VISIONS and VOYAGES

Decadal Survey Report at LPSC

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Visions and Voyages: Decadal Survey Report at LPSC

The Waterway Ballroom filled to capacity as Steve Squyres prepared to release the results of the recent Decadal Survey to the planetary science community during the 42nd LPSC.

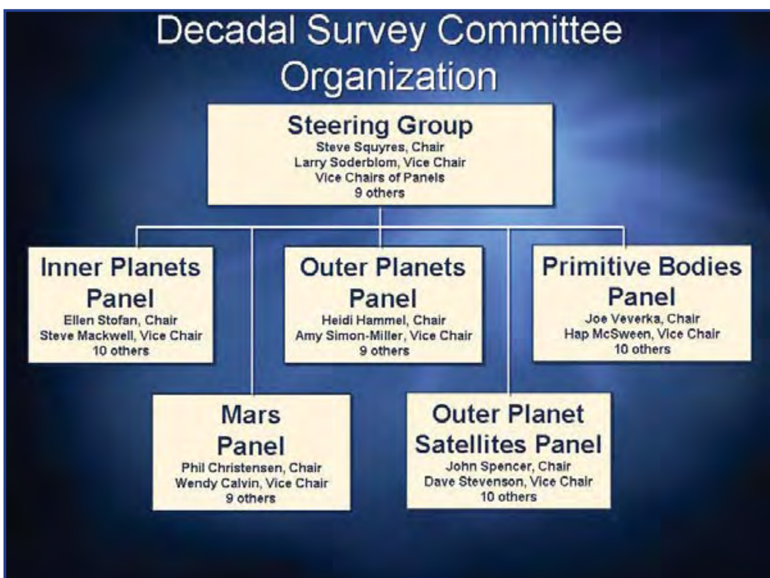
On March 7, 2011, the much-anticipated report of the Planetary Science Decadal Survey for the years 2013–2022 was released. As the Decadal Survey was being finalized in 2010, Dr. Steven Squyres (chair of the Decadal Survey Steering Committeer) expressed his wish for an early release of the Decadal Survey and identified the 42nd Lunar and Planetary Science Conference (LPSC) in The Woodlands, Texas, as the optimal forum. He and Dr. Jim Green (Director of NASA's Planetary Science Division) prepared materials for the special evening session at LPSC that described the mandate, the survey process, the recommendations, and NASA's response to the survey. The Decadal Survey committee, which consisted of a broad spectrum of experts in the planetary community, was guided by 199 white papers on an array of exploration and scientific topics submitted by the planetary science community itself. The report, entitled *Vision and Voyages for Planetary Sciences in the Decade 2013–2022*, is the second such planetary Decadal Survey, and reflects the consensus of the committee and the community. It is intended to provide guidance for both NASA and the National Science Foundation as they develop exploration and research strategies for the coming decade. Squyres spoke for approximately an hour, followed by comments from Green on the potential outlook from NASA Headquarters in the decade ahead and the impact of the report. This was followed by a round of probing and interesting questions from the attendees (estimated at more than 1000, including several overflow rooms). This first Decadal Survey release has been followed by a series of Town Hall meetings at various locations and venues across the country, hosted by key members of the panel, intended to explain the Decadal Survey to the planetary and international communities and answer questions about specific components. What follows is a transcript of Squyres' presentation, with only minor editing for clarity. To view Squyres' PowerPoint slides while reading this article, go to *www.lpi.usra.edu/decadal/2013_2022/SquyresLPSC.ppt*.

SQUYRES: Thank you very much . . . it is a tremendous pleasure for me to be able to be here and talk to you about the Decadal Survey tonight; I've been wanting to do this for months. It's nice to be able to finally be able to do it. So . . . what is the Decadal Survey? Every ten years at the request of NASA and the National Science Foundation, the NRC carries out a decadal survey for planetary science. This is the second planetary Decadal Survey; it's modeled after stuff that the astronomy community has been doing for something like 50 years. It involves very broad participation from the planetary science community and it is the primary scientific input that Jim Green at NASA and that NSF use to design their program of planetary exploration.

This is an extraordinary thing. It's an instance where a federal agency looks to its constituents, to our community, for actionable advice on what they ought to do, and then they actually listen and they go off and do it. And it represents an amazing opportunity for us as a community and one that we try to take full advantage of. And the Decadal Survey that we participated in applies to the decade from 2013 to 2022. And we had three guiding principles. The first is that science comes first. This is spelled out in our Statement of Task; it's axiomatic — what we do must be first and foremost guided by the science. The second is community involvement, this is OUR Decadal Survey, as a community, and we did everything that we could to involve the community from the very start, where we went out and got the white papers, to the very end when we had 18 peer reviewers . . . and I'm sure a bunch of you are in this room; thank you for what you did for the report. And finally there's transparency and openness. We tried to make this process as inclusive as we possibly could, to make it as visible as we possibly could, to anybody who was interested.

Our activities were governed by a Statement of Task. The Statement of Task (you can see it on the NRC website) was provided to us by NASA and NSF, with input from the White House's Office of Management and Budget. It was the guiding document for all that we did. And it particularly emphasized two things, one was that our recommendations should be science driven, and the second — and this is the way in which this decadal differed from those that have come before — was that it stressed that we should recommend a program that would be implementable within projected budgetary resources. And what that did was it made it necessary for us to put attention, on not just the science, but also on the costs of the science.

Organization of the Decadal Survey: There was a steering group, that I chaired, Vice Chair was Larry Soderblom; we had five panels, one for the inner planets, one for the outer planets, one for primitive bodies, one for Mars, and one for outer planet satellites. This structure parallels the structure that was used for the last planetary decadal. The one difference, this last time there was a separate panel for astrobiology, and the feedback we got from the astrobiology community was no, they didn't want to be hanging off of the end of the org. chart all by themselves, they wanted to be integrated into the rest of the process. So there was astrobiology representation on all of these groups, just as there was for all of the science disciplines. And the vice chairs of all of the panels served as some of the members of the steering group, so what that did was provide connectivity and good communication between the groups.

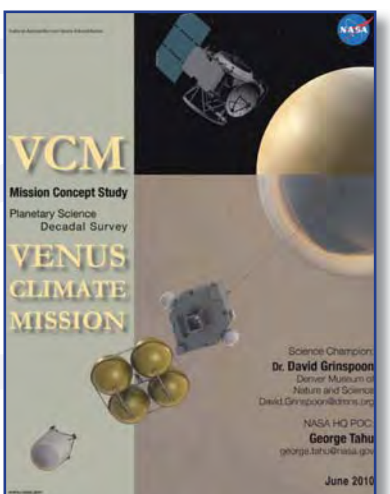


We had many, many, many forms of input from the community. The goal of a Decadal Survey is to seek out the community's views and to build a consensus around those views. So we had more than a dozen townhall meetings, I think it was something like 15 or 16, at all of those conferences that you see listed up there. You, the community, submitted 199 white papers. (I was tempted to write one myself, just so we'd have an even 200!) One hundred and ninety-nine white papers with 1669 individual authors and endorsers. So it was an outpouring of information and contribution from our community. The white papers were the primary input that we used to assess our community's views on what the science should be. Many white paper authors (I'm sure a number of you in this room) were invited to panel meetings, to talk about your white papers, and to describe things in more detail. We had open sessions of meetings webcast; if you would like to relive every moment of every one of our meetings you can do it online. (I don't recommend it but you can.) And then the draft report was reviewed by 18 peer reviewers from the community, so we had community input from start to finish.

Chapters in the Report: There are 12, and the first two are kind of boilerplate stuff that goes at the beginning. Chapters 9, 10, and 11 are the ones at the end that provide the primary recommendations. Chapters 4 through 8 were written by each of the panels and they summarize the science associated with those panels. But when you first sit down to read the report, the chapter you should look at first is Chapter 3. Chapter 3 is a breathtaking summary, and I can say that because I didn't really contribute much to writing it; Larry Soderblom led the writing of that chapter. But it is a breathtaking summary of the state of knowledge in planetary science and what are the current big questions.

We identified three overarching themes. We've given them the names "Building New Worlds," this means basically understanding origins of planetary systems; "Planetary Habitats," looking for the requirements for life, in our solar system; and "Workings of Solar Systems," how planetary processes work. Chapter 3 expands on those in great detail, identifying a number of key questions for each. Now, I'm not going to read each of the key questions off of each of these slides, you can read them yourselves. But what they do is they seek to take those three overarching themes and write them down into a series of questions that can then be addressed by the program of science and exploration. I don't mean just the missions; I mean R&A, what NSF does, all of that. These can be used to guide our program of planetary exploration, "Building New Worlds," and "Planetary Habitats," looking for the kind of places where life could take hold, and in fact may have taken hold. And then "Workings of Solar Systems" uses the planets as a solar system scale laboratory to understand the processes that have shaped them and that have shaped our own planet.

The only thing I want you to get out of this next slide is that we had a lot of meetings. The panels, represented by the brightly colored boxes here, met three times. Their process began (see the yellow box at the upper left) with the community white papers. White papers went into the panels, [there were] many, many presentations from members of the community at the panel meetings, and then [there were] a series of interactions between the panels, back and forth with the steering group. And importantly, that orange bar across the top that says "Mission Studies and Cost Estimation" — I'll talk about that in more detail — but that was the crucial process by which the most promising scientific missions were identified by the community, and were then studied at a sufficient level of detail that we could actually do reasonable assessments of their probable costs.



Based on the science identified via white papers and other community inputs, 25 mission candidates were chosen for detailed study.

Mission Studies: Based on the science that was identified from the white papers and other community inputs, we identified a total of 25 mission candidates. This part of the job was really fun. One of my favorite parts of the whole flight project game has always been the part I call the blank piece of paper . . . when you have a set of science objectives and you sit down with a blank sheet of paper in front of you and you say, "Okay, what kind of mission can do this?" We did that 25 times.

The studies were performed by APL, by Goddard, and by JPL. And each study team included at least one (and some cases several) member of the panels, to provide careful input to the study process. The studies were funded by Jim Green at NASA; it was a lot of money that we spent, and I want to thank Jim publicly, right here, and I think I'd like to [ask] everybody to give him a round of applause, right now.

There was Jim's funding, there were three fantastic groups of study teams at Goddard, and at JPL, and at APL, and then there were our points of contact at NASA Headquarters who worked really hard — a lot of people worked very, very hard — to make this happen; they did a fantastic job. All of the study reports have been posted on the web, and all of them are included in the Decadal Survey report.

Now, once you have a mission study done, you have enough information to give you a sense of what the mission looks like, but we still need a cost number. The mission study process that took place internal to Goddard, internal to APL, JPL . . . those all generated cost numbers. We disregarded those cost numbers. Those cost numbers, [even with] as much effort as went into them, were generated by people who were believers in these missions. They were generated by people who were the advocates of these missions. And in order to be responsive to our Statement of Task, we felt it was very important to use cost numbers that had been generated independently, by unbiased outside experts. And so the NRC contracted with Aerospace Corporation to conduct a process that we call Cost and Technical Evaluations, or C-A-T-E (CATEs), and these were done for a selected subset of the highest-priority missions as identified by the panels. And I'll tell you in a moment how that prioritization was done.

And here's a key point: The techniques that are used to generate these CATE cost estimates, they're based on multiple methodologies, one of the most important [of which] is using the actual, as-built and as-flown, costs of analogous missions. This is not a grass-roots, bottoms-up, "here's what we think it's gonna cost" based on some work breakdown structure. This is instead a process that takes into account, as best we could, the optimism that is inherent in these advocacy cost numbers that are sometimes used. Now, the good news is these numbers are probably realistic. The bad news is you're gonna see some sticker shock. Here's an example, shown in the picture on the right, you can see the original estimate from the project, if you will, of the cost of this particular mission, at 2.2 billion dollars. The cost estimate that arose out of the CATE process was 3.5 billion dollars. It's a factor of pi over two, if you do the math. (And by the way, all the costs that I will quote you, are FY '15 dollars.)

The criteria that the panels used for prioritizing and making recommendations: [There were] two primary ones. The first and most important was science return per dollar. This was science return as judged by the experts on our panels, based on the inputs that they get from the community. It is dollars as determined by the CATE process and Aerospace Corporation. Now, I recognize that science return is not an easily quantifiable thing; it's hard to attach a number to. So, we are using the best judgment of the best experts that we could get to give us their considered opinion on science return per dollar when they did the writings.

The second criterion was programmatic balance, and programmatic balance takes two forms, one is balance across the solar system, balance across the range of solar system targets. The other is balance in terms of mission size, a mix of small, medium, and large missions. And those two are obviously linked because some parts of the solar system, the outer solar system for example, are hard to get to with small missions. And then there were also two gates, if you will, that any candidate mission had to get through to be recommended. One was readiness of the appropriate technologies, the other was availability of trajectories; you've gotta be able to get from here to there in the decade in question.

The Process: All of the priorities, and all the recommendations you're about to see, were guided, as strongly as we could be guided, by community inputs. That was our guide star. The prioritization that you're going to see, within the subject area of a given panel, was done by that panel. So, for example, if it was necessary to prioritize, say, a Mercury mission versus a Venus mission, both of those fell within the area of responsibility of the inner planets panel, so we looked to that panel to do the prioritization. That was where the greatest expertise lay.

I felt very strongly from the start that it was important to push the responsibility as deep down into this organizational structure as we could because that was the part of the structure that was most in touch with the views of the community. So, everything that you see that was within the realm of a single panel was recommended to us by that panel. That doesn't mean that when it got to the steering group we didn't ask penetrating questions; we did. We asked tough questions; we said, "Do you really mean that?", and some cases we sent them back to do more work. But in the end there was not a single recommendation from the panels in terms of that kind of prioritization that we changed at the steering group. Within the steering group, we handled cross-panel prioritization, so when things came up from different panels the relative prioritization was done at the steering group, again using these criteria and guided by community input.

And here's a key point: All the priorities and recommendations you're about to hear were arrived at by achieving very strong consensus. We had 16 people on the steering group, and if we voted on something and the answer was 16 to nothing, 15 to one, maybe 14 to two, okay, that's good enough. Something comes out 10 to 6 . . . we're not done. We've got to get back to work. So, everything that you're gonna hear was arrived at by strong consensus, and most of it, I'm pleased to say, was by unanimous consensus.

Our Budget Wedge: At the beginning of this process we needed something to shoot at; we needed some estimate of what the budget might be. So, we went to Jim Green, [and he] provided us with this, in Appendix E of our report. The colorful curves on the left that you see dropping off, this is real year millions of dollars on the vertical axis and the horizontal axis is fiscal year.

And those things that you see rolling off, that is the run-out of the current program. So, everything that we're committed already to doing now is in there. The ongoing Discovery missions, the missions that are currently in flight, the New Frontiers-3 mission that has not been selected yet but has been committed to, all of that is in here. So, the big, reddish-pink area up there to the upper right, that's what's left. And that's the wedge that we sought to fill with all of this good science.

Now, we recognized from the start that this is a projection handed to us in the year 2010 of what might happen as far out as 2022. There is no reason to expect that the reality is going to be this, exactly. So, we recognized from the start that this was something to shoot at, but that our report must include clearly delineated trip wires and decision rules that will enable the agency to respond to our recommendations, in the event that the reality, as it surely must be, is going to turn out to be different from this.

Now, many of you have probably already seen this. This is a recent budget, very recent, literally in the last few weeks, that is put out by OMB. Okay, and I've circled numbers, probably hard for you to see, in red, and then there's some stuff highlighted in yellow at the bottom. The stuff in red has a number for FY 2012 — the budget that's actually being talked about in Washington right now — that is basically just what we assumed, and is a perfectly good number.

But then in FY '13, '14, '15, and '16, the funding for planetary science declines precipitously, in this particular budget projection. Now, I will return again to the subject of this budget and what its actual fate is likely to be at the end of my presentation. I will, however, read what it says in yellow, right here: In accordance with the President's proposal to implement a five-year non-discretionary, non-security discretionary spending freeze, budget figures shown for the years after FY 2012 are notional. It's an interesting word, notional. They're notional and do not represent policy; funding decisions will be made on a year-by-year basis. So this has not yet come to pass, but this is something that we, as a community, need to take seriously, and I'll return to this subject later.

The Recommendations: First recommendation, [for] ongoing and approved missions, we recommend that NASA continue the missions that are currently in development and continue the missions that are currently in flight subject to senior review. All of NASA's ongoing missions are subjected on a regular basis to a senior review process in which a review board is convened, looks at the science they've been

Mission Directorate:	Science
Theme:	Planetary Science

FY 2012 Budget Request

Budget Authority ($ millions)	FY 2010	Ann CR. FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
FY 2012 President's Budget Request	**1,364.4**	**-**	**1,488.9**	**1,365.7**	**1,326.4**	**1,271.0**	**1,188.9**
Planetary Science Research	161.6	-	183.9	196.0	208.6	208.4	210.5
Lunar Quest Program	94.5	-	114.5	81.2	48.9	28.1	19.5
Discovery	184.5	-	175.6	205.1	245.7	265.5	242.8
New Frontiers	279.6	-	176.9	265.8	245.5	291.1	296.3
Mars Exploration	438.2	-	594.4	433.1	408.7	309.0	245.9
Outer Planets	100.6	-	120.8	80.5	82.2	84.1	88.5
Technology	105.5	-	122.9	104.1	86.6	84.9	85.4

Note: The new Planetary Science Decadal survey, developed by the National Academy of Sciences, will be released in March 2011. The decadal survey is designed to broadly canvas the field of planetary science to determine the current state of knowledge and then identify and prioritize the most important scientific questions and associated missions during the 2013-2022. NASA will re-examine all elements of the Planetary Science program and may modify future budget and content to better align with the findings and recommendations of the report.

The FY 2011 appropriation for NASA was not enacted at the time that the FY 2012 Request was prepared; therefore, NASA is operating under a Continuing Resolution (P.L. 111-242, as amended). Amounts in the "Ann. CR FY 2011" column reflect the annualized level provided by the Continuing Resolution.

In accordance with the President's proposal to implement a five-year non-security discretionary spending freeze, budget figures shown for years after FY 2012 are notional and do not represent policy. Funding decisions will be made on a year-by-year basis.

achieving, looks at the science they plan to achieve, and passes judgment along to NASA Headquarters. That's a good process; it's working, it should continue. The missions that are currently in development, things like GRAIL, Juno, New Frontiers-3 [the selection of which was just announced], MSL/MAVEN, development of those should continue. So, we don't see any problems with the missions that are currently in development or flying.

The Research and Analysis program, NASA's planetary and R&A program: We recommend a modest increase to R&A funding. I wish we could have recommended more but we have to be realistic. What we recommend is a 5% bump in the first year, above the FY '11 number (whatever that turns out to be eventually), and then a gradual increase of 1.5% per year above inflation, in each successive year. We all know how much pressure there is on the programs that we write proposals for, we all know how oversubscribed these proposals are, we all have a strong sense that if NASA spends more money on R&A they're going to get more good science, and that's the reason for this recommendation. At the same time it's got to come out of something, and so we couldn't recommend it going up as much as we would have liked to.

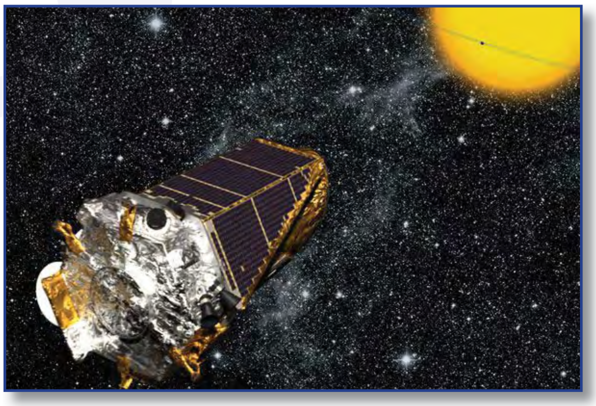
All of the recommendations you're gonna see downstream from this slide are consistent, fully consistent with this funding increase. So this funding increase is accounted for in everything else that you're gonna see. Also, it's not on this slide, but I'll also mention that another recommendation on R&A was that NASA seek to reduce the number of proposals that people in our community have to write, by combining programs, by increasing grant sizes. There's an enormous burden on our community in writing and reviewing proposals and we would like to see NASA take some steps to reduce that burden.

Technology Development: Having a good technology program is fundamental to having a sound, healthy program of flight projects. The flight projects depend on the availability of technology; that was a critical gate through which every mission candidate had to get, and in many cases there were missions that would have been great, but the technology wasn't ready enough. And we don't think the NASA

Planetary Science Division should rely on anybody else in NASA to develop for them technologies that are only going to be used by NASA planetary missions.

So, we recommend that NASA PSD (the Planetary Science Division) establish a technology development program and rigorously protect it from incursions on that budget. A problem we've had in the past is when money gets tight, technology money is always a tempting target to go after. Go after it, the technologies don't get developed, and so the next mission that gets selected is selected with inadequate understanding of its technology, and that one overrides. It's a vicious circle. And we recommend that this program be funded about 6 to 8% of the NASA planetary budget; that winds up being about 100 million dollars. And again, all of the recommendations you'll see downstream are consistent with that level of technology program.

The Discovery Program: We love the Discovery program, the community loves the Discovery program. NASA's last round of community-submitted proposals to Discovery, I think it was 28 (is that right?), 28 proposals came from our community. Discovery has produced — and you can see the results of five particular Discovery missions here — spectacular cost-effective science and can continue to do so well into the future. We recommend continuing the Discovery program, at its current funding level, adjusted for inflation, with a cost cap per mission that is also adjusted for inflation. And when you inflate that to FY '15 dollars, it winds up being about 500 million. And we really strongly urge NASA to assure a regular, predictable cadence, no more than 24 months between AOs, but a regular, predictable cadence of Discovery AOs. [Responding to] these Discovery AOs is a huge job, it's a big, big pushup for this community, and when you have AO dates moving around, it's so hard to keep your team together; to keep your team moving forward, you need to have reliable dates, so they should come on a regular cadence.

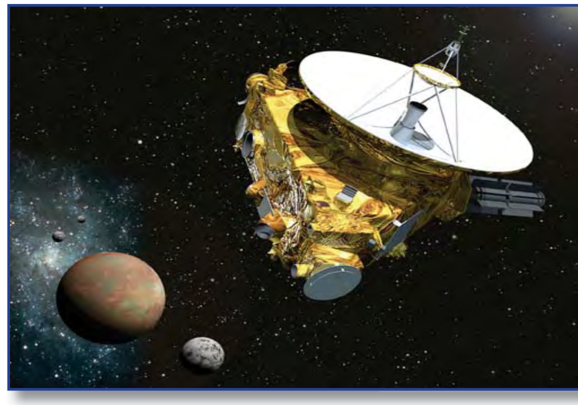


The Kepler mission, part of NASA's highly successful Discovery program, was launched in 2009. Using the prolific planet-hunting Kepler spacecraft, astronomers have discovered 1235 candidate planets orbiting other suns since the Kepler mission's search for Earth-like worlds began. The goal of the Discovery program is to achieve outstanding results by launching many smaller missions using fewer resources and shorter development times. Credit: NASA/Kepler mission/Wendy Stenzel.

We make no recommendations for specific Discovery missions, [in other words], the way Discovery works, and our Statement of Task was quite explicit on that. We were not asked, nor should we have been, to provide specific recommendations for specific Discovery missions; we rely on the creativity of this community to generate the best proposals. But you will see in our report very strong support for Discovery as a program because of all the science potential it still has.

Mars Trace Gas Orbiter: This is kind of a special case that doesn't quite fall into New Frontiers or Discovery or anything else. This is a mission that has been discussed between NASA and the European Space Agency; it would follow up on groundbased observations that suggest that there is methane in the atmosphere of Mars, and would provide data that will help reveal sources and sinks of methane and a variety of other trace gases. The deal that has been negotiated with ESA is a very favorable one for NASA. NASA provides the launch vehicle, and then most of the science payload, with ESA providing the spacecraft. So this is a good deal for NASA, and we recommend that NASA carry out this mission as currently planned, as long as this division of responsibility with ESA is preserved. Now, the deal with ESA on this mission is part of a longer-term discussion with ESA of a joint program of Mars exploration in 2018 and beyond, and I'll return to that in a few moments.

New Frontiers: We feel that the New Frontiers Program, which arose out of the last Decadal Survey, has been a big success. New Horizons is in great shape and on its way to Pluto, the Juno development is going well, and it provides a way for community-derived PI-led missions to address science that is beyond the capabilities of a Discovery mission. So, we recommend that New Frontiers continue; it's been a success and we should keep going. We, however, recommend a restructuring of the New Frontiers cost cap. Currently, the New Frontiers cost cap — if you take it and you inflate it to FY '15 dollars, is about 1.05 billion dollars, including the cost of a launch vehicle. We recommend that instead the cost be 1.0 billion FY '15 dollars, excluding launch vehicle costs.



New Horizons, part of the New Frontiers program, is on its way to Pluto. The goal of the New Frontiers program is to explore the solar system with frequent, medium-class, high-science-return spacecraft missions. Credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI).

Now, this represents a modest increase in the cap, and we made these recommendations for two reasons: One is that by having that modest increase in the cap, we were able to capture, under that cap, some very appealing New Frontiers mission candidates, which I'll show you in just a moment. The other reason is that by excluding launch vehicle costs we help to protect New Frontiers proposal teams from the extreme volatility in the cost of launch vehicles these days. Rocket costs are going crazy and mostly up. And it's very difficult for a team to realistically plan a mission if they don't even know what the rocket's gonna cost. By taking it out of the cap we protect the proposal teams from that volatility.

And we recommend that NASA select two more New Frontiers missions, those are the New Frontier-4 and New Frontiers-5 in the coming decade. For the New Frontiers-4 selection, we recommend that NASA choose from among these five mission candidates. A Comet Surface Sample Return, just what it sounds like . . . samples from the surface of comet nucleus. A Lunar South Pole-Aitken Basin sample return, again just what it sounds like. And a Saturn Probe, an atmospheric entry probe. This is the big piece of Saturn science that Cassini didn't do. (Those of you who have been in this business for a really long time will remember that there was once a mission that was talked about called SOP2, Saturn Orbiter and two probes, one probe to go into Saturn, the other to go into Titan. Cassini captured most of that but it didn't capture the Saturn Probe. This is the Saturn Probe.) A Trojan Asteroid Tour and Rendezvous mission and a Venus In Situ Explorer. This is a Venus lander to go to the venusian surface and look at composition, atmosphere, and so forth.

We assign no relative priorities among these five. These five bubble up to the top among many possible candidates; they were all close enough to one another in terms of science in return per dollar, that we feel that it is best to rank these five based on the AO and peer review process. So NASA should choose New Frontiers-4 from among these five. However, if the New Frontiers-3 mission, which NASA will select sometime in the coming months, addresses the science of any one of those five, you can pluck that one off the list, and it goes from five down to four.

For New Frontiers-5, we recommend adding two more candidates to the list, and again all of this is based on those criteria that I told you about, science return per dollar and programmatic balance. The two candidates are an Io Observer, this is a mission to go into orbit around Jupiter — highly eccentric orbit, many flybys of Io — and a Lunar Geophysical Network, a network of geophysical stations on the surface of the Moon. And again, no relevant priorities among those.

The Flagships: I've got a long list of flagship missions for you; I wish we could do them all, but it's worth listing all of these and prioritizing all of these, because as you'll see when we get downstream, it winds up being relevant to the decision rules.

The first-priority Flagship that we recommend is that we begin a joint NASA/ESA Mars Sample Return campaign, with the MAX-C (that's Mars Astrobiology Explorer-Cacher mission), but dramatically descoped from what is being discussed right now. Our second recommended priority, very close to MAX-C actually, is the detailed investigation of an ocean on Europa, using a substantially descoped version of the Jupiter Europa Orbiter mission. The third-ranked Flagship mission is the first in-depth exploration of an ice giant planet, a Uranus orbiter and probe. And I'll address, in just a moment, why we picked Uranus over Neptune. It was just for practical, pragmatic reasons. And then finally, either an Enceladus Orbiter or a Venus Climate Mission, and there's no relative order or ranking between those two.

Let's do MAX-C first. The view that was expressed very clearly by the Mars science community was that Mars science has now reached the point where the most fundamental advances are going to come from study of returned samples. Now, MAX-C would do a little in situ science, but fundamentally it's about collecting and caching a well-characterized set of samples that would then come back to Earth as part of a three-mission sample return campaign that continues on into the next decade. One mission that caches the samples, a second mission that lands alongside it, grabs that sample cache and puts it into orbit around Mars, and a third mission that captures that sample from Mars' orbit and brings it back to Earth.

Artist's depiction of a Mars sample return mission. Credit: NASA.

This campaign would be fundamentally enabled from a cost perspective by the participation of the European Space Agency through all aspects of the campaign. So, maintaining that partnership with ESA is critical to the success of this. Of the three missions in the campaign, only MAX-C is recommended for the decade that we talked about; the others would come downstream from that. And the view that we got from the Mars panel was that that sample cache does not have a short shelf life; it can sit there for a while if it has to.

Important point: This campaign, Mars Sample Return, is multi-decadal in character; it has to be. And so we make this recommendation with full realization of the implication that it has for the next decade, and we based its priority on its anticipated total science return, that is, the return of the science from the samples, and the cost to NASA of the entire campaign. That was how it was judged.

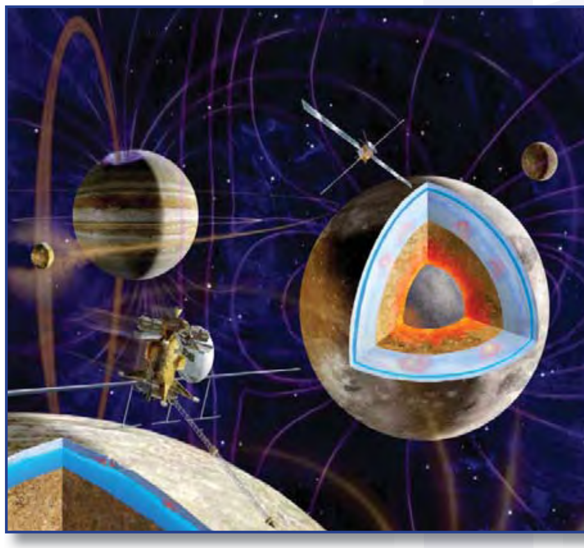
Now, this one costs a lot of money. Remember I showed you that one that jumped up to 3.5 billion dollars? That was MAX-C. The CATE estimate for this thing was 3.5 billion, and in the judgment of the Decadal Survey this is too large a fraction of the planetary budget to be spending on Mars; it's too much to achieve programmatic balance. And so our recommendation was that NASA fly MAX-C only if it can be conducted at a cost to NASA of 2.5 billion, and that number was not arrived at arbitrarily.

The mission as it's now being discussed is a mission jointly with ESA that would deliver two rovers to the same spot on the martian surface. It would deliver the ESA ExoMars Rover, and the NASA MAX-C sample caching rover. And the cost of accommodating both of those vehicles is what we believe drives the cost of this mission to 3.5 billion.

As sort of a proof of concept that there was actually a 2.5 billion dollar mission out there, we asked Aerospace to study the case where you use the Mars Science Laboratory entry, descent, and landing system to deliver a single rover, with the capabilities of one of these, to the martian surface, and that number came back at a little less than 2.5 billion. And that was for NASA alone. So, if you throw in an ESA contribution as well, we're quite confident that a really good mission can be done for 2.5 billion. But we leave it to those two agencies to work out exactly the details on what that would look like. Critically, we thought that the descopes have to be shared equitably between NASA and ESA because it's so important to preserve the partnership with ESA. We can't force all the bad news on ESA; it's got to be a fair split between NASA and ESA. Now, if that goal of 2.5 billion cannot be achieved, for whatever reason, our recommendation is that MAX-C should be deferred to a subsequent decade or cancelled.

And there's no plan B, there's no alternate plan for Mars exploration recommended; this was what was told to us by our Mars panel. Mars Sample Return's the next right thing to do, and if you can't do MAX-C for less than 2.5 billion, then there are other high-priority Flagship missions on that list that take precedence over something else you might do at Mars.

Second priority: JEO. If you look at the last decadal where Mars and the rest of the solar system were treated separately, the two highest priorities were Mars Sample Return and Europa. We're seeing the same thing here. There may be another ocean in the solar system on Europa, and this is a mission to study and try to characterize that ocean.



The goal for the Jupiter Europa Orbiter mission is to characterize the processes within the jovian system and determine whether the Jupiter system harbors habitable worlds. Credit: NASA/JPL/Michael Carroll.

Problem is, this one is very expensive; the CATE estimate for the cost of JEO was 4.7 billion dollars. That's a scary big number and it's too large a fraction of the planetary budget; we just simply cannot afford this mission at 4.7 billion. So we recommend that NASA fly JEO, but only if changes to both the mission and the planetary budget make it possible to do this one without it forcing the cancellation of other recommended missions.

This will require a reduction in mission scope and hence its cost, and it will also, we believe, require an increase in the NASA planetary budget in the form of a new start for this mission that comes with money attached, because this thing is so expensive. So, one of our strongest recommendations regarding Europa is that NASA immediately begin an effort to try to find some major cost savings in JEO. And if you look in our report there are some specific suggestions on how to do that.

I also point out that the science of JEO would be enhanced substantially if, as hoped, it would be carried out in tandem with ESA's Ganymede Orbiter mission. If you fly both of these at the same time you get Europa science and Ganymede science, but you also get terrific Jupiter-system science from two different places within the jovian system. Two different vantage points on the planet, two different points within the magnetosphere, and so forth. So it's very nice synergy with the mission that ESA is talking about.

The third one, a Uranus Orbiter and Probe. This is a cool mission! I mean, if you look at the solar system, there's basically three kinds of planets: you've got terrestrial planets, you've got gas giants, and you've got ice giants. And the ice giants are fundamentally different from the gas giants in terms of their composition, in terms of their evolution, and we think that a mission to one of these planets has the same kind of potential for discovery that Cassini did at Saturn or Galileo at Jupiter.

Now, you could choose Uranus or you could choose Neptune. The reason for zeroing in on Uranus was practical, it was not scientific. Remember I mentioned those two gates. It turns out that in the decade that we're looking at the trajectories to Uranus are better. Second, doing a good Neptune mission is enabled best if you have the technology of aerocapture available to you, which we don't yet have. So, for this decade, Uranus is the proper choice; if this got pushed downstream to a later decade, Neptune could be a very strong candidate as well.

Before, I mentioned the importance of a technology program. We have in our report, in Chapter 11, some specific, precise recommendations regarding the technologies to invest in. It is important that these technologies be linked (since the money's coming out of your budget, Jim) to the missions that you want to fly in the planetary division. So we particularly emphasize mission technology development is linked to a Titan Saturn System Mission — which is a very high priority mission from the outer planet satellites group; it didn't rise to the same level as Europa in our study, but it's clearly a high priority and an area where there should be some technology development; technology specific to the Neptune mission — if Uranus doesn't happen and we get downstream and we can choose between Uranus and Neptune, Neptune could be a fine choice; and then there are two more missions, the [Mars] sample return lander and the sample return orbiter and that sample return campaign, and there are important technologies needed there, for example, the Mars ascent vehicle that's gonna blast those samples off the surface and put them in orbit around Mars.

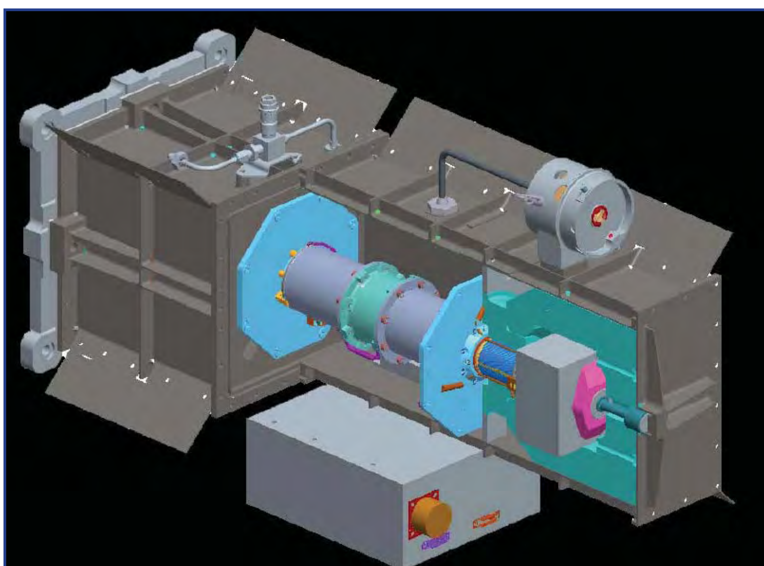
I'm gonna show you some budget charts. So this is what we've called the Cost-Constrained Program. The black line that you see here, that black line is the same as that red wedge that I showed you at the beginning. That was the target we were hoping to kinda hit. Taking these colorful curves, we'll go from the bottom up, the blue one at the bottom, that's the R&A program, and you see it increasing at the level that we recommend. Yellow, that's Discovery, it starts off low because we've got Discovery missions in development now, but then it grows out to the level that we suggested. The black and the gray, that's the Technology Program. The big, fat orange one there, that's MAX-C, and that's MAX-C at 2.5 billion. MAX-C at 3.5? Do the math. It totally busts the curve, you can't do it, you've got no way of getting there. So that's MAX-C at 2.5. The two purple ones, that's New Frontiers-4 and New Frontiers-5. And then the green one is the beginning of the Uranus mission. Where is Europa? There's Europa (see the blue wedge). That's Europa at 4.7. You can see why we feel it is so imperative that NASA find a way to descope that mission and bring the cost down to something reasonable. It is a fabulous mission, but at 4.7 it's an intractable problem that needs to get fixed.

I talked about decision rules. What happens if the funding is less? What happens if we don't get the black line in that plot? Our recommendation is that the first thing NASA do, if the funding is less, is descope or delay Flagship missions. If we get into a program where the only missions that we are flying are Flagships, that return data in 10 years or 15 years, or get the samples back in 20 years, that leads to an unacceptable stagnation of our program. We must preserve Discovery, we must preserve New Frontiers, so the first thing to go after is the Flagships. And that was what our community told us emphatically. We should slip New Frontiers or Discovery missions only if adjustments to the Flagships can't solve the problem, and throughout any process like this NASA should place high priority on preserving R&A and technology development funding. That wording was chosen very carefully. It doesn't say that those two are absolutely sacrosanct, but it stresses the great importance to the health of our discipline, of R&A and technology.

So let's just follow this through. What happens in the face of what might be declining budgets? We say protect R&A, protect technology, protect Discovery, and protect New Frontiers. So let's look at MAX-C. We recommend that NASA fly a 2018 NASA/ESA Mars mission only if two conditions are met. One is that the cost to NASA is no more than 2.5 — and based on the work that we did we truly believe that there's a good mission in there at 2.5 — and the other is that it leads realistically to sample return. A mission that sends another rover, another MER-class rover, to run around, pick up samples, and take some pictures, but doesn't get those samples back, does not rise to the level of importance that makes it our top Flagship. So there's gotta be a pathway to sample return, and that probably means preserving that partnership with ESA. If it turns out that for whatever reason — technology's not ready, partnership with ESA falls apart, whatever — if Mars '18 does not meet these criteria, then the second priority is JEO; there's no recommended plan B for Mars. Okay?

If you can't afford JEO , if JEO can't be descoped from that 4.7 down to something we can actually swallow, then the third priority is the Uranus Orbiter and Probe and that one costs out at a whopping 2.7 billion. So it ain't cheap either. If that's not affordable — and this is why we have those two other Flagships in there — there's a Venus climate mission at 2.4 billion and an Enceladus Orbiter mission at 1.9 billion. And if you can't afford any of those, you've got no Flagships at all.

Launch vehicle costs: This is a big concern. Launch vehicle costs were the reasons that we recommended restructuring the New Frontiers caps. Launch vehicle costs are growing, they're very, very volatile, and it's a big threat to our planetary program. We recommend a couple of steps that could be taken to help reduce launch costs. One is dual manifesting: Look for opportunities to launch two vehicles together on the same rocket. There's risk involved in doing that but there's also a benefit. Another is block buys across NASA, not just NASA planetary, but across all of NASA of certain launch vehicles. NASA used to procure Delta-2 launch vehicles this way; if you buy them as a group, if you buy several at once, maybe you can get a deal.



The Advanced Stirling Radioisotope Generator (ASRG) would provide a high-efficiency power source alternative, and the system efficiency would reduce the required amount of radioisotope by a factor of three or four compared to radioisotope thermoelectric generators, thereby significantly reducing radioisotope cost, radiological inventory, and system cost. Credit: NASA.

And finally, there are critical technologies, and aerocapture is a great example, that can be implemented and exploited to reduce substantially the mass of spacecraft and therefore reduce the performance and hence the cost of the launch vehicles that we use. So, these are all things that maybe we can take advantage of, but fundamentally we've got a problem here, and our reason for recommending restructuring of the New Frontiers caps is because of that problem.

Plutonium-238, this is another big issue. The amount of plutonium that we have for our spacecraft power systems is dwindling alarmingly, and unless NASA and the Department of Energy can get their act together via the congressional process to restart plutonium-238 production, it's ultimately going to be impossible for NASA to do any missions to the deep outer solar system; you also need these things for a long lived lunar seismic network, there's a 14-day lunar night.

Now, one thing that we think can be done to really help this problem is to place greater emphasis on the development of the ASRG, the Advanced Stirling Radioisotope Generator. This is a device that is able to produce power from plutonium-238, at a factor of three or four higher efficiency, so it dramatically reduces the amount of plutonium that you need. We recommend that JEO switch to ASRGs now, and include that in any descoped version of the mission because it uses so much less plutonium.

The thing about these ASRGs, though, is they're complicated little machines, they've got lots of moving parts, and they have not been proven out as something that can last the 15- or 20-year timescales that might be associated with some of these deep space missions. So, this is one of our highest-priority recommended technologies and we would like to see ASRG development given a level of attention comparable to what you would give to a flight project, they're so important.

Interaction with NASA's human exploration program: Now, this, of course, is a rapidly evolving situation, but looking at it realistically, the bodies that we're going to be sending humans to, in the foreseeable future, are limited to some planetary objects, particularly the Moon, asteroids, and Mars and the moons of Mars. Now, we have missions, recommended missions, via New Frontiers, via the Discovery program, via the Flagships, to all of these objects.

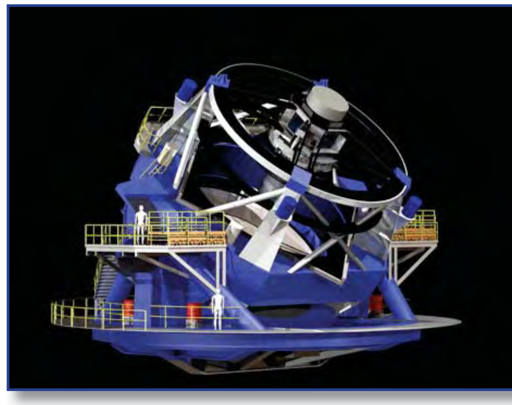
When we have a peer-reviewed NASA planetary mission to one of these objects, we feel that it is imperative to maintain the science focus of such missions. In particular, what we don't want to see happen is, let's say, a proposal team proposes a mission to one of these objects, a New Frontiers mission. They write their proposal, they get it in, they get it accepted, and then after all that, the human exploration folks show up with a bunch of new requirements and maybe not enough money to pay for them. That's the kind of situation we want to avoid.

Now, that sounds very negative, but I will also point out that there's a wonderful recent example of a partnership between the exploration part of NASA and the planetary part of NASA, and that's LRO. That's an ESMD (exploration) mission; it was carried out using scientific instruments that were well planned, well designed, and well calibrated, did its exploration-related goals, and operations have now been handed over to NASA Code S and it's producing terrific science with a wonderful set of instruments. So these partnerships with ESMD can be very successful if they're crafted well at the start as LRO was.

Supporting NASA activities, I won't go through this on a whole lot of detail, we recommend continuation and upgrading of the planetary data system, we recommend roughly 1% of the cost of each flight project be set aside for education and outreach, we recommend continued NASA support for telescope facilities, IRTF, Keck, Goldstone, Arecibo, and VLBA. Expand the capabilities of Deep Space Network, and we have specific recommendations regarding the communications bands for uplink and downlink and for the sample return missions coming up. And we recommend that when NASA plan these sample return missions they take into account the full cap cost of receiving and curating those samples when planning these missions. That doesn't mean that the projects pay for those costs, but it means that the most important science gets done, after the missions get back down to Earth, after the samples get back to Earth. You've gotta keep that in mind. And we recommend that NASA establish a program of instrument development for these future sample return missions.

The National Science Foundation: NSF supports many observatories that are important to planetary astronomy; we recommend the continued support of those observatories. The Office of Polar Programs supports a lot of important work in Antarctica, both terrestrial Mars analog studies, planetary analog studies, and importantly collection of meteorites, we recommend that that continue. We recommend expanded NSF funding for laboratory research in planetary science. Now, let me tell you something; I briefed our report (Dale Cruikshank was there to help me do it) to the National Science Foundation and there was a lot more detail than what you see here. One of the things they said back to me is, look, we'd love to support planetary research, but we need to get proposals from your community, and not just proposals where you scratch out NASA on the cover page and write in NSF. So it is important if we want to make these recommendations that our community actually follow up with good proposals.

Finally, and very importantly, there's this Large Synoptic Survey Telescope, LSST. This is a groundbased facility that is being developed for a variety of different causes, some of them, many of them, astrophysical, but it's a facility that has enormous potential for doing planetary science, particularly the science of primitive bodies. And so we came out very strongly in support of completion of LSST and its use for planetary science.



The 8.4-meter Large Synoptic Survey Telescope (LSST) will use a special three-mirro design, creating an exceptionally wide field of view, and will have the ability to survey the entire sky in only three nights. Credit: LSST Corporation.

Upcoming Events: Tonight is the unveiling here at LPSC of the Decadal Survey, but we want to have many opportunities, much more opportunity than we'll have all of us together in this one room tonight, to discuss this among ourselves as a community. We've set up a series of Town Hall meetings, and you can see the list of them here, Mountain View, California, College Park, Maryland, down the list. Here are the dates. Members of the Decadal Steering group (and I'm looking at my friends in the front row, I know a number of you have signed up to do these) are going to be present at all of these to interact with the community, to answer your questions, to talk about the implementation of the Decadal Survey. We have the AGs, the analysis groups, we've already set up briefings for OPAG and MEPAG, in Virginia and in Portugal coming up, I anticipate that there will be others and if there are any AG chairs out there who would like to talk to me about this, please come and see me. And there's also a great deal of international interest in this; I'll be briefing this at the EGU meeting in Vienna in April and at the Japanese Geophysical Union in Tokyo in May.

I've got two more things to say, and here's the first. I've said a lot tonight about descopes and how important it is that we descope some of these missions. Descoping is a difficult thing; descoping requires discipline, it requires giving up some of our most cherished hopes of what a mission might be like. It's a hard thing to do. But let me remind you about two of my favorite descoped missions. There was once a mission called the Grand Tour; it was big, it was aggressive, it was comprehensive, it took advantage of a once-in-more-than-a-century alignment of the outer planets. It was too much; we couldn't afford it, it got descoped massively. It became something we all know as Voyager.

Some of you will also remember that there was once a mission called VOIR, Venus Orbiting Imaging Radar. Spectacular mission, with radar to map the surface of Venus. Big, complicated, aggressive; again, too much, massively descoped. That mission became Magellan. Two massively descoped missions, Voyager and Magellan, and between them they revolutionized our understanding of five planets. So descoping, when it's done right, can lead to great missions.

Here's my final point, and this is probably the most important thing that I have to say to you tonight. I showed you this budget earlier. This budget is a projection by OMB of what the future of planetary exploration might look like. Now, if that budget were actually implemented, it would mean the end of Flagship-class science at NASA, in the planetary program. But this budget, this is just the first step in a long process. This is not set in stone by any means. I mean, the language that comes with this from OMB, even that language says that it's notional. Now, this budget is the first step in the process from the executive branch of the government. NASA works for the executive branch, Jim Green works for NASA, and when Jim Green is handed this budget, his job is to go off and figure out how to implement it. But there's a lot more to the process than that. There's the legislative part, and that's a big part of the budget process too, and the legislative branch of the government, the Congress, is answerable to its constituents and those constituents include us. So, those of us who care about planetary exploration have not just the right, but I believe the obligation, to speak to our congressional representatives about the planetary budget and to make it very clear what program we would like to see. Now, the timing here is exquisite. This budget just came out a few weeks ago, and at virtually the exact moment that we get handed this budget projecting possibly the decline of planetary science in this country, at the same moment, we as a community have produced the Decadal Report. This arose from our community, it has the full weight of the National Research Council behind it, and that counts for a lot in Washington, D.C.

This is a report that clearly articulates a compelling program of planetary exploration that includes Flagship-class science. So we have the opportunity here, with this report, to use this as a rallying point and to speak together as a community with one voice in support of Jim Green's and our program of planetary exploration. If we do not speak up, then there is some chance that we'll see a program like the one represented by this budget and all that it implies. But if we can speak together, with a single voice, reach out to our congressional representatives in support of this NRC plan for planetary exploration, I think we have a good chance of getting the kind of program that we all really want to see. Thank you.

Editor's note: To download the Decadal Survey report or view the video and PowerPoint files of the presentations by Squyres or Green, visit *www.lpi.usra.edu/decadal/2013_2022/*. For a schedule of upcoming Town Hall meetings, go to *solarsystem.nasa.gov/2013decadal/index.cfm*.

The *Lunar and Planetary Information Bulletin* collects, synthesizes, and disseminates current research and findings in the planetary sciences to the research community, science libraries, educators, students, and the public. The *Bulletin* is dedicated to engaging, exciting, and educating those with a passion for the space sciences while developing future generations of explorers.

The *Bulletin* welcomes articles dealing with issues related to planetary science and exploration. Of special interest are articles describing web-based research and educational tools, meeting highlights and summaries, and descriptions of space missions. Peer-reviewed research articles, however, are not appropriate for publication in the *Bulletin*. Suggested topics can be e-mailed to the editors, who will provide guidelines for formatting and content.

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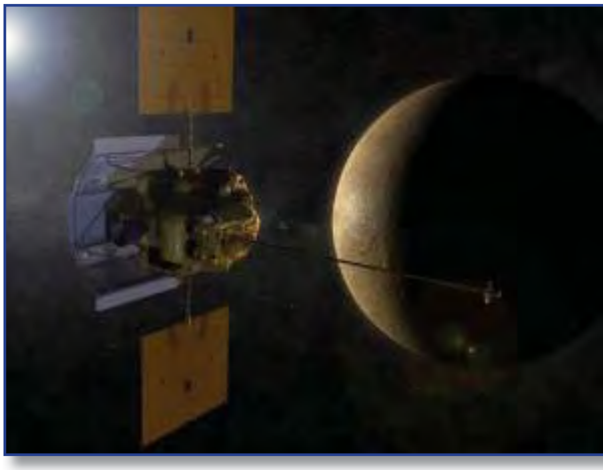


Artist's concept of MESSENGER in orbit around Mercury. Credit: NASA.

NASA's MESSENGER Spacecraft Begins Historic Orbit Around Mercury

NASA's MErcury Surface, Space ENvironment, Geochemistry, and Ranging (MESSENGER) spacecraft successfully achieved orbit around Mercury at approximately 9:00 p.m. EDT on March 17. This marks the first time a spacecraft has accomplished this engineering and scientific milestone at our solar system's innermost planet.

"This mission will continue to revolutionize our understanding of Mercury during the coming year," said NASA Administrator Charles Bolden, who was at MESSENGER mission control at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland, as engineers received telemetry data confirming orbit insertion. "NASA science is rewriting text books. MESSENGER is a great example of how our scientists are innovating to push the envelope of human knowledge."

At 9:10 p.m. EDT, engineers at the Operations Center received the anticipated radiometric signals confirming nominal burn shutdown and successful insertion of the MESSENGER probe into orbit around the planet Mercury. MESSENGER rotated back to the Earth by 9:45 p.m. EDT and started transmitting data. Upon review of the data, the engineering and operations teams confirmed the burn executed nominally with all subsystems reporting a clean burn and no logged errors.

MESSENGER's main thruster fired for approximately 15 minutes at 8:45 p.m., slowing the spacecraft by 1929 miles per hour and easing it into the planned orbit about Mercury. The rendezvous took place about 96 million miles from Earth. Over the subsequent weeks, APL engineers focused on ensuring the spacecraft's systems were all working well in Mercury's harsh thermal environment. Starting March 23, the instruments were turned on and checked out, and on April 4 the mission's primary science phase began.

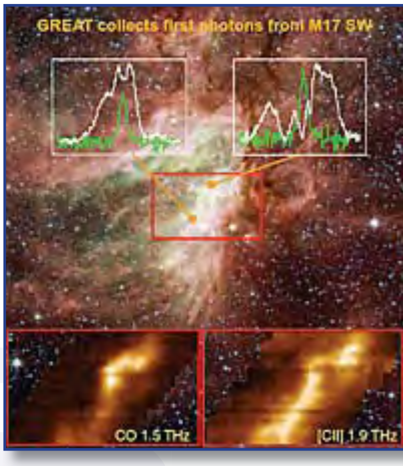
"Despite its proximity to Earth, the planet Mercury has for decades been comparatively unexplored," said Sean Solomon, MESSENGER principal investigator, of the Carnegie Institution of Washington. "For the first time in history, a scientific observatory is in orbit about our solar system's innermost planet. Mercury's secrets, and the implications they hold for the formation and evolution of Earth-like planets, are about to be revealed."

For more information about the mission, visit *www.nasa.gov/messenger.*

SOFIA Completes First Flight of German Science Instrument

The Stratospheric Observatory for Infrared Astronomy (SOFIA) completed its first science flight Wednesday, April 6, using the German Receiver for Astronomy at Terahertz Frequencies (GREAT) scientific instrument. GREAT is a high-resolution far-infrared spectrometer that finely divides and sorts light into component colors for detailed analysis.

SOFIA is the only operational airborne observatory. It is a joint program between NASA and the German Aerospace Center (DLR). The observatory is a heavily modified Boeing 747SP aircraft carrying a



High-resolution far-infrared spectra of the nebula Messier 17 (M17) obtained with the GREAT spectrometer and SOFIA on the night of April 5–6, 2011, superimposed on a Spitzer infrared image. Credit: Spectra: GREAT Team/NASA/DLR/USRA/DSI; background IR image: NASA/JPL-Caltech/Spitzer.

reflecting telescope with an effective diameter of 100 inches. Flying at altitudes between 39,000 and 45,000 feet, above the water vapor in Earth's lower atmosphere that blocks most infrared radiation from celestial sources, SOFIA conducts astronomy research not possible with groundbased telescopes.

"SOFIA's onboard crew seamlessly combined scientists, engineers, and technicians from the U.S. and Germany, working together on an observatory developed in the U.S., using a telescope and instrument built in Germany, to gather data of great interest to the entire world's scientific community," said Bob Meyer, NASA's SOFIA Program manager at NASA's Dryden Flight Research Center.

GREAT Principal Investigator Rolf Guesten of the Max Planck Institute for Radio Astronomy in Bonn, Germany, and his team conducted observations high above the central and western United States beginning the night of April 5 with their instrument installed on SOFIA's telescope. Among their targets were IC 342, a spiral galaxy located 11 million light-years from Earth in the constellation Camelopardalis ("The Giraffe"), and the Omega Nebula (known as M17), 5000 light-years away in Sagittarius. The team captured and analyzed radiation from ionized carbon atoms and carbon monoxide molecules to probe the chemical reactions, motions of matter, and flows of energy occurring in interstellar clouds. Astronomers have evidence that such clouds in both IC 342 and M17 are forming numerous massive stars.

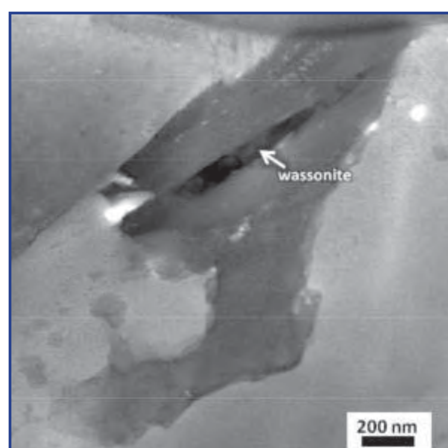
GREAT focused on strong far-infrared emissions from interstellar clouds that cool the clouds. The balance between heating and cooling processes regulates the temperature of the interstellar material and controls initial conditions for the formation of new stars.

For more information about SOFIA, visit *www.nasa.gov/SOFIA*. For more information about SOFIA's science mission, visit *www.sofia.usra.edu* or *www.dlr.de.en/sofia/*.

Scientists Find New Type of Mineral in Historic Meteorite

NASA and co-researchers from the United States, South Korea, and Japan have found a new mineral named "Wassonite" in one of the most historically significant meteorites recovered in Antarctica in December 1969. The new mineral was discovered within the meteorite, which is officially designated "Yamato 691 enstatite chondrite." The meteorite was discovered the same year as other landmark meteorites Allende and Murchison and the return of the first Apollo lunar samples. The study of meteorites helps define our understanding of the formation and history of the solar system.

The meteorite likely originated from an asteroid orbiting between Mars and Jupiter. Wassonite is among the tiniest, yet most important, minerals identified in the 4.5-billion-year-old sample. The research team, headed by NASA space scientist Keiko Nakamura-Messenger, added the mineral to the list of 4500 officially approved by the International Mineralogical Association.



A bright field scanning transmission electron microscope (STEM) micrograph showing a Wassonite grain in dark contrast. Credit: NASA.

"Wassonite is a mineral formed from only two elements, sulfur and titanium, yet it possesses a unique crystal structure that has not been previously observed in nature," said Nakamura-Messenger.

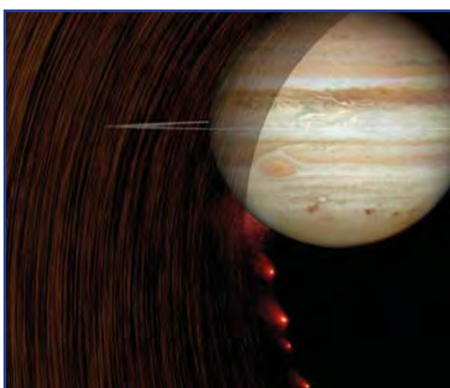
In 1969, members of the Japanese Antarctic Research Expedition discovered nine meteorites on the blue ice field of the Yamato Mountains in Antarctica. This was the first significant recovery of Antarctic meteorites and represented samples of several different types. As a result, the United States and Japan conducted systematic follow-up searches for meteorites in Antarctica that recovered more than 40,000 specimens, including extremely rare martian and lunar meteorites.

Researchers found Wassonite surrounded by additional unknown minerals that are being investigated. The mineral is 50 × 450 nanometers (less than one-hundredth the width of a human hair). It would have been impossible to discover without NASA's transmission electron microscope, which is capable of isolating the Wassonite grains and determining their chemical composition and atomic structure.

The new mineral's name was approved by the International Mineralogical Association. It honors John T. Wasson, professor at the University of California, Los Angeles (UCLA). Wasson is known for his achievements across a broad swath of meteorite and impact research, including the use of neutron activation data to classify meteorites and to formulate models for the chemical makeup of bulk chondrites.

"The beauty of this research is that it really demonstrates how the Johnson Space Center has become a pre-eminent leader in the field of nanoscale analysis," said Simon Clemett, a space scientist at Johnson and co-discoverer of the new mineral. "In the words of the great English poet William Blake, we are now able 'to see the world in a grain of sand'. "

To see more images of Wassonite, visit *www.nasa.gov/centers/johnson/home/wassonite.html*.



This artist's concept shows Comet Shoemaker-Levy 9 heading into Jupiter in July 1994, while its dust cloud creates a rippling wake in Jupiter's ring. The comet, as imaged by NASA's Hubble Space Telescope, appears as a string of reddish fragments falling into Jupiter from the south. Credit: NASA.

NASA Spacecraft Reveal Mysteries of Jupiter and Saturn Rings

In a celestial forensic exercise, scientists analyzing data from NASA's Cassini, Galileo, and New Horizons missions have traced telltale ripples in Saturn's and Jupiter's rings to specific collisions with cometary fragments that occurred decades ago.

Jupiter's ripple-producing culprit was Comet Shoemaker-Levy 9. The comet's debris cloud hurtled through the thin Jupiter ring system on a collision course into the planet in July 1994. Scientists attribute Saturn's ripples to a similar object — likely another cloud of comet debris — plunging through the inner rings in 1983. The findings are detailed in two papers published March 31 in the journal *Science*.

"We're finding evidence that a planet's rings can be affected by specific, traceable events that happened in the last 30 years, rather than a hundred million years ago," said Matthew Hedman, a Cassini imaging team associate, lead author on one of the papers, and a research associate at Cornell University in Ithaca, New York. "The solar system is a much more dynamic place than we gave it credit for."

Scientists learned about the patchy patterns in Jupiter's rings in the late 1990s from Galileo's visit to Jupiter. Unfortunately, the images from that mission were fuzzy, and scientists didn't understand why such patterns would occur. Not until Cassini entered orbit around Saturn in 2004 and started sending back thousands of images did scientists have a better picture of the activity. A 2007 science paper by Hedman and colleagues first noted corrugations in Saturn's innermost ring, dubbed the D ring.

A group including Hedman and Mark Showalter, a Cassini co-investigator based at the SETI Institute in California, saw that the grooves in the D ring appeared to wind together more tightly over time. Playing the process backward, Hedman demonstrated the pattern originated when something tilted the D ring off its axis by about 300 feet (100 meters) in late 1983. The scientists found Saturn's gravity on the tilted area warped the ring into a tightening spiral.

Cassini imaging scientists received another clue around August 2009 when the Sun shone directly along Saturn's equator and lit the rings edge-on. The unique lighting conditions highlighted ripples not previously seen in another part of the ring system. Whatever happened in 1983 was big — not a small, localized event.

The collision tilted a region more than 12,000 miles (19,000 kilometers) wide, covering part of the D ring and the next outermost ring, called the C ring. Unfortunately, spacecraft were not visiting Saturn at that time, and the planet was on the farside of the Sun out of sight from ground- or spacebased telescopes.

Hedman and Showalter, the lead author on the second paper, wondered whether the long-forgotten pattern in Jupiter's ring system might illuminate the mystery. Using Galileo images from 1996 and 2000, Showalter confirmed a similar winding spiral pattern by applying the same math they had applied to Saturn and factoring in Jupiter's gravitational influence. Galileo was launched on a space shuttle in 1989 and studied Jupiter until 2003.

Unwinding the spiral pinpointed the date when Jupiter's ring was tilted off its axis between June and September 1994. Shoemaker-Levy plunged into the jovian atmosphere in late July. The Galileo images also revealed a second spiral, which was calculated to have originated in 1990. Images taken by New Horizons in 2007, when the spacecraft flew by Jupiter on its way to Pluto, showed two newer ripple patterns, in addition to the fading echo of the Shoemaker-Levy impact.

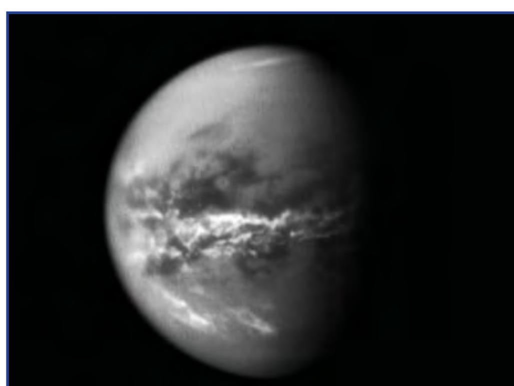
"We now know that collisions into the rings are very common — a few times per decade for Jupiter and a few times per century for Saturn," Showalter said. "Now scientists know that the rings record these impacts like grooves in a vinyl record, and we can play back their history later."

For more information about Cassini, visit *www.nasa.gov/cassini*. For more information about Pluto New Horizons, visit *www.nasa.gov/newhorizons*.

Cassini Sees Seasonal Rains Transform Titan's Surface

As spring unfolded at Saturn, April showers on the planet's largest moon, Titan, brought methane rain to its equatorial deserts, as revealed in images captured by NASA's Cassini spacecraft. This is the first time scientists have obtained current evidence of rain soaking Titan's surface at low latitudes.

Extensive rain from large cloud systems, spotted by Cassini's cameras in late 2010, apparently darkened the surface of the moon. The best explanation is these areas remained wet after methane rainstorms. The observations released in March in the journal *Science*, combined with



NASA's Cassini spacecraft chronicles the change of seasons as it captures clouds near the equator of Saturn's largest moon, Titan. Credit: NASA/JPL/SSI.

earlier results in *Geophysical Research Letters* in February, show the weather systems of Titan's thick atmosphere and the changes wrought on its surface are affected by the changing seasons.

"It's amazing to be watching such familiar activity as rainstorms and seasonal changes in weather patterns on a distant, icy satellite," said Elizabeth Turtle, a Cassini imaging team associate at the Johns Hopkins University Applied Physics Laboratory, and lead author of the publication. "These observations are helping us to understand how Titan works as a system, as well as similar processes on our own planet."

The Saturn system experienced equinox, when the sun lies directly over a planet's equator and seasons change, in August 2009. (A full Saturn "year" is almost 30 Earth years.) Years of Cassini observations suggest Titan's global atmospheric circulation pattern responds to the changes in solar illumination, influenced by the atmosphere and the surface, as detailed in the *Geophysical Research Letters* paper. Cassini found the surface temperature responds more rapidly to sunlight changes than does the thick atmosphere. The changing circulation pattern produced clouds in Titan's equatorial region.

Clouds on Titan are formed of methane as part of an Earth-like cycle that uses methane instead of water. On Titan, methane fills lakes on the surface, saturates clouds in the atmosphere, and falls as rain. These observations suggest that recent weather on Titan is similar to that over Earth's tropics. In tropical regions, Earth receives its most direct sunlight, creating a band of rising motion and rain clouds that encircle the planet.

"These outbreaks may be the Titan equivalent of what creates Earth's tropical rainforest climates, even though the delayed reaction to the change of seasons and the apparently sudden shift is more reminiscent of Earth's behavior over the tropical oceans than over tropical land areas," said Tony Del Genio of NASA's Goddard Institute for Space Studies, New York, a co-author and a member of the Cassini imaging team.

On Earth, the tropical bands of rain clouds shift slightly with the seasons but are present within the tropics year-round. On Titan, such extensive bands of clouds may only be prevalent in the tropics near the equinoxes and move to much higher latitudes as the planet approaches the solstices. The imaging team intends to watch whether Titan evolves in this fashion as the seasons progress from spring toward northern summer.

NASA's Cassini spacecraft has spotted a glowing patch of ultraviolet light near Saturn's north pole that marks the presence of an electrical circuit that connects Saturn with its moon Enceladus. Credit: NASA/JPL/University of Colorado/Central Arizona College.

Cassini Sees Saturn Electric Link with Enceladus

NASA is releasing the first images and sounds of an electrical connection between Saturn and one of its moons, Enceladus. The data collected by the agency's Cassini spacecraft enable scientists to improve their understanding of the complex web of interaction between the planet and its numerous moons. The results of the data analysis are published in the journals *Nature* and *Geophysical Research Letters*.

Scientists previously theorized an electrical circuit should exist at Saturn. After analyzing data that Cassini collected in 2008, scientists saw a glowing patch of ultraviolet light emissions near Saturn's north pole that marked the presence of a circuit, even though the moon is 240,000 kilometers

(150,000 miles) away from the planet. The patch occurs at the end of a magnetic field line connecting Saturn and its moon Enceladus. The area, known as an auroral footprint, is the spot where energetic electrons dive into the planet's atmosphere, following magnetic field lines that arc between the planet's north and south polar regions.

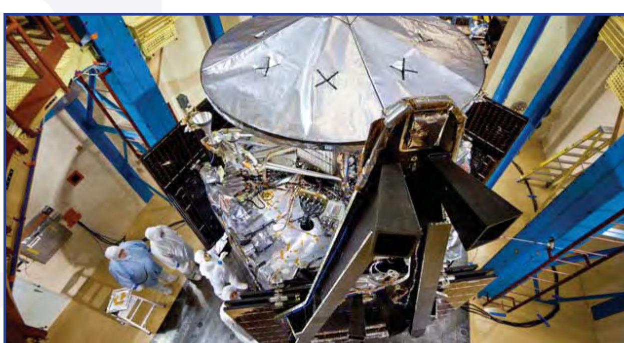
The auroral footprint measures approximately 1200 kilometers (750 miles) by less than 400 kilometers (250 miles), covering an area comparable to California or Sweden. At its brightest, the footprint shone with an ultraviolet light intensity far less than Saturn's polar auroral rings, but comparable to the faintest aurora visible at Earth without a telescope in the visible light spectrum. Scientists have not found a matching footprint at the southern end of the magnetic field line.

Jupiter's active moon Io creates glowing footprints near Jupiter's north and south poles, so scientists suspected there was an analogous electrical connection between Saturn and Enceladus. It is the only known active moon in the Saturn system with jets spraying water vapor and organic particles into space. For years, scientists used space telescopes to search Saturn's poles for footprints, but they found none.

In 2008, Cassini detected a beam of energetic protons near Enceladus aligned with the magnetic field and field-aligned electron beams. A team of scientists analyzed the data and concluded the electron beams had sufficient energy flux to generate a detectable level of auroral emission at Saturn. A few weeks later, Cassini captured images of an auroral footprint in Saturn's northern hemisphere. In 2009, a group of Cassini scientists led by Donald Gurnett at the University of Iowa detected more complementary signals near Enceladus consistent with currents that travel from the moon to the top of Saturn's atmosphere, including a hiss-like sound from the magnetic connection. That paper was published in March in *Geophysical Research Letters.*

The water cloud above the Enceladus jets produces a massive, ionized "plasma" cloud through its interactions with the magnetic bubble around Saturn. This cloud disturbs the magnetic field lines. The footprint appears to flicker in these new data, so the rate at which Enceladus is spewing particles may vary. "The new data are adding fuel to the fire of some long-standing debates about this active little moon," said Abigail Rymer, co-author of the Nature study and a Cassini team scientist based at the Johns Hopkins University Applied Physics Laboratory. "Scientists have been wondering whether the venting rate is variable, and these new data suggest that it is."

To see a video and hear the sounds of the electrical connection, and to get more information about the Cassini mission, visit *www.nasa.gov/cassini* or *saturn.jpl.nasa.gov*.



NASA's fully assembled Juno spacecraft is currently undergoing testing at Lockheed Martin Space Systems near Denver. Technicians are inspecting some of the spacecraft's components. Credit: NASA/JPL-Caltech/LMSS.

NASA's Jupiter-Bound Spacecraft Taking Shape in Denver

NASA's Juno spacecraft is currently undergoing environmental testing at Lockheed Martin Space Systems near Denver. The solar-powered Juno spacecraft will orbit Jupiter's poles 33 times to find out more about the gas giant's origins, structure, atmosphere, and magnetosphere. The launch window for Juno from the Cape Canaveral Air Force Station in Florida opens August 5, 2011.

In this photo, taken on January 26, Juno had just completed acoustics testing that simulated the acoustic and vibration environment the spacecraft will experience during launch. The photo shows Lockheed Martin technicians inspecting the spacecraft just after the test. All three solar array wings are installed and stowed, and the spacecraft's large high-gain antenna is in place on the top of the avionics vault.

Juno was sealed in a large thermal vacuum chamber, where it was exposed to the extreme cold and vacuum conditions it will experience on its voyage to Jupiter. The two-week-long test simulated many of the flight activities the spacecraft will execute during the mission. Juno shipped from Lockheed Martin's facility to Kennedy Space Center in April, and is undergoing final preparations for launch.

More information about Juno is online at *www.nasa.gov/juno*.

NASA Releases Images of Man-Made Crater on Comet

This pair of images shows the before-and-after comparison of the part of Comet Tempel 1 that was hit by the impactor from NASA's Deep Impact spacecraft. Credit: NASA/JPL-Caltech/ University of Maryland/Cornell.

NASA's Stardust spacecraft returned new images of a comet showing a scar resulting from the 2005 Deep Impact mission. The images also showed the comet has a fragile and weak nucleus. The spacecraft made its closest approach to Comet Tempel 1 on Monday, February 14, at 11:40 p.m. EST at a distance of approximately 178 kilometers (111 miles). Stardust took 72 high-resolution images of the comet. It also accumulated 468 kilobytes of data about the dust in its coma, the cloud that is a comet's atmosphere. The craft is on its second mission of exploration called Stardust-NExT, having completed its prime mission collecting cometary particles and returning them to Earth in 2006.

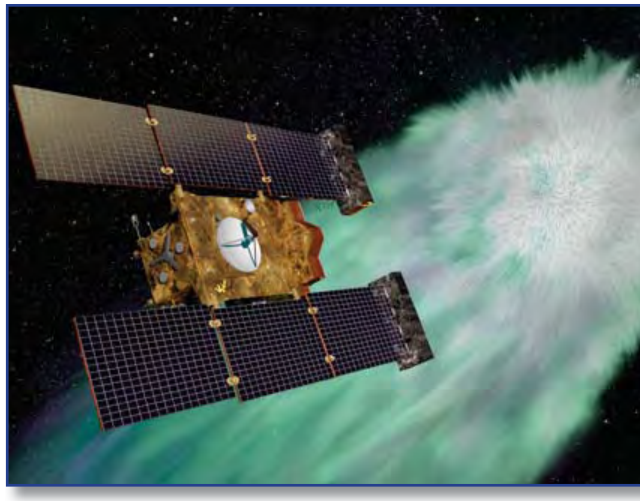
The Stardust-NExT mission met its goals, which included observing surface features that changed in areas previously seen during the 2005 Deep Impact mission; imaging new terrain; and viewing the crater generated when the 2005 mission propelled an impactor at the comet. "This mission is 100 percent successful," said Joe Veverka, Stardust-NExT principal investigator of Cornell University. "We saw a lot of new things that we didn't expect, and we'll be working hard to figure out what Tempel 1 is trying to tell us."

Several of the images provide tantalizing clues to the result of the Deep Impact mission's collision with Tempel 1. "We see a crater with a small mound in the center, and it appears that some of the ejecta went up and came right back down," said Pete Schultz of Brown University. "This tells us this cometary nucleus is fragile and weak based on how subdued the crater is we see today."

Engineering telemetry downlinked after closest approach indicates the spacecraft flew through waves of disintegrating cometary particles, including a dozen impacts that penetrated more than one layer of its protective shielding.

More information about Stardust-NExT is available at *stardustnext.jpl.nasa.gov*.

NASA Stardust Spacecraft Officially Ends Operations



Artist's concept of NASA's Stardust-NExT mission, which flew by Comet Tempel 1 on February 14, 2011. Credit: NASA/JPL-Caltech/LMSS.

NASA's Stardust spacecraft sent its last transmission to Earth at 7:33 p.m. EDT on Thursday, March 24, shortly after depleting fuel and ceasing operations. During a 12-year period, the venerable spacecraft collected and returned comet material to Earth and was reused after the end of its prime mission in 2006 to observe and study another comet during February 2011.

The Stardust team performed the burn to depletion because the comet hunter was literally running on fumes. The depletion maneuver command was sent from the Stardust-NExT mission control area at Lockheed Martin Space Systems in Denver. The operation was designed to fire Stardust's rockets until no fuel remained in the tank or fuel lines. The spacecraft sent acknowledgment of its last command from approximately 312 million kilometers (194 million miles) away in space.

"Stardust's motors burned for 146 seconds," said Allan Cheuvront, Lockheed Martin Space Systems Company program manager for Stardust-NExT in Denver. "We'll crunch the numbers and see how close the reality matches up with our projections. That will be a great dataset to have in our back pocket when we plan for future missions."

Launched February 7, 1999, Stardust flew past the asteroid Annefrank and traveled halfway to Jupiter to collect the particle samples from Comet Wild 2. The spacecraft returned to Earth's vicinity to drop off a sample return capsule eagerly awaited by comet scientists.

NASA re-tasked the spacecraft as Stardust-NExT to perform a bonus mission and fly past Comet Tempel 1, which was struck by the Deep Impact mission in 2005. The mission collected images and other scientific data to compare with images of that comet collected by the Deep Impact mission in 2005. Stardust traveled approximately 21 million kilometers (13 million miles) around the Sun in the weeks after the successful Tempel 1 flyby. The Stardust-NExT mission met all mission goals, and the spacecraft was extremely successful during both missions. From launch until final rocket engine burn, Stardust traveled approximately 5.69 billion kilometers (3.54 billion miles).

After the mileage logged in space, the Stardust team knew the end was near for the spacecraft. With its fuel tank empty and final radio transmission concluded, history's most traveled comet hunter will move from NASA's active mission roster to retired.

"This kind of feels like the end of one of those old western movies where you watch the hero ride his horse toward the distant setting Sun — and then the credits begin to roll," said Stardust-NExT project manager Tim Larson from NASA's Jet Propulsion Laboratory. "Only there's no setting Sun in space."

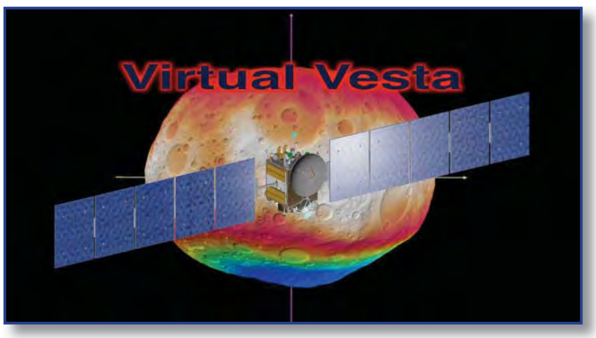
Dawn Gets Vesta Target Practice

There is an old chestnut about a pedestrian who once asked a virtuoso violinist near Carnegie Hall how to get to the famed concert venue. The virtuoso's answer: Practice!

The same applies to NASA's Dawn mission to the giant asteroid Vesta. In the lead-up to orbiting the second most massive body in the asteroid belt this coming July, Dawn mission planners and scientists have been practicing mapping Vesta's surface, producing still images and a rotating animation that includes the scientists' best guess to date of what the surface might look like.

The animation and images incorporate the best data on the dimples and bulges of Vesta from groundbased telescopes and NASA's Hubble Space Telescope. The topography is color-coded by altitude. The cratering and small-scale surface variations are computer-generated, based on the patterns seen on Earth's Moon, an inner solar system object with a surface appearance that may be similar to Vesta.

"We won't know what Vesta really looks like until Dawn gets there," said Carol Raymond, Dawn's deputy principal investigator, based at NASA's Jet Propulsion Laboratory, who helped orchestrate the activity. "But we needed a way to make sure our imaging plans would give us the best results possible. The products have proven that Dawn's mapping techniques will reveal a detailed view of this world that we've never seen up close before."



A new video shows the scientists' best guess to date of what the surface of the protoplanet Vesta might look like. It was created as part of an exercise for NASA's Dawn mission involving mission planners at NASA's Jet Propulsion Laboratory and science team members at the German Aerospace Center and the Planetary Science Institute. Credit: NASA/JPL-Caltech/ESA/UCLA/DLR/PSI/STScI/UMd.

Vesta is one of the brightest asteroids in the night sky. Under the right conditions, Vesta can be seen with binoculars. But the best images so far from groundbased telescopes and Hubble still show Vesta as a bright, mottled orb. Once in orbit around Vesta, Dawn will pass about 650 kilometers (400 miles) above the asteroid's surface, snapping multiangle images that will allow scientists to produce topographic maps. Later, Dawn will orbit at a lower altitude of about 200 kilometers (120 miles), getting closer shots of parts of the surface.

The Dawn mission will have the capability to map 80% of the asteroid's surface in the year the spacecraft is in orbit around Vesta. (The north pole will be dark when Dawn arrives in July 2011 and is expected to be only dimly lit when Dawn leaves in July 2012.) The mission will map Vesta at a spatial resolution on the order of the best global topography maps of Earth made by NASA's Shuttle Radar Topography mission.

Starting in August 2009, Dawn's optical navigation lead, Nick Mastrodemos, based at JPL, developed a computer simulation of the orbits and images to be taken by the spacecraft. He adapted software developed by Bob Gaskell of the Planetary Science Institute in Tucson. Mastrodemos created a model using scientists' best knowledge of Vesta and simulated the pictures that Dawn would take from the exact distances and geometries in the Dawn science plan.

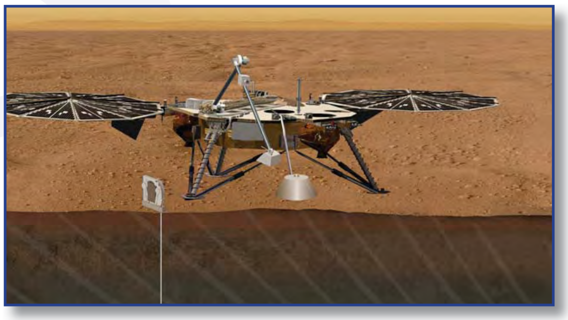
He sent those images to two teams that use different techniques to derive topographical heights from imaging. One, led by Thomas Roatsch, was based at the Institute of Planetary Research of the German Aerospace Center (DLR) in Berlin. The other, led by Gaskell, was based at the Planetary Science Institute in Tucson. (Like the Roatsch team, the Gaskell team did not have prior knowledge of the model from which the simulated data were created.) The groups sent their digital terrain models back to JPL, including the video produced by Frank Preusker from DLR that is based on his full stereo processing.

Mastrodemos compared their products to the original model he made. Both techniques reproduced the known dataset well with only minor differences in spatial resolution and height accuracy. "Working through this exercise, the mission planners and the scientists learned that we could improve the overall accuracy of the topographic reconstruction, using a somewhat different observation geometry," Mastrodemos said. "Since then, Dawn science planners have worked to tweak the plans to implement the lessons of the exercise."

The exercise helped both teams get an early start on updating their software and planning the necessary computer resources. "In order to plan for proper stereo coverage of an unknown body like Vesta, practice is essential," said Roatsch, who is responsible for the framing camera team's stereo observation planning.

For more information, visit dawn.jpl.nasa.gov or *www.nasa.gov/dawn*.

NASA Selects Investigations for Future Key Missions



An artist's concept portrays the proposed Geophysical Monitoring Station mission for studying the deep interior of Mars. Credit: NASA/JPL-Caltech.

NASA has selected three science investigations from which it will pick one potential 2016 mission to look at Mars' interior for the first time; study an extraterrestrial sea on one of Saturn's moons; or study in unprecedented detail the surface of a comet's nucleus. Each investigation team will receive $3 million to conduct its mission's concept phase or preliminary design studies and analyses. After another detailed review in 2012 of the concept studies, NASA will select one to continue development efforts leading up to launch. The selected mission will be cost-capped at $425 million, not including launch vehicle funding.

NASA's Discovery Program requested proposals in June 2010. The selected investigations could reveal much about the formation of our solar system and its dynamic processes.

The planetary missions selected to pursue preliminary (Phase A) design studies are:

— Geophysical Monitoring Station (GEMS) would study the structure and composition of the interior of Mars and advance understanding of the formation and evolution of terrestrial planets. Understanding more about the deep interior of another planet would enable important new comparisons with what is known about Earth's interior.

— Titan Mare Explorer (TiME) would provide the first direct exploration of an ocean environment beyond Earth by landing in, and floating on, a large methane-ethane sea on Saturn's moon Titan.

— Comet Hopper would study cometary evolution by landing on a comet multiple times and observing its changes as it interacts with the Sun.

In addition, three selected technology development proposals will expand the ability to catalog near-Earth objects, or NEOs; enhance the capability to determine the composition of comet ices; and validate a new method to reveal the population of objects in the poorly understood, far-distant part of our solar system.

Created in 1992, the Discovery Program sponsors frequent, cost-capped solar system exploration missions with highly focused scientific goals. The program's 11 missions include MESSENGER, Dawn, Stardust, Deep Impact, Kepler, and Genesis. For more information, visit *discovery.nasa.gov*.

42nd Lunar and Planetary Science Conference

March 7–11, 2011, The Woodlands, Texas

The 42nd Lunar and Planetary Science Conference (LPSC), held in March at The Woodlands Waterway Marriott Hotel and Convention Center in The Woodlands, Texas, was a resounding success, setting new records once again for attendance and number of submitted abstracts. Almost 1800 planetary scientists from all over the world gathered this year at the annual meeting, which featured 557 oral presentations and 1178 poster presentations. More than one-fourth of the participants were students, which not only indicates the importance placed on the meeting throughout the planetary science community, but also reinforces the LPSC as a meeting both accessible and important to young scientists.

Mary Ann Hager of the Lunar and Planetary Institute explained one of the LPI's newest outreach services, helping researchers create or change planetary science entries in Wikipedia.

Recent data and results from current missions, including Hayabusa, EPOXI, MESSENGER, Cassini, and a fleet of ongoing lunar and Mars missions, all contributed to the variety of groundbreaking research unveiled at the conference, which was chaired by Dr. Stephen Mackwell of the Lunar and Planetary Institute and Dr. Eileen Stansbery of NASA Johnson Space Center. The conference was organized by the staff of the Lunar and Planetary Institute.

"LPSC is definitely the number one conference to attend in terms of catching up with the latest developments in planetary science research," said Dr. Channon Visscher, a postdoctoral fellow at the Lunar and Planetary Institute. "It also offers to chance to meet and collaborate with some of the most prominent planetary researchers from around the world."

Participants circulated among hundreds of posters during the poster session and exhibitor showcase.

Oral and poster sessions covered such diverse topics as cosmochemical origins, near-Earth objects, asteroid geophysics, planetary impact craters, lunar magma oceans, material and environmental analogs, iron meteorites, and planetary fluvial processes, to name just a few. Special sessions featured planetary cryospheres, planetary magmatic volatiles, and results from the EPOXI mission flyby of Comet Hartley 2. The complete program and abstracts are available at *www.lpi.usra.edu/meetings/lpsc2011/*.

The plenary session on Monday afternoon featured the Masursky Lecture by Dr. Robin Canup of the Southwest Research Institute, entitled "Formation of Planetary

Dr. Robin Canup talked about planetary satellite formation during the Masursky Lecture.

Steve Squyres presented the first public release of the highly anticipated results of the Decadal Survey.

Japanese scientists presented results from the Hayabusa mission, the first space mission to have made physical contact with an asteroid and returned to Earth.

Satellites." The session also recognized the recipients of the 2010 Dwornik Student Awards and the 2011 LPI Career Development Awards.

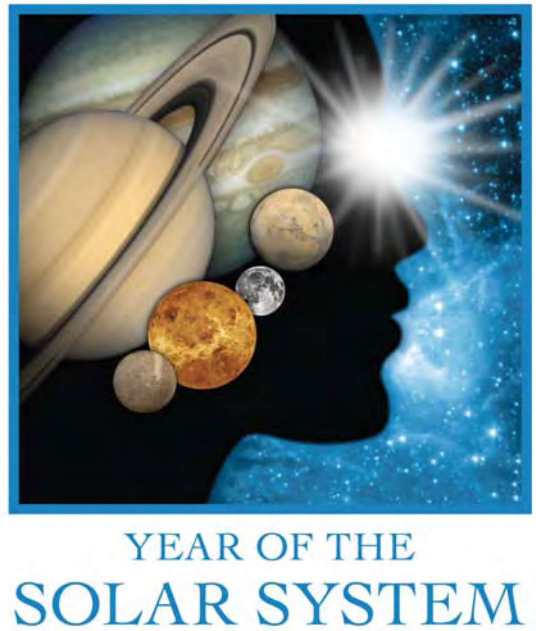
One of the highlighted events at this year's LPSC was the first public release of the results of the community-wide Decadal Survey, presented by Dr. Steve Squyres (see related cover story in this issue). Squyres' hour-long presentation on Monday evening was followed by a response from Dr. Jim Green of the Planetary Science Division of NASA Headquarters.

Plans are already underway for the 43rd LPSC, which will be held March 19–23, 2012, in The Woodlands, Texas. Meeting announcements and other details will be available at *www.lpi.usra.edu/meetings/lpsc2012/*.

Attendees of the Women in Planetary Science breakfast on Tuesday.

"Spotlight on Education" highlights events and programs that provide opportunities for planetary scientists to become involved in education and public outreach and to engage science educators and the community. If you know of space science educational programs or events that should be included, please contact the Lunar and Planetary Institute's Education Department at shupla@lpi.usra.edu.

Continuing the Year of the Solar System (YSS)



Spanning a martian year — 23 months — the Year of the Solar System celebrates the amazing discoveries of numerous NASA missions as they explore our near and distant neighbors and probe the very outer edges of our solar system. Each month, from October 2010 to August 2012, audiences explore different aspects or our solar system — its formation, volcanism, ices, and life — weaving together activities, resources, and ideas that teachers, clubs, and organizations can use to engage audiences. For more information, visit *solarsystem.nasa.gov/yss*.

The topic for April was *Water, Water Everywhere*. As we celebrate Earth Day 2011, we should remember to take care of our water resources on our home planet, even as we are discovering water almost everywhere in our solar system!

May's topic is *Volcanism!* The site includes a variety of activities on volcanism; volcanism in the solar system is also an exciting theme for Astronomy Day events!

The topic for June is *Impacts* as we prepare for Dawn's arrival at Vesta.

NEW! Get Involved! Share Your YSS Events and Stories: Advertise your YSS Events on the YSS Calendar. Share your YSS stories through the YSS story space, Flickr, and YouTube. Visit *solarsystem.nasa.gov/yss/getinvolved.cfm*.

Link to YSS from Your Website: We invite you be a YSS partner during the Year of the Solar System! Post the YSS graphic element on your website and link to the YSS page. You can find YSS graphics at *solarsystem.nasa.gov//yss/display.cfm?Year=2010&Month=12&Tab=Downloads*.

Ideas? Feedback? Contact us at *planetaryforum@lpi.usra.edu*.

CosmoSparks Reports and Slide Sets

Created by Planetary Science Research Discoveries (PSRD), CosmoSparks reports give quick views of big advances in cosmochemistry, with links to further details. Visit *www.psrd.hawaii.edu/CosmoSparks/index.html*. PSRD annotated slide sets are associated with PSRD articles, which provide the full context, additional graphics, and references. Go to *www.psrd.hawaii.edu/Archive/Archive-PSRDpresents.html*.

New "Discoveries in Planetary Science" PowerPoints

The DPS Education Subcommittee announces the fourth release of "Discoveries in Planetary Science" classroom PowerPoints, covering six new topics:

- A Thousand New Planets
- Buried Martian Carbonates
- The Lunar Core
- A Six Planet System
- Martian Gully Formation
- Propellers in Saturn's Rings

These are succinct summaries of discoveries too recent to appear in "Intro Astronomy" college textbooks; each set consists of just three slides to be shown: the discovery itself, a basic explanation based on good planetary science, and the "big picture" context. Another page for further information is provided as well. PowerPoints and PDF files can be downloaded from *dps.aas.org/education/dpsdisc*.

Feedback from the community on how these slide sets are used and received is welcomed, and will be used to improve future releases. Planetary scientists with recent or upcoming results of broad interest are encouraged to submit them for consideration by providing an initial draft using the template provided on the website. For more information, contact Nick Schneider and Dave Brain at *dpsdisc@aas.org*.

ASP Conference on Science Education and Public Outreach

The Astronomical Society of the Pacific announces a National Conference on Science Education and Public Outreach Baltimore, Maryland, July 31–August 3, 2011.

The Astronomical Society of the Pacific (ASP), in partnership with the American Geophysical Union (AGU) and the Space Telescope Science Institute (STScI), is pleased to announce the 2011 national conference, "Connecting People to Science." The conference website is now accepting registrations at *www.astrosociety.org/events/meeting.html*.

Everyone working in education, public outreach, and science communication in space, Earth, and physical science is cordially invited to consider how best to share the results of our work with each other and the public, how to improve our practice, and how to make connections across science disciplines. Participants will include people working in formal education, informal settings, on the web, and in the media.

Share Your Lunar Education Efforts at the NASA Lunar Science Forum

The NASA Lunar Science Institute is pleased to announce the fourth annual NASA Lunar Science Forum, to be held July 19–21, 2011. This year's forum will feature sessions on recent scientific results from the Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite and dedicated side-conferences for graduate students and young lunar professionals, as well as the annual recognition of scientific accomplishments and associated keynote lecture. As in past years, science sessions are structured to report on both recent results and future opportunities for lunar science, exploration, education, and outreach. We also look forward to news on the upcoming lunar missions GRAIL and LADEE, and welcome abstracts across many fields of lunar science.

For more information, visit *lunarscience2011.arc.nasa.gov*.

NASA Research Announcement for Competitive Program for Informal Education Institutions

The 2011 NASA Research Announcement: Competitive Program for Science Museums and Planetariums Plus Opportunities for NASA Visitor Centers and Other Informal Education Institutions (CP4SMP+), Announcement Number NNH11ZHA004N, has been released. Proposals must be submitted electronically via the NASA proposal data system NSPIRES or Grants.gov. Proposals are due June 29. For more information, go to *https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={AEF75D0F-2272-7DE7-D52A-295B47C8F5CF}&path=open*

NASA Accepting Applications from "Inspired" High School Students

U.S. high school students are invited to participate in NASA's Interdisciplinary National Science Program Incorporating Research Experience (INSPIRE) through an online learning community. INSPIRE is designed to encourage students in grades 9–12 to pursue careers in science, technology, engineering, and math (STEM).

Applications are being accepted through June 30. Students selected for the program will have the option to compete for unique grade-appropriate experiences during the summer of 2012 at NASA facilities and participating universities. The summer experience provides students with a hands-on opportunity to investigate education and careers in the STEM disciplines. For more information, go to *www.nasa.gov/education/INSPIRE*.

LPI Career Development Award Recipients Announced

The Lunar and Planetary Institute (LPI) is proud to announce the winners of the fourth LPI Career Development Award. The award is given to graduate students who submitted a first-author abstract to the 42nd Lunar and Planetary Science Conference (LPSC), and recipients received an $800.00 travel stipend to help cover their expenses for attending the conference. The meeting provides an invaluable opportunity for students, not only to present their own research, but also to hear and see firsthand the latest-breaking results from other researchers in their field. Opportunities are also provided for students to meet and network with an international group of distinguished researchers.

Congratulations to the 2011 recipients: Humberto Carvajal-Ortiz, *Indiana University;* Jonathan Craig, *University of Arkansas;* Joshua Garber, *University of California, Davis;* Maria Gritsevich, *Moscow State University;* Samantha Kate Harrison, *The Open University;* Matthew Huber, *Universität Wien;* Richard Kraus, *Harvard University;* Eriita Jones, *The Australian National University;* Marianne Mader, *University of Western Ontario;* Collen Milbury, *University of California, Los Angeles;* Ian O. McGlynn, *University of Tennessee;* Jan Raack, *Westfälische Wilhelms-Universität;* Aidan Ross, *University College London;* M. Shanmugam, *Physical Research Laboratory, PLANEX;* and Amy J. Williams, *University of California, Davis.*

LPI Selects Planetary Science Interns

The Lunar and Planetary Institute (LPI) has announced the selection of the 2011 class of the LPI Summer Intern Program in Planetary Science. The LPI's highly competitive intern program offers undergraduates the opportunity to experience cutting-edge research in lunar and planetary science, working one-on-one with scientists at the LPI and the NASA Johnson Space Center on a project of current interest in planetary science. This year's program will run from June 6 through August 12. The selected students were chosen from an applicant pool of more than 250 students.

The selected interns are: Rachel Barnett, *University of New Mexico;* Kelly Nickodem, *University of Notre Dame;* Kevin Michael Cannon, *Queen's University;* Spenser Pantone, *Weber State University;* Mattias Pär Karl Ek, *University of Gothenburg;* Kathryn Elizabeth Powell, *Rice University;* Julia Gorman, *University of Rochester;* Lee Saper, *Brown University;* Samantha Jacob, *University of Hawaii at Manoa;* Lillian Shaffer, *University of Houston;* Erica Ruth Jawin, *Mt. Holyoke College;* and Yifan Wang, *Imperial College London.*

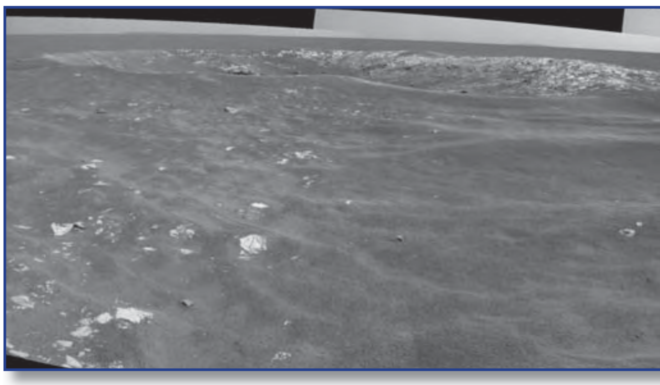
Center for Lunar Science and Exploration Announces 2011 Intern Class

The Center for Lunar Science and Exploration of the Lunar and Planetary Institute (LPI) and NASA Johnson Space Center is pleased to announce the 2011 class of Lunar Exploration Summer Interns. The program provides students with an opportunity to be involved in lunar exploration activities, thus effectively training a new generation of space exploration leaders. Working in teams, the interns will identify sites on the Moon's surface where the nation's lunar science priorities can be accomplished with robotic and human exploration missions.

The 10-week program runs May 31 through August 5, 2011. Applications were accepted from graduate students in geology, planetary science, and related programs, as well as undergraduates with at least 50 semester hours of credit in those fields. Now in its fourth year, the program continues to produce successful outcomes. Last year's interns submitted seven abstracts that were accepted for presentation at the 42nd Lunar and Planetary Science Conference. Additionally, the 2008 intern team recently published a peer-reviewed paper that outlines the strategic advantages of a mission to the Schrödinger Basin on the Moon. The Lunar Exploration Summer Intern Program is supported with funding from the LPI and the NASA Lunar Science Institute at NASA Ames Research Center.

Congratulations to the 10 students chosen to participate in this year's program: David Blair, *Purdue University;* Sarah Crites, *University of Hawaii;* Myriam Lemelin, *Université de Sherbrooke;* Daniela Nowka, *Freie Universität Berlin;* Agata Przepiorka, *Space Research Centre of the Polish Academy of Sciences;* Stephanie Quintana, *Colorado School of Mines;* Carolyn Roberts, *SUNY at Buffalo;* Kirby Runyon, *Temple University;* Claudia Santiago, *University of Texas-El Paso;* and Tiziana Trabucchi, *University of New Brunswick.*

Mars Tribute Marks Memories of Shepard's Flight



NASA's Mars Exploration Rover Opportunity recorded this view of a crater informally named "Freedom 7" shortly before the 50th anniversary of the first American in space: astronaut Alan Shepard's flight in the Freedom 7 spacecraft. Credit: NASA/JPL-Caltech.

The team exploring Mars via NASA's Opportunity rover for the past seven years has informally named a martian crater for the Mercury spacecraft that astronaut Alan Shepard christened Freedom 7. On May 5, 1961, Shepard piloted Freedom 7 in America's first human spaceflight.

The Opportunity team used the rover to acquire images covering a cluster of small, relatively young craters along its route toward a long-term destination. The cluster's largest crater, spanning about 25 meters (82 feet), is the one called "Freedom 7." The diameter of Freedom 7 crater, about 25 meters (82 feet), happens to be equivalent to the height of the Redstone rocket that launched Shepard's flight.

"Many of the people currently involved with the robotic investigations of Mars were first inspired by the astronauts of the Mercury Project who paved the way for the exploration of our solar system," said Scott McLennan of the State University of New York at Stony Brook. Shepard's flight was the first of six Project Mercury missions piloted by solo astronauts.

Rover team member James Rice of NASA Goddard Space Flight Center said, "The first 50 years of American manned spaceflight have been built upon immeasurable courage, dedication, sacrifice, vision, patriotism, teamwork and good old-fashioned hard work, all terms that embody and define the United States and her people. Alan Shepard's brave and historic 15-minute flight in Freedom 7 put America in space, and then a scant eight years later, Americans were standing upon the surface of the Moon." Shepard himself would later walk on the Moon when he commanded the Apollo 14 mission in early 1971, less than 10 years after his Freedom 7 flight. He died on July 21, 1998.

NASA Selects Classroom Teachers for SOFIA Science Flights

NASA has selected six teachers to work with scientists onboard the Stratospheric Observatory for Infrared Astronomy (SOFIA) during research flights in May and June. This is the first team of educators selected to participate in SOFIA's Airborne Astronomy Ambassadors program.

SOFIA is a highly modified Boeing 747SP aircraft fitted with a 100-inch- (2.5-meter-) diameter telescope. It analyzes infrared light to study the formation of stars and planets; chemistry of interstellar gases; composition of comets, asteroids and planets; and supermassive black holes at the center of galaxies. Infrared observations are optimal for studying low-temperature objects in space such as the raw materials for star and planet formation and for seeing through interstellar dust clouds that block light at visible wavelengths.

"Enabling educators to join SOFIA's scientific research and take that experience back to their schools and communities is a unique opportunity for NASA to enhance science and math education across the country," said John Gagosian, SOFIA program executive at agency headquarters in Washington. "More than 70 teachers flew on NASA's previous flying observatory, the Kuiper Airborne Observatory, from 1991 through 1995, and that program had long-lasting, positive effects on both the teachers and their students." One of the teachers, Coral Fanin (now Clark), is a member of USRA's SOFIA education and outreach team.

The six teachers selected for the SOFIA program submitted applications that included plans for taking their training and flight experience back to their classrooms. The teachers selected are Marita Beard, *Branham High School, San Jose, California;* Mary Blessing, *Herndon High School, Herndon, Virginia;* Cris DeWolf, *Chippewa Hills High School, Remus, Michigan;* Kathleen Joanne Fredette, *Desert Willow Intermediate School, Palmdale, California;* Theresa Paulsen, *Mellen School District, Mellen, Wisconsin;* and Margaret Piper, *Lincoln Way High School, Frankfort, Illinois.*

"We know teachers who participate in science research programs return inspired, and their students' engagement with technical subjects are measurably increased for many years afterward," said Dana Backman, manager of SOFIA's education and outreach programs. "Airborne Astronomy Ambassadors is an outstanding opportunity for NASA to reach out to both new and veteran teachers of science, technology, engineering and math to bring the excitement of real science research into the classroom and the community at large."

NASA's international partners in developing and operating SOFIA, the German Aerospace Center (DLR) and the German SOFIA Institute (DSI), will fly educators as well. The DLR and DSI plan to announce their first two ambassadors later this month. USRA manages the science operations for SOFIA.

Two NASA Sites Win Webby Awards

Two NASA websites have been recognized in the 15th Annual Webby Awards — the leading international honor for the world's best Internet sites. NASA's main website, *www.nasa.gov*, received its third consecutive People's Voice Award for best government site. NASA's Global Climate Change site at *climate.nasa.gov*, which won last year's People's Voice Award for science, won the 2011 judges' award for best science site. "NASA is committed to sharing its compelling story with people everywhere and with every communication tool," said David Weaver, NASA's associate administrator for

communications. "We are very grateful to the online community for its continued support of what we are doing, and are excited about our future."

NASA recently posted new interactive pieces on the 30th anniversary of the space shuttle program and the 50th anniversary of the first U.S. spaceflight. And in the last year, the agency has streamlined its online video presentation into a single player and deployed a version of the site optimized for mobile devices.

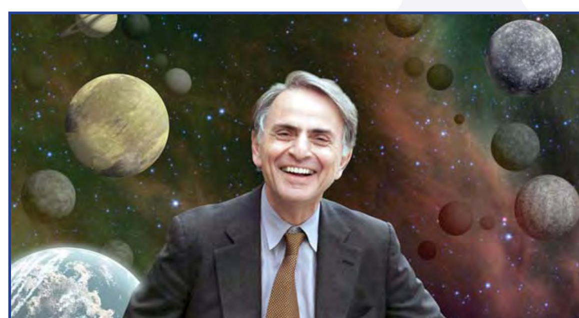
NASA has had a Web presence almost since HTML was invented in the early 1990s, but the site's popularity skyrocketed after a 2003 redesign and relaunch focused on making it more usable and understandable for the general public. Since then, there have been more than 1.5 billion visits to the site, and its customer-satisfaction ratings are among the highest in government and comparable to popular commercial sites.

Reaching beyond the agency's website, NASA's online communications include a Facebook page with more than 368,000 "likes"; a Twitter feed with more than a million followers; and more than 160 accounts across a variety of social media platforms. Last fall, NASA placed first by a wide margin in the L2 Digital IQ Index for the Public Sector study that ranks 100 public sector organizations in the effectiveness of their websites, digital outreach, social media use and mobile sites.

Presented by the International Academy of Digital Arts and Sciences, the Webby Award recognizes excellence in technology and creativity. The academy created the awards in 1996 to help drive the creative, technical, and professional progress of the Internet and evolving forms of interactive media. While members of the International Academy of Digital Arts and Sciences select the Webby award winners, the online community determines the winners of the People's Voice Awards.

NASA Announces 2011 Carl Sagan Fellows

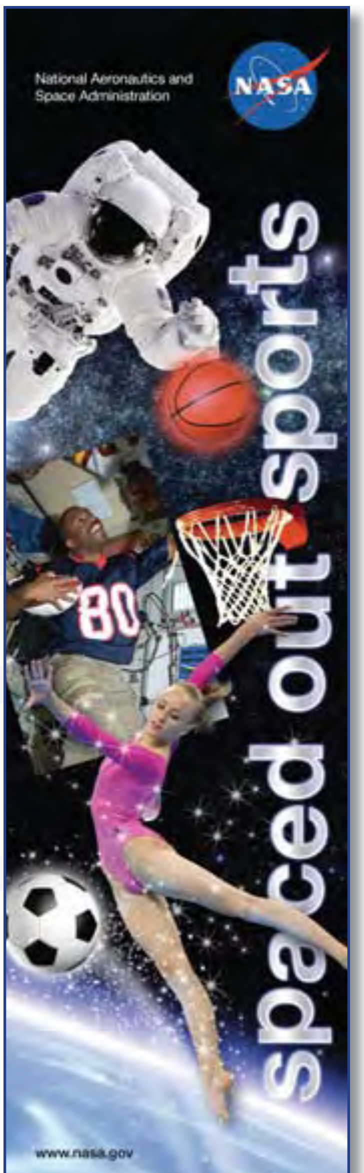
NASA has selected five potential discoverers as the recipients of the 2011 Carl Sagan Postdoctoral Fellowships, named after the late astronomer. The Carl Sagan Fellowship takes a theme-based approach, in which fellows will focus on compelling scientific questions, such as "Are there Earth-like planets orbiting other stars?" Sagan once said, "Somewhere, something incredible is waiting to be known," which is in line with the Sagan Fellowship's primary goal: to discover and characterize planetary systems and Earth-like planets around other stars. Planets outside of our solar system are called exoplanets. The fellowship also aims to support outstanding recent postdoctoral scientists in conducting independent research broadly related to the science goals of NASA's Exoplanet Exploration Program.



The Sagan Fellowship program, named after the late Carl Sagan, supports talented young scientists in their mission to explore the unknown. Following the path laid out by Sagan, these bright fellows will continue to tread the path, make their own discoveries and inspire future Sagan fellows. Credit: NASA/Cosmos Studies.

Previous Sagan Fellows have contributed significant discoveries in exoplanet exploration, including the first characterizations of a super-Earth's atmosphere using a groundbased telescope; and the discovery of a massive disk of dust and gas encircling a giant young star, which could potentially answer the long-standing question of how massive stars are born.

The program, created in 2008, awards selected postdoctoral scientists with annual stipends of approximately $64,500 for up to three years, plus an annual research budget of up to $16,000. Topics range from techniques for detecting the glow of a dim planet in the blinding glare of its host star, to searching for the crucial ingredients of life in other planetary systems. The 2011 Sagan Fellows are David Kipping, who will work at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, to combine theory and observation to conduct a search for the moons of exoplanets; Bryce Croll, who will work at the Massachusetts Institute of Technology in Cambridge to characterize the atmospheres of both large and small exoplanets using a variety of telescopes; Wladimir Lyra, who will work at NASA's Jet Propulsion Laboratory in Pasadena, California, to study planet-forming disks and exoplanet formation; Katie Morzinski, who will work at the University of Arizona, Tucson, to commission and employ high-contrast adaptive optics systems that will directly image Jupiter-like exoplanets; and Sloane Wiktorowicz, who will work at the University of California, Santa Cruz, to use a technique called optical polarimetry to directly detect exoplanets.



NASA Announces Spaced Out Sports Challenge Winners

NASA has announced three winners in the Spaced Out Sports competition, which challenged U.S. students in fifth through eighth grades to create games for astronauts to play onboard the International Space Station. The challenge is part of a broader agency education effort to engage students in science, technology, engineering, and mathematics (STEM) activities.

Students at K.W. Barrett Elementary School in Arlington, Virginia, got the top prize for creating a game entitled "Save the World." Second-place honors went to students at Kinser Elementary School, a Department of Defense Education Activity (DoDEA) School in Okinawa, Japan, for their "Alligator Clip Capture" game. Third-place was awarded to students at Manhattan Beach Middle School in Manhattan Beach, California, for their "Independence Day" game.

"Save the World" features teams gathering objects and building devices to save Earth from incoming meteorites. In "Alligator Clip Capture," players race around the station's Destiny Lab retrieving alligator clips of varying point values. "Independence Day" challenges players to throw batons through 'Liberty Rings' to gain points. All three games will be played onboard the station.

"I was delighted to see this level of engagement from the student teams, and I want to congratulate all three winning teams on their hard work and creativity," said Leland Melvin, NASA Associate Administrator for Education. "I am especially pleased to note that one of the winning teams is from a DoDEA school. April is the Month of the Military Child, and NASA is kicking off a new initiative to engage military families in our education programs." NASA will kick off its Military Families Initiative at an education summit in Orlando later this month.

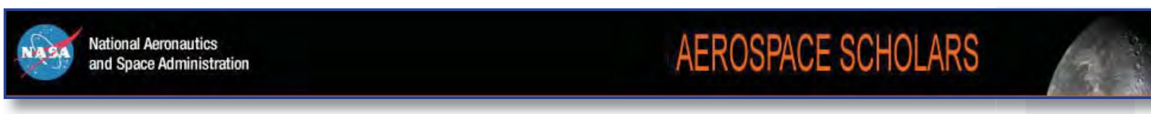
The Spaced Out Sports challenge, a Teaching from Space project, was unveiled last fall and focused on helping students learn and apply Sir Isaac Newton's Laws of Motion. Using the accompanying curriculum, teachers led students through a study of Newton's laws, highlighted by hands-on activities, and video podcasts featuring NASA scientists and engineers explaining how the laws are used in the space program.

The videos also feature celebrity athletes explaining the science behind their sports. Contributors include Olympic gymnast Nastia Liukin; NASCAR driver Juan Pablo Montoya; Women's National Basketball Association player Temeka Johnson; National Hockey League player Ryan O'Reilly; and members of the National Football League's New Orleans Saints. Astronauts Melvin and Nicole Stott also are featured.

Students learned the differences in a game played in the gravity environment of Earth and the same game played in a microgravity environment, such as the space station. They used the knowledge to design or redesign a game to illustrate and apply Newton's laws.

"Response to the challenge was very encouraging, with more than 55 submissions," said Katie Wallace, director of NASA's Stennis Space Center's Office of Education in Bay St. Louis, Mississippi, where the challenge and accompanying curriculum were developed. "Even more encouraging was seeing students excited about, and involved in, learning science. Hopefully, they will continue in these studies and consider STEM careers."

Community College Scholars Selected to Design Robotic Rovers



Eighty students from community colleges in 28 states and Puerto Rico have been selected to travel to a NASA center to develop robotic rovers. The National Community College Aerospace Scholars program encourages students to pursue careers in science, technology, engineering, and mathematics (STEM) disciplines. The students will visit either the Jet Propulsion Laboratory in Pasadena, California, April 27–29 or the Johnson Space Center in Houston May 12–14. Participants were selected based on completion of web-based assignments during the school year. The students will establish teams and form fictitious companies pursuing Mars exploration. Each team will shape a company infrastructure to develop and design a prototype rover. The onsite experience includes a tour of NASA facilities and briefings from agency scientists, engineers, and astronauts.

The program is based on the state of Texas' Aerospace Scholars, originally created in partnership with NASA and the Lone Star state's educational community. The programs are designed to encourage community and junior college students to enter careers in science and engineering and ultimately join the nation's highly technical workforce. Through this program, NASA continues the agency's investment in educational programs that attract and retain students in STEM disciplines critical to NASA's future missions.

For a complete list of the students, their states and the community colleges they represent, visit *www.nasa.gov/offices/education/programs/descriptions/National_Community_College_Aerospace_Scholars.html*.

In celebration of Hubble's 21st anniversary, astronomers at the Space Telescope Institute pointed Hubble's eye at an especially photogenic pair of interacting galaxies called Arp 273. The larger of the spiral galaxies, known as UGC 1810, has a disk that is distorted into a rose-like shape by the gravitational tidal pull of the companion galaxy below it, known as UGC 1813.

NASA's Hubble Celebrates 21st Anniversary with "Rose" of Galaxies

To celebrate the 21st anniversary of the Hubble Space Telescope's deployment into space, astronomers at the Space Telescope Science Institute in Baltimore pointed Hubble's eye at an especially photogenic pair of interacting galaxies called Arp 273.

"For 21 years, Hubble has profoundly changed our view of the universe, allowing us to see deep into the past while opening our eyes to the majesty and wonders around us," NASA Administrator Charles Bolden said." I was privileged to pilot space shuttle Discovery as it deployed Hubble. After all this time, new Hubble images still inspire awe and are a testament to the extraordinary work of the many people behind the world's most famous observatory."

Hubble was launched April 24, 1990, onboard Discovery's STS-31 mission. Hubble discoveries revolutionized nearly all areas of current astronomical research from planetary science to cosmology. "Hubble is America's gift to the world," Sen. Barbara Mikulski of Maryland said. "Its jaw-dropping images have rewritten the textbooks and inspired generations of schoolchildren to study math and science. It has been documenting the history of our universe for 21 years. Thanks to the daring of our brave astronauts, a successful servicing mission in 2009 gave Hubble new life. I look forward to Hubble's amazing images and inspiring discoveries for years to come."

The newly released Hubble image shows a large spiral galaxy, known as UGC 1810, with a disk that is distorted into a rose-like shape by the gravitational tidal pull of the companion galaxy below it, known as UGC 1813. A swath of blue jewel-like points across the top is the combined light from clusters of intensely bright and hot young blue stars. These massive stars glow fiercely in ultraviolet light. The smaller, nearly edge-on companion shows distinct signs of intense star formation at its nucleus, perhaps triggered by the encounter with the companion galaxy.

Arp 273 lies in the constellation Andromeda and is roughly 300 mllion light-years away from Earth. The image shows a tenuous tidal bridge of material between the two galaxies that are separated from each other by tens of thousands of light-years. A series of uncommon spiral patterns in the large galaxy are a tell-tale sign of interaction. The large, outer arm appears partially as a ring, a feature seen when interacting galaxies actually pass through one another. This suggests the smaller companion dived deep, but off-center, through UGC 1810. The inner set of spiral arms is highly warped out of the plane, with one of the arms going behind the bulge and coming back out the other side. How these two spiral patterns connect is not precisely known.

For the greatest hits of Hubble videos and images, visit *www.nasa.gov/mission_pages/hubble/multimedia/index.html*.

Space Technology Hall of Fame honorees Tinh Trinh, Ray Schwarz, and David Wolf of the NASA Johnson Space Center in Houston.

NASA Device Inducted into Space Technology Hall of Fame

A rotating device developed by NASA inventors to grow better living tissue specimens was inducted into the Space Technology Hall of Fame in April. The Space Foundation honored the NASA team who created the device, which promises help for several diseases, during a ceremony at the 27th National Space Symposium in Colorado Springs, Colorado. Developed in 1986 by a group of NASA engineers and researchers at the agency's Johnson Space Center in Houston, the device, known as the bioreactor, enables the growth of tissue, cancer tumors and virus cultures outside the body in space and on Earth. It has many advantages over typical laboratory methods.

Lab-grown cell cultures tend to be small, flat, and two-dimensional, unlike normal tissues in the body. However, tissues grown in the bioreactor are larger and three-dimensional, with structural and chemical characteristics similar to normal tissue. The bioreactor has no internal moving parts, which minimizes forces that might damage the delicate cell cultures.

Three of the co-developers of the bioreactor also are being inducted in the Space Technology Hall of Fame: Dr. David Wolf, NASA astronaut, physician, and electrical engineer; Tinh Trinh, senior mechanical engineer, Wyle Integrated Science and Engineering Group; and Ray Schwarz, chief engineer and co-founder of Synthecon Inc.

The bioreactor has been used for experiments onboard the space shuttle, the Russian Mir space station, and on Earth. Researchers across the United States use this technology to study cancer, stem cells, diabetes, cartilage and nerve growth, and infectious disease. Researchers at the National Institutes of Health used the methods to propagate the human immunodeficiency virus (HIV) in artificial lymph node tissue. This research resulted in the ability to study the virus life cycle under controlled conditions outside of the human body.

The bioreactor is a spinoff technology that entered the commercial world when Synthecon licensed it in 1993. A closed tubular cylinder forms the bioreactor's cell culture chamber, which is filled with a liquid medium in which cells grow. The chamber rotates around a horizontal axis, allowing the cells to develop in an environment similar to the free fall of microgravity. Oxygen, required by cells for growth, is fed into the liquid medium through a porous wall in the chamber. The importance of this cell culture technique is that fluid mechanical conditions obtained in microgravity, and emulated on Earth, allow the growth of tissues in the laboratory that cannot be grown any other way.

The 2011 Space Technology Hall of Fame organizational inductees are those that developed the technology and refined it for commercial use: NASA's Johnson Space Center, Regenetech Inc., and Synthecon Inc. All three are based in Houston.

Elisabetta Pierazzo

Elisabetta ("Betty") Pierazzo, Senior Scientist at the Planetary Science Institute in Tucson, Arizona, died at her home on May 15. She was 47 years old. Born in Italy, Pierazzo arrived in the U.S. in 1989 and the following year attended graduate school at the Department of Planetary Sciences at the University of Arizona, receiving her Ph.D. in 1997. The quality of her graduate work was recognized by the University of Arizona with the Gerard P. Kuiper Memorial Award. She continued at the University of Arizona as a Research Associate, and in 2002 joined the Planetary Science Institute as a Research Scientist, then was promoted to Senior Scientist in 2007.

Pierazzo was an expert in the area of impact modeling throughout the solar system, as well as an expert on the astrobiological and environmental effects of impacts on Earth and Mars. Her work ranged widely, from providing detailed insights into the Chicxulub impact that caused the extinction of the dinosaurs, to putting constraints on the thickness of the ice shell of Jupiter's moon Europa. She was interested in the rise of life and explored the delivery of organics to planets and Europa by comets as well as the creation of subsurface hydrothermal systems by impacts that may have been favorable sites for life on Mars. An expert on Meteor Crater in Arizona, she made several appearances on national and international broadcasts of programs, including National Geographic specials, explaining the formation of this well-known structure.

In addition to her science, she passionately promoted science education and public outreach. She took time away from her successful research career to teach undergraduates at the University of Arizona, developed interactive websites and impact rock and meteorite kits for classroom use, and as well as created professional development workshops for elementary and middle school science teachers. An active member of the planetary community, she served on numerous NASA review panels, was an associate editor of *Meteoritics and Planetary Sciences*, reviewed papers for numerous scientific journals, served as organizer of workshops and meetings on impact cratering held around the world, and was an organizer of the 2007 Meteoritical Society Meeting held in Tucson, Arizona.

Pierazzo was noted for the intensity with which she approached both life and work. Whether it was in the office, the classroom, on the volleyball court, the soccer field, or dance floor, her enthusiasm and joy in the activity was irresistible. She was cherished by many people for her staunch friendship and support. She inspired countless people as a colleague, teacher, mentor, and friend.

Over the past six months, Pierazzo battled a rare form of cancer. She dealt with it aggressively, and never let it overwhelm her. She was always looking toward the future. In the last week of her life, in the midst of chemotherapy, she was grading class papers, working on research papers, writing reviews, and preparing education proposals with her colleagues, all the while finding time to spend precious moments with her family and friends. She was ultimately and suddenly struck down by a pulmonary embolism. Hers is a great loss to all those who knew her and worked with her.

— *Text courtesy of the Planetary Science Institute*

Heinz-Hermann Koelle

Heinz-Hermann Koelle died on February 20, 2011, in Berlin, Germany, at the age of 85. Koelle was an aeronautical engineer who made the preliminary designs on the rocket that would emerge as the Saturn I. Koelle was born in 1925 in the Free City of Danzig, son of a lieutenant-colonel in the police. After Germany annexed Danzig in 1939, Koelle joined the Luftwaffe and served as a pilot during the war. During his time in a prisoner of war camp after the war, Koelle turned his back on military matters and turned to the field of civilian spaceflight. In 1948 he re-formed the pre-war German Society for Space Travel, which brought him into contact with Werner von Braun. In 1951 he and another ex-pilot helped von Braun publish his book *Mars Project* in Germany.

Koelle started studying mechanical engineering at the University of Stuttgart, and led the Astronautical Research Institute between 1952 and 1954. On his graduation, von Braun invited him to join the Army Ballistic Missile Agency (ABMA) team at the Redstone Arsenal in Huntsville, Alabama. He arrived in the U.S. in April 1955, three months before President Dwight D. Eisenhower announced the country's intent to launch a satellite during the International Geophysical Year in 1957, and Koelle was put in charge of the Preliminary Design Section of the Structures and Mechanics Laboratory. When ABMA was turned over to NASA in 1960, the Redstone Arsenal became the Marshall Space Flight Center (MSFC), and the Preliminary Design Section became the Future Projects Office. In 1960 he also became a naturalized American Citizen, and took his doctorate in Engineering at the Technical University of Berlin in 1963.

As Koelle watched the Vietnam War force reduction in NASA budgets, he concluded that the rapid progress he had been a part of was no longer possible, and decided to look for other work. In 1965, he accepted a teaching position at the Technical University of Berlin. Upon the death of Eugen Sänger in 1964, he was offered the Chair of Space Technology in Europe in 1965, a position he held for 30 years. He received the 1952 Medal of the French Aeroclub and the 1963 Hermann Oberth Gold Medal. In 2007 he received the Space Pioneer Awards of the National Space Society.

James L. Elliott

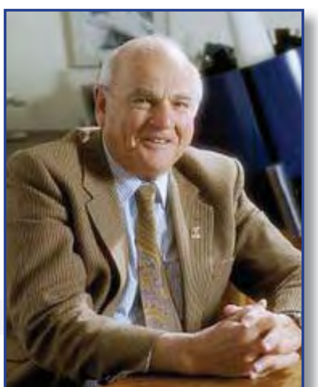
James Ludlow Elliot, a professor of planetary astronomy and physics at MIT who discovered the rings of Uranus in 1977, died on March 3 from cancer-related complications. He was 67. Elliot was known as one of the great observational planetary astronomers of the modern era. Among his accomplishments were leading the team that discovered the ring system of Uranus, and discovery of the atmosphere of Pluto. He was committed to excellence in teaching and mentoring, and was a staunch advocate for women in science.

Elliot was born on June 17, 1943, in Columbus, Ohio. He received an undergraduate degree in physics from MIT in 1965 and a Ph.D. in astronomy from Harvard University in 1972. While a graduate student at Harvard, Elliot was an avid observer on the 60-inch telescope at the Agassiz Station in Harvard, Massachusetts. He held a postdoctoral position at Cornell University, and joined the faculty of Cornell's Astronomy Department in 1977. He returned to MIT in 1978, after he discovered Uranus's rings alongside Edward Dunham and Douglas Mink. He was also the director of MIT's Wallace Astrophysical Observatory.

Elliot was one of the pioneers in the technique of stellar occultations: watching a star as a planetary object moves in front of it, and studying the planetary object from the effect on the star's light. Elliot used occultations to probe planetary atmospheres as well as the physical properties of small bodies in the outer solar system. But catching occultations can be challenging, since the events themselves might last only seconds and there are no second chances. To record them electronically, a team must be completely prepared. Elliot, however, excelled in coordination and preparation. When the planet Uranus was about to cross in front of a star in 1977, he and his team were flying in the Kuiper Airborne Observatory, telescopic equipment trained on the star, waiting. Because of the uncertainty in the event's timing, they turned their equipment on about an hour in advance. To their surprise, the starlight disappeared briefly several times before the planet moved in; after the planet had moved on, the star winked out again several times. They realized that the symmetric dips in the star's brightness — before Uranus itself hid the star and after the star reemerged — were caused by a ring system around the planet. Their discovery was confirmed by several more occultation events, and eventually with direct imaging from the Voyager 2 spacecraft and Hubble Space Telescope. Elliot received a NASA Medal for Exceptional Scientific Achievement for this discovery.

Elliot was especially supportive of women in astronomy. At a science celebration at MIT held in his honor in June 2010 (called the "Jimboree"), nearly two dozen of his former and current students — more than half of them women — spoke about their research, as well as life lessons learned from Elliot. One common theme was his gift for engaging his students deeply in his research, and then sending them off on their own with his utter trust that they could do the research themselves. He also conveyed to all his students a strong work ethic, admonitions to always be prepared, and reminders to always trust the data. Besides being a wonderful mentor and teacher, Elliott was an avid gardner, hiker, and Ohio State football fan. His easy laughter and sense of humor will be deeply missed by his friends and colleagues.

— Text courtesy of MIT News



Baruch Blumberg

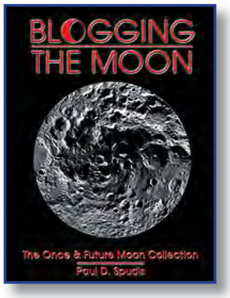
Baruch Blumberg, Distinguished Scientist at the NASA Lunar Science Institute, died on April 5, 2011, shortly after giving the keynote speech at the International Lunar Research Park Exploratory Workshop held at NASA Ames Research Center. He was 85 years old.

Blumberg was an American biologist who discovered the hepatitis B virus and later developed the diagnostic test and vaccine for it. He was subsequently awarded the 1976 Nobel Prize in Medicine for "discoveries concerning new mechanisms for the origin and dissemination of infectious diseases."

Blumberg first attended Far Rockaway High School in the early 1940s, a school that also produced fellow laureates Burton Richter and Richard Feynman. In 1945 he graduated with honors from Union College in Schenectady, New York. He entered the graduate program in mathematics at Columbia University but his interests turned to medicine and he enrolled at Columbia's College of Physicians and Surgeons, from which he received his M.D. in 1951. He began graduate work in biochemistry at Balliol College in Oxford and earned his Ph.D. in 1957.

He was a member of the Fox Chase Cancer Center in Philadelphia and held the rank of University Professor of Medicine and Anthropology at the University of Pennsylvania. Blumberg also served as the President of the American Philosophical Society, the oldest learned society in the United States. From 1999 to 2002, he was also director of the NASA Astrobiology Institute at the Ames Research Center, and in 2008 became a Senior Scientist at the NASA Lunar Science Institute.

Books

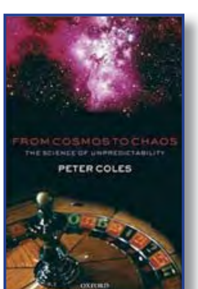


Blogging the Moon: The Once & Future Moon Collection.
By Paul D. Spudis. Apogee Prime, 2011. 328 pp, with bonus DVD. Paperback, $27.95.
www.apogeeprime.com

For over two decades Paul Spudis has had a front row seat to the U.S. national space program and has written extensively about space policy and space science. His opinions and insights recently found a home on the *Air and Space Magazine* blog, *The Once and Future Moon*. Beginning with his reporting from India in October of 2008 (as the principal investigator of NASA's Mini-SAR, watching his radar being launched to the Moon onboard Chandrayaan-1), Spudis' easy-to-read essays have followed and reported on the growing upheaval in the space community and the battle being waged for the ideological control of and funding for space exploration, and the resulting chaos. While covering the progress of lunar return under the Vision for Space Exploration (approved by two different Congresses of different parties with overwhelming majority votes) was the original purpose of his blog, historic events intervened. As our direction in space became more uncertain, the space community began eating its own, and the posting of science essays took a smaller role in the unfolding space policy drama. In keeping with his call for a strong U.S. human space program, Spudis outlines and explains the importance of creating a sustainable space program through the use of the Moon's resources to create new capabilities to live and work in space and move humanity off planet. These essays and reader comments are compiled in *Blogging the Moon*.

Geographies of Mars: Seeing and Knowing the Red Planet.
By K. Maria D. Lane. University of Chicago Press, 2010. 272 pp., Hardcover, $45.00.
www.press.uchicago.edu

One of the first maps of Mars, published by an Italian astronomer in 1877, with its pattern of canals, fueled belief in intelligent life forms on the distant Red Planet — a hope that continued into the 1960s. Although the martian canals have long since been dismissed as a famous error in the history of science, Lane argues that there was nothing accidental about these early interpretations. She argues that the construction of Mars as an incomprehensibly complex and engineered world both reflected and challenged dominant geopolitical themes during a time of major cultural, intellectual, political, and economic transition in the Western world. This book telescopes in on a critical period in the development of the geographical imagination, when European imperialism was at its zenith and American expansionism had begun in earnest. Astronomers working in the new observatories of the American Southwest or in the remote heights of the South American Andes were inspired by their own physical surroundings and used representations of Earth's arid landscapes to establish credibility for their observations of Mars. With this simple shift to the geographer's point of view, Lane explains some of the most perplexing stances on Mars taken by familiar protagonists such as Percival Lowell, Alfred Russel Wallace, and Lester Frank Ward. *Geographies of Mars* offers a new view of the mapping of far-off worlds.



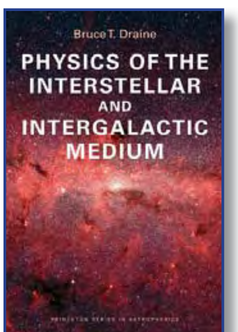
From Cosmos to Chaos: The Science of Unpredictability.
By Peter Coles. Oxford University Press, 2010. 224 pp., Paperback, $26.95. *www.oup.com*

Cosmology has undergone a revolution in recent years. The exciting interplay between astronomy and fundamental physics has led to dramatic revelations, including the existence of the dark matter and the dark energy that appear to dominate our cosmos. But these discoveries only reveal themselves through small effects in noisy experimental data. Dealing with such observations requires the careful application of probability and statistics. But it is not only in the arcane world of fundamental physics that probability theory plays such an important role. It has an impact in many aspects of our everyday life, from the law courts to the lottery. Why then do so few people understand probability? And why do so few people understand why it is so important for science? Why do so many people think that science is about absolute certainty when, at its core, it is actually dominated by uncertainty? This book attempts to explain the basics of probability theory, and illustrate their application across the entire spectrum of science.

How Old is the Universe?

By David A. Weintraub. Princeton University Press, 2010. 380 pp., Hardcover, $29.95.
www.press.princeton.edu

Astronomers have determined that our universe is 13.7 billion years old. How exactly did they come to this precise conclusion? This book tells the incredible story of how astronomers solved one of the most compelling mysteries in science and, along the way, introduces readers to fundamental concepts and cutting-edge advances in modern astronomy. The age of our universe poses a deceptively simple question, and its answer carries profound implications for science, religion, and philosophy. Weintraub traces the centuries-old quest by astronomers to fathom the secrets of the nighttime sky. Describing the achievements of the visionaries whose discoveries collectively unveiled a fundamental mystery, he shows how many independent lines of inquiry and much painstakingly gathered evidence, when fitted together like pieces in a cosmic puzzle, led to the long-sought answer. Astronomers don't believe the universe is 13.7 billion years old — they know it. By focusing on one of the most crucial questions about the universe and challenging readers to understand the answer, Weintraub familiarizes readers with the ideas and phenomena at the heart of modern astronomy. Offering a unique historical approach to astronomy, this book sheds light on the inner workings of scientific inquiry and reveals how astronomers grapple with deep questions about the physical nature of our universe.



Physics of the Interstellar and Intergalactic Medium.

By Bruce T. Draine. Princeton University Press, 2011. 540 pp., Paperback, $65.00.
www.press.princeton.edu

This is a comprehensive and richly illustrated textbook on the astrophysics of the interstellar and intergalactic medium — the gas and dust, as well as the electromagnetic radiation, cosmic rays, and magnetic and gravitational fields, present between the stars in a galaxy and also between galaxies themselves. Topics include radiative processes across the electromagnetic spectrum; radiative transfer; ionization; heating and cooling; astrochemistry; interstellar dust; fluid dynamics, including ionization fronts and shock waves; cosmic rays; distribution and evolution of the interstellar medium; and star formation. While it is assumed that the reader has a background in undergraduate-level physics, including some prior exposure to atomic and molecular physics, statistical mechanics, and electromagnetism, the first six chapters of the book include a review of the basic physics that is used in later chapters. This graduate-level textbook includes references for further reading, and serves as an invaluable resource for working astrophysicists.

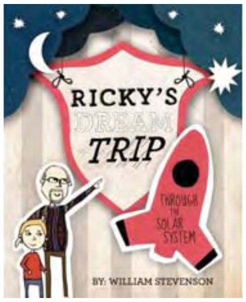
DVD

Hubble's Amazing Rescue.

Produced by PBS, 2009, one disc. $24.99. *www.shoppbs.org*

In the spring of 2009, NASA sent a shuttle crew on a risky mission to service the Hubble Space Telescope for the last time. The astronaut servicing team had to carry out the first ever in-space repairs of Hubble's defective instruments, a task that required ingenious engineering fixes and the most intensive NASA spacewalk ever. NOVA presents the inside story of the mission and the extraordinary challenges faced by the rescue crew.

For Kids!



Ricky's Dream Trip Through the Solar System.

By William Stevenson. Off the Bookshelf, 2010, 46 pp. Paperback, $11.99. *offthebookshelf.com*

Ricky's Dream Trip Through the Solar System is about a little boy whose grandfather (Pop Pop) enters his dream. They board a dream rocket ship and tour the solar system planet by planet. The concept of the book is to open the minds of elementary school children about the eight planets and our dwarf planet. Once the imagination of the children is piqued through this very personal vignette, it is anticipated that parents and educators will be able to expand and build upon their interest to learn more about astronomy and our relationship to the universe. For ages 9 to 12.

Robot Calculator: Galactic Addition.

From Hog Wild Toys. $16.95. *hogwildtoys.com*

These Robot Calculators have movable arms, hands that squeeze, and hold small objects like pens, pencils, and their very own night lights (batteries included). Plus they're loaded with other fun features you'll love: a disk magnet to hold paper clips and a note holder to hold notes, a detachable push button night light, and they stand up or lay down flat, making them the hardest working calculators on the planet! Each robot measures about 6" × 3.5", taking up only a little space on your desk.

The Magic School Bus: The Secrets of Space.

Produced by the Young Scientists Club. $21.99. *kidssciencekits.com*

Ms. Frizzle and her students take Young Scientists on a wild ride into the secrets of space with spectacular experiments. Youngsters construct a night-vision flashlight, design a solar system mobile, build a constellation box, draw constellation cards, recreate the phases of the Moon, make a model of a solar eclipse, observe magic beads change color, assemble a working telescope, and more! This kit includes an interactive space poster with sheets of planet and star stickers. Seatbelts, everyone! Get ready to discover *The Secrets of Space!* For ages 5 and up.

I Love Rockets! DVD.

Produced by A Wrench in the Works Entertainment, 2010, one disc. $19.99. *www.amazon.com*

Here is a fun and educational journey into the world of rockets and space travel for children of all ages. Through historical video and interesting facts, children will learn about all the different types of rockets in history, how they work, and what each mission accomplished. This DVD features the history of space travel, including the very first rocket to reach space, the first animal in space, the first Moon landing, the first rocket-powered airplane, the first space shuttle, the International Space Station, Moonwalks, and spacewalks; video of real rocket launches from the very first space rocket to the space shuttle; real sounds of rocket launches; real voices of the astronauts and mission control; and dazzling views of the Moon and Earth from space.

June

5–8 **Astrobiology Graduate Student Conference (AbGradCon 2011),** Bozeman, Montana. *http://abgradcon2011.org/*

5–10 **Second Workshop on Robotic Autonomous Observatories,** Malaga, Spain. *http://arae.iaa.es:8000/malaga-2011/index.php*

6–10 **8th Serbian Conference on Spectral Line Shapes in Astrophysics,** Divcibare, Serbia. *http://www.scslsa.matf.bg.ac.rs/*

6–10 **Eighth International Planetary Probe Workshop,** Portsmouth, Virginia. *http://www.planetaryprobe.org/*

8–10 **24th Space Cryogenics Workshop,** Coeur d'Alene, Idaho. *http://www.spacecryogenicsworkshop.org/*

8–10 **International Workshop on Planning and Scheduling for Space,** Darmstadt, Germany. *http://www.congrexprojects.com/11c05/*

13–15 **A Wet vs. Dry Moon: Exploring Volatile Reservoirs and Implications for the Evolution of the Moon and Future Exploration,** Houston, Texas. *http://www.lpi.usra.edu/meetings/volatiles2011/*

13–15 **The International Conference on Exploring Mars Habitability,** Lisbon, Portugal. *http://www.congrex.nl/11a14/*

14–17 **The Second CoRoT Symposium: Transiting Planets, Vibrating Stars and Their Connection,** Marseille, France. *http://symposiumcorot2011.oamp.fr/*

14–18 **Ringberg Workshop on Geophysical and Astrophysical Fluid Flow: Baroclinic Instability and Protoplanetary Accretion Disks,** Ringberg Castle, Germany. *http://www.mpia-hd.mpg.de/Baroclinic2011/*

16–17 **24th Meeting of the NASA Mars Exploration Program Analysis Group,** Lisbon, Portugal. *http://mepag.jpl.nasa.gov/meeting/jun-11/index.html*

18–21 **Very Wide Field Surveys in the Light of Astro2010,** Baltimore, Maryland. *http://widefield2011.pha.jhu.edu/*

19–22 **Second Joint Meeting of the Planetary and Terrestrial Mining Sciences Symposium (PTMSS) and the Space Resources Roundtable (SRR),** Ottawa, Ontario, Canada. *http://www.isruinfo.com*

20–23 **Titan Science Meeting,** Abbaye Saint-Jacut-de-la-Mer, France. *http://www.sp.ph.ic.ac.uk/~ingo/Titan_Meeting/Titan_Science_Meeting/Welcome.html*

20–24 **Ninth IAA Low-Cost Planetary Missions Conference,** Laurel, Maryland. *http://lcpm9.jhuapl.edu/index.php*

21–24 **Discover the Cosmos and Change the World!,** Tenerife, Canary Islands, Spain. *http://www.starmus.com/pages/en/conferences.php*

27–Jul 1 **Joint Mars Express/Venus Express Workshop,** Villanueva de la Canada, Spain. *http://www.rssd.esa.int/mexdataworkshops/*

28–Jul 7 **IUGG/IAMAS General Assembly,** Melbourne, Australia. *http://www.iugg2011.com/program-iamas.asp*

July

3–8 **Origins 2011: The International Astrobiology Society and Bioastronomy Joint International Conference,** Montpellier, France. *http://www.origins2011.univ-montp2.fr/*

4–8 **European Week of Astronomy and Space Science (JENAM-2011),** St. Petersburg, Russia. *http://www.jenam2011.org/conf/*

4–8 **SKA Science and Frontiers of Astronomy in the Era of Massive Datasets: The Promise and Challenges,** Banff, Canada. *http://www.ska2011.org/Home.html*

5–8 **40th Young European Radio Astronomers Conference (YERAC),** Alcala de Henares, Spain. *http://www.yerac.org/*

11–15 **Magnetospheres of the Outer Planets 2011,** Sendai, Japan. *http://mop2011.jimdo.com/*

17 **AI in Space: Intelligence Beyond Planet Earth,** Barcelona, Spain. *http://www.congrex.nl/11M10/*

17 **Second Annual Lunar Graduate Conference (LunGradCon 2011),** Mountain View, California. *http://lasp.colorado.edu/ccldas/lgc2011/*

17–22 **2011 Gordon Research Conference on Origins of Solar Systems,** South Hadley, Massachusetts. *http://www.grc.org/programs.aspx?year=2011&program=origins*

18–22 **From Interacting Binaries to Exoplanets: Essential Modeling Tools,** Tatranska Lomnica, Slovakia. *http://www.astro.sk/IB2E/*

19–21 **Lunar Science Forum 2011,** Moffett Field, California. *http://lunarscience.nasa.gov/lsf2011/*

25–29 **2011 Sagan Exoplanet Summer Workshop: Exploring Exoplanets with Microlensing,** Pasadena, California. *http://nexsci.caltech.edu/workshop/2011/*

27–29 **Rings 2011,** Ithaca, New York. *http://rings2011.astro.cornell.edu*

30–Aug 3 **Connecting People to Science: The 2011 Education and Public Outreach Conference of the Astronomical Society of the Pacific,** Baltimore, Maryland. *http://www.astrosociety.org/events/meeting.html*

August

1–5 **6th Heidelberg Summer School: Characterizing Exoplanets — From Formation to Atmospheres,** Heidelberg, Germany. *http://www.mpia.de/imprs-hd/SummerSchools/2011/*

7–12 **12th Annual Summer School on Adaptive Optics,** Santa Cruz, California. *http://www.cfao.ucolick.org/aosummer/2011/index.php*

8–11 **AOGS2011 — Asia Oceania Geosciences Society,** Taipei, Taiwan. *http://www.asiaoceania.org/aogs2011/public.asp?page=home.htm*

8–12 **74th Annual Meeting of the Meteoritical Society,** London, England, UK. *http://www.metsoc2011.org/London_Met_Soc_2011/Welcome.html*

10–12 **Stars, Companions, and Their Interactions: A Memorial to Robert H. Koch,** Villanova, Pennsylvania. *https://sites.google.com/site/rhkochconference/home*

14–19 **Goldschmidt 2011,** Prague, Czech Republic. *http://www.goldschmidt2011.org/*

22–25 **Magnetic Fields in Stars and Exoplanets,** Potsdam, Germany. *http://www.aip.de/thinkshop7/*

25–26 **Fifth Meeting of the NASA Small Bodies Assessment Group,** Pasadena, California. *http://www.lpi.usra.edu/sbag/*

30–31 **New Horizons Workshop on Icy Surface Processes,** Flagstaff, Arizona. *carrie.l.chavez@nasa.gov*

September

5–9 **Summer School on Astronometry,** Antalya, Turkey. *http://www.tug.tubitak.gov.tr/aass/*

11–17 **Extreme Solar Systems II,** Moran, Wyoming. *http://ciera.northwestern.edu/Jackson2011/*

12–16 **Fifth International Conference on Mars Polar Science and Exploration,** Fairbanks, Alaska. *http://www.lpi.usra.edu/meetings/polar2011/*

14–16 **Second Planetary Consortium Meeting,** Flagstaff, Arizona. *http://www.planetarycraterconsortium.nau.edu/PCCMeeting.htm*

19–21 **Journees 2011: Systemes de reference spatio-temporels,** Vienna, Austria. *http://info.tuwien.ac.at/hg/meetings/journees11/index.html*

19–23 **New Horizons in Time Domain Astronomy,** Oxford, United Kingdom. *http://www.physics.ox.ac.uk/IAUS285/*

21–23 **Nitrogen in Planetary Systems: The Early Evolution of the Atmospheres of Terrestrial Planets (COST CM-0805),** Barcelona, Spain. *http://ulisse.busoc.be/cost/barcelona-meeting.php*

26–Oct 1 **Joint Assembly: CPS 8th International School of Planetary Sciences,** Hyogo, Japan. *https://www.cps-jp.org/~pschool/pub/2011-09-26/index.html*

October

3–7 **EPSC-DPS 2011: A Joint Meeting of the European Planetary Science Congress and the American Astronomical Society Division for Planetary Sciences,** Nantes, France. *http://meetings.copernicus.org/epsc-dps2011/*

9–12 **Geological Society of America Annual Meeting,** Minneapolis, Minnesota. *http://www.geosociety.org/meetings/2011/*

16–20 **Third International Conference on Biosphere Origin and Evolution,** Rethymno, Crete, Greece. *http://conf.nsc.ru//BOE-2011*

26–28 **First International Planetary Cave Research Workshop: Implications for Astrobiology, Climate, Detection, and Exploration,** Carlsbad, New Mexico. *http://www.lpi.usra.edu/meetings/caves2011/*

November

7–9 **Annual Meeting of the Lunar Exploration Analysis Group (LEAG 2011),** Houston, Texas. *http://www.lpi.usra.edu/meetings/leag2011/*

7–9 **Workshop on Formation of the First Solids in the Solar System (Solids 2011),** Kauai, Hawaii. *http://www.lpi.usra.edu/meetings/solids2011/*

13–20 **Second Arab Impact Cratering and Astrogeology Conference (AICAC II),** Casablanca, Morocco. *http://www.fsac.ac.ma/aicaii/index.html*