quick action on Targets of Opportunity, e.g. SPICA [Space Infrared Telescope for Cosmology and Astrophysics]. Howard said he had called SPICA to Mary Cleave's attention; at present, there was no direction favoring its inclusion in the strategic plan. Kennicutt asked if the response to opportunities needed to be entrepreneurial: could some systematic approach be developed? Howard said if the general program was stable, a systematic approach would be possible and good. Christopher McKee expressed agreement that collaboration needed to build up among scientists; e.g. ground-based radio astronomy had risen to high priority both in the U.S. and Europe. Conversation established that NASA's budget was five times that of ESA, though ESA spent a greater share on science.

Martin Harwitt [audience] said that, having worked extensively with the Europeans, he welcomed involvement with the Japanese: there did not seem to be any formal way to accomplish this. He believed Targets of Opportunity were too limited to permit this; he urged the subcommittee think about how it might be achieved. Richard Howard suggested two approaches: First, the subcommittee could consider, within SMD's existing budget and structure, how it might structure a response to opportunities. He noted, however, that limited funds were available to the Explorer program. Second, new initiatives could be proposed that addressed small gaps in the science plan, e.g. balloon payloads. It was difficult but not impossible to get such new things into the program.

* * *

Presentation:

'Balloon and Rocket programs'

W. Vernon Jones

Executive Secretary,

Scientific Ballooning Planning Team

W. Vernon Jones reported on the status of astrophysics sounding rockets; balloon flight observations; Ultra Long Distance Balloons [ULDB] development, and the

Antarctic Long-Duration Balloon [LDB] Development, and other program activities. He concluded by presenting information on the Balloon Roadmap Team and NASA's response to the roadmap team's recommendations.

Discussion:

David Spergel asked if the SMEX [Small Explorer] program was lost, what could be done to recover some of that; he said he was aware of concerns that small rockets might be going away. Richard Howard said he could not say. Vernon Jones said the program's financial situation was 'very, very grim.' Spergel said super-pressure balloons offered the opportunity to do interesting science; was this funded from R&A? Howard said it had been funded out of R&A; now, the operational aspects had been moved to the basic balloon program. He said the program had been supported 'in the margin, as best as we can;' it offered a great capability; involved younger scientists and provided great benefit and success. The question remained: where could additional funds be found? All funding, he added, was very tight for the next two-three years; more generally, Howard said he had 'mortgaged' the division's future to get through FY'06 and FY'07; until he knew the reality of the FY'07 budget, he could make no promises.

Lucy Forston said education and outreach was very important to ballooning; did a compendium exist showing the program's efforts? Jones said not, though he acknowledged one should. His program, he added, worked with headquarters EPO people; they, however, had no money to contribute, so the program had been spending more than intended.

Michael Cherry asked if the 2008 launch from Australia could circumnavigate the globe. Jones said no, as that would involve carrying ballast over Sao Paulo and other populated areas in months when thunderstorms might occur.

Richard Howard noted given inflation, and given that as programs continued their infrastructure costs tended to rise, 'level funding' actually meant a progressive decline in funds available for program activities. David Spergel pointed to possible tradeoffs between balloons and sounding rockets: he thought ULDB's raised many possibilities; perhaps resources should be concentrated there. Jones commented that for the balloons, '100 days of operation is nothing; they can fly and fly.'

* * *

Further Discussion: Subcommittee Recommendations

David Spergel said the subcommittee had discussed most recommendations on his list. He would prepare a PowerPoint presentation for the NAC Science Committee; subcommittee members would receive copies over the weekend. Heidi Hammel urged that the written submission to the NAC be done first, with the PowerPoint extracted from it; discussion of the letter brought out points she thought the PowerPoint might gloss over. Spergel said he would see if the schedule permitted this.

Regarding the subcommittee's next meeting, David Spergel suggested it be held the Monday and half-day Tuesday immediately proceeding the full February 2007 workshop; further, if most workshop activities of high interest to the subcommittee could be scheduled for Wednesday, that would permit subcommittee members to attend without committing to the entire week.

Michael Werner [Jet Propulsion Laboratory; audience] asked if a recommendation would be made on international cooperation. David Spergel said no clear plan had been presented; ideas on the subject were welcome. He noted that in

some international projects NASA's contribution was vital. Richard Howard suggested the helio- and astrophysics divisions might discuss this. Spergel commented that if the Explorer program was healthy, he would imagine a well-defined effort directed at targets of opportunity. Howard added that a strategy was needed on how to respond to the next target of opportunity. Robert Kennicutt said that as the Japanese were unaware of the division's receptivity to collaboration; 'word should be got to the street' on this. Heidi Hammel suggested the various subcommittees form a task force to consider the issues and move discussion forward. Spergel suggested it made more sense for the planetary committee to pursue this; Howard said that would allow everyone to be aware of the discussion.

On a new topic, Heidi Hammel expressed concern with the 'gloom and doom' in the climate between the science community and headquarters; she urged that this be discussed. She made reference to letters received from Administrator Michael Griffin; she believed some of what had been said had 'very serious implications' for the division. David Spergel said he shared her concerns; adding that it benefited both the NASA and the scientific community to work together as closely as possible. The letters, he added, did not make clear that Administrator Griffin believed the subcommittee existed to help him. The subcommittee should affirm this, he stated, adding that an 'inherent conflict' might exist, as the subcommittee view was that the program consisted of exciting things and it wished was to have the resources to do everything. Alan Dressler endorsed Spergel's comments: further, he stated that in years of attending NASA advisory meetings, he did not believe he had ever heard anyone promote something out of self-interest. Reading the letters, Dressler felt the Administrator was either unaware of this or did not share that view; either was cause for concern. Richard Howard said the subcommittee was a place where such discussion could ensue; it was good that anyone's concerns could be put on the table. Robert Kennicutt termed the subcommittee a key interface; he believed relationships were better than he had previously encountered. Spergel expressed the hope that the new SMD associate administrator would make good use of the advisory system; he was concerned, however, that what the subcommittee 'sent up' was not flowing through the science advisory committee to the NAC. Spergel noted that, generally, it was matters other than science issues that flowed to the NAC. He stressed that, in the end, the success of processes depended on the individuals involved: much, therefore, depended on who was added to the NAC Science Committee and who became head of SMD.

Richard Howard called attention to what occurred outside the formal process, e.g. meetings had been held on how to proceed on the Beyond Einstein prioritization and on the importance of maintaining the division's competed lines. The result was that WISE and Kepler were back in the program 'and on track.' Howard added that he valued the subcommittee's discussion and advice; that it was factored in, and that he believed the interaction between the division directors and the division was moving in the right direction. He believed that part of the subcommittee's importance was as an open session where discussion could go back and forth.

Heidi Hammel quoted Administrator Griffin's letter as stating that participation of science in space exploration would not involve the transfer of new moneys to SMD; rather, it would be about redirecting the money already being spent. Her 'worst nightmare,' she said, was that the pending workshops would identify highly attractive projects that could be done 20 years from now, and that in the next few years, 'half of SMD's program funding' would be redirected to those programs. In consequence, she feared that 'science as we now know it will cease to be done.' She believed this would follow because the Administrator's 'sole focus' was on humans in space. David Spergel took exception, saying that humans in space, while the 'top

priority,' was 'not the only priority.' Spergel said his own nightmare was not that great ideas would emerge, but mediocre ones, which would not be vetted by the National Academy and the community.

Kathryn Flanagan said the subcommittee should affirm it was open to all new possibilities, but that these needed to be vetted by the National Academy. Alan Dressler said he did not see these nightmares occurring; among other reasons, it would be years before there would be anything to divert funds to. Hammel did not agree; she believed the subcommittee should speak for the community in this regard. Richard Howard said Administrator Griffin had said that National Academy prioritization would drive the science. His own biggest nightmare, he added, was that the workshop would occur; the decadal survey accomplished; then something would come along that 'looks really great' but was unranked in the decadal survey, and someone would have to decide whether or not to do it. David Spergel commented that this was one reason to prepare the white papers; he wished to ensure that the processes were respected, with no one 'end-running' an idea to SMD.

Heidi Hammel said persons in planetary science would not be happy to spend half its budget on a study of lunar surface chemistry, which she did not regard as a planetary program. Eric Smith commented that some people's nightmares were other people's fondest dreams. Alan Dressler said the 'big thing' would occur in planetary: if the budget was indeed a zero sum game, this was dangerous to the science Hammel wished to do.

David Spergel said that if short-term funding was a 'zero sum game,' then the Administrator was doing the subcommittee a service by being clear about that. He had heard people state, mistakenly, that the lunar initiative might bring them new funding; he added that some new ideas might be so compelling that the community would wish to make a tradeoff. Spergel cited Hubble as a model: the HST program had likely brought more funds to astronomy than it would otherwise have received. Alan Dressler said he thought it likely that planetary science would receive the greatest impact: perhaps a rebalancing was needed that put more funds into planetary. Eric Smith commented that any rebalancing would come from the NAC science committee. David Spergel doubted much of this would be on the table soon; further, he doubted the Administrator wanted the subcommittees to suggest that budget decision were theirs to make.

Kathryn Flanagan asked if NAC meetings were open. David Spergel said they were: the next was at Goddard Space Flight Center, October 12.

The meeting adjourned at 4 p.m.

Appendix A: Astrophysics Subcommittee

David Spergel, Chair
Department of Astrophysical Sciences
Princeton University

Eric P. Smith, Executive Secretary
Astrophysics Division
NASA Science Mission Directorate

Michael Cherry
Physics Department
Louisiana State University

Robert N. Clayton
Department of Geophysical Sciences
University of Chicago

Neil J. Cornish
Department of Physics
Montana State University

Brenda Dingus
Institute of Geophysics and Planetary Physics
Los Alamos National Laboratory

Alan Dressler
Carnegie Observatories
Carnegie Institute of Washington

Debra Fisher
Department of Physics and Astronomy
San Francisco State University

Kathryn Flanagan
Kavil Institute for Astrophysics and Space Research
Massachusetts Institute of Technology

Lucy Forston
Adler Planetarium and Astronomy Museum
Chicago, IL

Thomas Greene
NASA Ames Research Center
Moffet Field, CA

Heidi B. Hammel
Space Science Institute
Ridgefield, CT

Craig J. Hogan
Astronomy Department
University of Washington

Robert C. Kennicutt
Institute of Astronomy
University of Cambridge
Cambridge, UK

Fred K. Y. Lo
National Radio Astronomy observatory
Academy Sinica
Charlottesville, Virginia

John C. Mather
NASA Goddard Space Flight Center
Greenbelt, MD

Christopher F. McKee
Department of Physics
University of California, Berkeley

Belinda Wilkes
Harvard-Smithsonian Center for Astrophysics
Cambridge, MA

Appendix B: Attendees
Astrophysics Subcommittee
September 14-15, 2006
Washington, D.C.

September 14, 2006:

Marc Allen, NASA/HQ
Ron Allen, STScI
Dominic Benford, GSFC
Kathleen Beres, Orbital
Jeff Branden, General Dynamics
Joe Bredekop, NASA HQ [SP?]
Devin Bryant, House Science Committee
Liz Burck, NASA
Mike Cherry, Louisiana State University
Mark Clampin, NASA GSFC
Robert Clayton, University of Chicago
Dominick Conte, General Dynamics
Larry Cooper, NASA HQ
Randall Cornell, Ball Aerospace
Michael Devirian, NASA JPL
Lamont DiBiasi, L.D.Biasi Associates
Robert Dimeo, OSTP
Dennis Ebbets, Ball Aerospace
Ed Feddeman, House Science Committee
Henry Ferguson, STScI
Gerald Fishman, NASA-MSFC
Kathryn Flanagan, MIT
Lucy Forston, Adler Planetarium
Linda Fuhrman, Draper Laboratory
John Gantt, Mizrub & Gantt
Jonathan Gardner, GSFL
Paul Geitauer, NASA HQ [SP?]
James Green, University of Colorado
F. Rick Harnden, NASA HQ
Martin Harwitt, Cornell University
Craig Hogan, University of Washington
Rick Howard, NASA HQ
Steve Johnson, Raytheon
Vernon Jones, NASA HQ
Mike Kaplan, Boeing
Katherina Kanann, NASA [SP?]
Robert Kennicutt, Cambridge University
Anita Kris.... NASA HQ [SP?]
Paul Hertz, NASA
Paul Marcum, NASA HQ
Mike Moon, NASA HQ
Lia La Piana, NASA HQ
David Leisawitz, NASA GSFC
Laurie Leshin, NASA GSFC

Fred Lo, NRAO
James Manning, STScI
John Mather, NASA GSFC
Lisa May, NASA/HQ
Maxim Mazkeifoy, Harvard Smithsonian [SP?]
John McCarthy, Orbital
Christopher Mckee, UC Berkeley
Julie McEnery, NASA GSFC
Jon Morse, OSTP
Stephen S. Murray, CGA
Chuck Nellie, NGST [SP?]
Marian Norris, NASA HQ
Bill Oegerle, NASA GSFC
Tom Prince, CalTech/JPL
Steve Prow, Lockheed Martin
Steve Ritz, NASA GSFC
Phil Sabelhaus, NASA
Michael Salamon, NASA
Ed Shaya, University of Maryland
Eric Smith, NASA
David Spergel, NASA
Robin Stebbins, NASA GSFC
Stacey Steep, House Science Committee
Harley Thronson, NASA GSFC
Wes Traub, NASA JPL
Allison Trepod, SRI International
Zlatan Tsveranov, NASA HQ
Stephen Unwin, NASA JPL
Michael Werner, NASA JPL
Nick White, NASA GFSC
Belinda Wilkes, Center for Astrophysics
Greg Wilmot, NASA SMD
Jennifer Wiseman, NASA
Dan Woods, NASA
Edward Wright, UCLA

September 15, 2006:

Kathleen Beres, Orbital
Preston Burch, NASA GSFC
Mike Cherry, Louisiana State University
Robert N. Clayton, University of Chicago
Dominick Conte, General Dynamics
Neil Cornish, Montana State University
Michael Devirian, NASA/JPL
Henry Ferguson, STScI
Kathryn Flanagan, MIT
Lucy Forston, Adler Planetarium
Linda Fuhrman, Draper Laboratory
Chuck Heltie, NGS
John Gantt, Mizred & Gantt
James Green, University of Colorado
Heidi B. Hammel, Space Science Institute
Steve Harrison, HGST
Jeffrey Hayes, NASA HQ
Craig Hogan, University of Washington
Rick Howard, NASA/HQ
W. Vernon Jones, NASA
David Leckrone, NASA GSFC
Dave Leisawitz, NASA GFSC
Fred Lo, NRAO
Mario Livio, STScI
Pam Marcum, NASA HQ
John Mather, NASA GFSC
Lisa May, NASA HQ
Chris McKee, UC Berkeley
Mike Moore, NASA HQ
Jon Morse, OSTP
Malcolm Niedner, NASA GSFC
Marian Norris, NASA HQ
Antonella Nota, STScI/ESA
Stephen Murray, CGA
Marc Postman, STScI
Wilt Sanders, NASA/HQ
Ed Shaya, University of Maryland
Eric Smith, NASA HQ
Ray Tacl??, NASA HQ [SP?]
Wes Traub, NASA JPL
Zlatan Tsveranov, NASA HQ
N. D. Tyson, AMNH
Steven Unwin, NASA JPL
Michael Werner, NASA JPL
Nicholas White, GSFC
Greg Winnars, NASA
Jennifer Wiseman, NASA HQ
Belinda Wilkes, WHAT
Edward Wright, UCLA