Astronomy Cast Episode 198
How is a Space Mission Chosen?

Fraser: Astronomy Cast Episode 198 for Monday September 13, 2010, How is a Space Mission Chosen? Welcome to Astronomy Cast, our weekly facts-based journey through the cosmos, where we help you understand not only what we know, but how we know what we know. My name is Fraser Cain, I'm the publisher of Universe Today, and with me is Dr. Pamela Gay, a professor at Southern Illinois University Edwardsville. Hi, Pamela, how are you doing?
Pamela: I'm doing well, how are you doing, Fraser?
Fraser: Great! It was great to hang out with you at DragonCon 2010 and do the live episode of the show. I hope everyone has had a chance to listen to that. What a party!
Pamela: It was definitely an amazing... I guess four days... all put together. Hopefully next year we'll get to see everyone who didn't have a chance to go out to see us this year. I'm already looking forward to DragonCon 2011 and go get your hotel rooms! They're already starting to sell.
Fraser: Yeah, absolutely. It's unbelievable how fast these hotel rooms book out. In fact they were starting to take reservations the last day of the con for the next year. You can start any time... and I think you can cancel so there's no problem to reserving now. So, this week... Space missions are expensive to build and launch so there's a lot of planning that goes into choosing exactly what's going to be shot into space. Space scientists and engineers recently went through the process of deciding on their science goals. So we thought we'd spend an episode explaining how this works and how the next generation of spacecraft and telescopes will be selected. And Pamela, this is kinda close to your heart... you were a member of the decadal survey... What is that?
Pamela: It's a project that every basically ten years the entire astronomy community and separately the entire planetary science community sits down and figures out what are our big science questions... what are our big technological needs... How can we take our entire field and come up with a few goals that as a field will allow us to fundamentally change how we understand the universe if we can just accomplish these goals. In astronomy we sat down and we didn't just look at the science and the telescopes and galaxies and that sort of stuff, but we also asked the question how can we better communicate astronomy to the public? This is where I got the chance to sit on one of the committees. One of the committees was dedicated to looking at astronomy education and public outreach... the type of stuff that we do here with Astronomy Cast and with the Zooniverse with Galaxy Zoo and Moon Zoo and with so many different online projects, and even Twitter was included in ways that we are currently reaching out to the public.
Fraser: Right, ok, so then can you sort of walk me through that? I mean I know that a scientist... as science moves forward, the scientists get bigger and deeper questions that they want to answer. So what is that process?
Pamela: Well, it's two-fold. It's on one hand, what technology do we need as a whole, for the entire community... things like the Great Observatories that NASA built... the Hubble, Chandra, Spitzer. All of these great orbiting observatories... Compton... they were built out of the recognition that to advance our entire field, we need versatile instruments that are on one hand geared towards specific questions. Hubble was geared at

figuring out what is the Hubble constant... what is the expansion rate of our universe. But on the other hand are flexible enough so that when things we never dreamed of are discovered, these instruments can be used to try to answer those questions. So on one hand we're trying do define what are the technologies that cost huge sums of money that will most effectively move our field forward, and guiding it on the other side is the question of what are the things that we most don't understand... that by figuring out these few things—dark energy, dark matter, gravitational waves—by understanding these questions, we can unravel major parts of the tangled web that is science and start to get a clearer understanding of our universe.

Fraser: In many situations, it's just there's one kind of observation that can help answer a question, and there's just no way to get at the information... no way to get the answer... tests of Einstein's relativity... where until you could actually put a spacecraft into orbit and orbit it around at a certain speed, you really couldn't complete one of those final things. I guess that was with Gravity Probe B. Or, gamma ray bursts where a gamma ray burst would go off and it might last for a couple of seconds, but there was no equipment that was able to slew around quickly enough to spot the afterglow. It took a mission.

Pamela: And that was where Swift came into play. And then we have WMAP which is one of the very first single-purpose missions. When it was built it was simply the Microwave Anisotropy Probe and then Wilkinson had his name added to it after its launch and unfortunately after his death. WMAP was built with the single purpose of better mapping the cosmic microwave background radiation than it had ever been mapped before. Planck is following in its footsteps doing an even more high-resolution survey of our microwave sky.

Fraser: So with this process, you were on the decadal survey. So what was the process that happened to kind of bring all these people together... all these ideas together... and actually boil it down into some specific technologies?

Pamela: It's basically a three-phase process. The first thing they do is appoint basically the leaders of the process... this is where you have your steering committee. They in turn figure out what are all the sub-committees we need. They appoint chairs of the sub-committees, chairs of the sub-committees appoint members of the committees, and then all the reporting begins. On the committee that I was sitting on, and from what I understand it worked the same on all the rest of the committees, each of us were given a very narrow goal, and we were told survey this slice of astronomy. So I surveyed new-media technologies. Then come back and tell us... what is the current state of the field, what are the current needs of the field... in very brief reports. Then all of the reports we wrote were synthesized by the committee chairs into a committee report which was then synthesized in its own way into the full report that came from the decadal survey. We also took input from the entire field where we asked the astronomy community—professional, citizen scientists, and amateur astronomers—what do you see as the greatest needs of the field? Write as white papers. So here we were getting white papers about the needs of postdoctoral researchers, the needs for how to change graduate school to better serve today's graduate students who have different things they need to learn than graduate students 20 years ago when teaching wasn't quite as strong an emphasis. So all this different input comes together.

Fraser: So, for example, you might talk to all of the black hole researchers and just say what are the big questions in your field that you need a tool to help you dig a little deeper. And they'll come back and give you their answers.
Pamela: Yeah, and this is where entire committees were put together, review papers were written, and a whole lot of trees died in the process of putting this document together. If it serves the way the last one served, it will be what defines what big missions are funded and what big telescopes are built here on the surface of the planet, as well.
Fraser: Ok, so all the scientists provide their recommendations, their wish lists, their dreams, their hopes and dreams; and then, as you said, it sounds like there's a whole lot of committees and sub-committees and meetings and bureaucracy but the purpose here is to just boil all this down into some core ideas.
Pamela: Yes. So with the last decadal survey, especially in the planetary side... and we're still waiting for the planetary report for the current decade... they came out with a list of missions. Many of those missions got built. So, we're hoping the exact same thing will happen with the current survey. With this year's results, it came back with on the space side of astrophysics, so no planets were involved, but strictly astrophysics, the recommendation was for a wide field infrared survey telescope. The way they described this is an observatory designed to settle essential questions in both extrasolar planets and dark energy research which will advance topics ranging from galaxy evolution to the study of objects within our own galaxy. So this is again a flexible instrument capable of answering a wide variety of questions and it's something we don't currently have. Spitzer is onto the warm side of its program, and it's not a wide field survey telescope. So we're looking for something that's a bit different, a lot more sensitive, and will fill a niche that's not currently being filled.
Fraser: How do they decide between whether they want to solve a very specific problem like WMAP or something more general like producing something like Hubble and, you know... well, I'll give you another question in a second... how do they decide? How do they pick that?
Pamela: Well, this really comes up with a mix of things, actually. Missions like WMAP aren't actually all that expensive. It's a single purpose satellite... it's in Earth's orbit... and by having the low-cost missions, you can answer a lot of very specific questions and not spend that much money in the grand scheme of things, compared to a wide field infrared survey telescope which will cost a ton of money. So here you have one high cost but very flexible instrument that can answer a whole lot of questions but then a small fleet of in some cases what we call Explorer programs... missions that range from tens of millions to in some cases... there's a variety of different NASA programs I know we're going to get to... but there's these different lower-cost missions that typically answer a single science ~~program~~ question. So they balance it out by looking at cost.
Fraser: Looking at cost... and then try to compare that to the boon to science.
Pamela: Right. So very flexible expensive instrument vs. lower cost single question instrument. And you come up with a menu... something where you can go a la carte and solve a lot of problems all at once.
Fraser: Right, or just provide a really powerful tool that has no specific thing like Hubble or James Webb. I know they have a few science goals that they're going to try to figure out, but Hubble can just be used for so much.

Pamela: Right, right. And what's neat is the way we often have to justify things is well, Hubble is going to determine the origins of planetary nebulae, which it's really quite shocking to think that we didn't fully understand the structure of planetary nebulae... we still don't understand the origins of the structure of planetary nebulae... but we didn't understand the diversity of the structure of planetary nebulae until Hubble was launched. So planetary nebulae was one of its original causes. Then, measuring the Hubble constant, of course, was one of its original causes. We use it to look at everything. And that's pretty amazing. Then WFIRST, the Wide Field Infrared Survey Telescope they're looking at is looking to be one of the next generation work horses of astronomy.
Fraser: Right, so scientists have gotten together and decided on the big science challenges that they're interested in solving, and this has boiled down, I guess, into a bunch of mission plans...
Pamela: Initiatives.
Fraser: Initiatives. So what space ships are we going to see over the next ten years?
Pamela: So what they're looking at... again, only on the astronomy side... they're looking at four different space-based initiatives and four different ground-based initiatives. On the space-based, we have three single-mission giant spend a lot of money get a really cool toy. There's WFIRST, which I just explained. They took LISA... this is a project that people have been talking about since the early nineties... a Laser Interferometry Space Antenna. It looks like it might finally get the kick in the funding pants that it needs to get itself built and into orbit. This is a series of satellites that will orbit together separated by a set distance with laser beams spanning that distance that will look for gravitational waves emitted by emerging black holes, by collapsing-down neutron stars, by a whole variety of different high-gravity events. We think there's gravity waves, we have all the secondary evidence you could possibly want, but we don't have any direct detections. LISA might finally do that for us if the mission gets put into orbit.
Fraser: Right... this is going to answer the question, "Are there gravity waves?"
Pamela: Finally! We just want a detection. It fills the niche that LIGOS has been trying to fill from the ground. And we've talked about this in episodes before... trying to detect gravity waves while on a planet is just hard because the UPS truck can screw you up.
Fraser: So what else?
Pamela: The third space-based mission that we're looking at is the International X-Ray Observatory. They describe this one as a high spectral resolution x-ray telescope that will lead will to great advances in broad fronts ranging from understanding of black holes, to cosmology, to life cycles of matter and energy in the cosmos. This is the replacement telescope for Chandra, in some ways. The next big instrument that launches and helps us dig deeper into the x-ray sky. Every time we build a new instrument we get a little higher resolution, we get a little more sensitive. We see these jumps. We saw them come with Spitzer, compared to IRAS that came before it. So this will be our next way to explore the high-energy universe.
Fraser: So, it's just going to be a much more powerful Chandra?
Pamela: Pretty much. That's what we're looking at right now. It will have more spectral capabilities, so there's a high-resolution spectroscopy coming out of it, so we'll be able to say better what are the atomic transitions getting observed... what are the specifics of the high energy universe that we can't quite get to. So it just brings the whole universe into a little bit better focus.

Fraser: And now these are the main missions, right?
Pamela: Right. And then there's also a fourth program to take NASA's Explorer program and keep it going into the future. So the Explorer missions, these are compact missions... WISE, IBEX... small short-term where they put calls out to the scientific community... what would you like to do next? They're not all that expensive of a mission, typically. They come in a variety of different sizes, ranging from missions of opportunity, where you get an instrument on something that's already about to launch, or you extend something that's already in orbit, for upwards of a few tens of millions of dollars out to much more significant projects that can range as much as 180 million dollars. So all these different projects... they span from single instruments out to missions like Swift and FUSE. It's a great way to get a lot of science done for not a lot of money. So that's where the fourth field of emphasis goes... keeping this program, which has produced so many great missions, keeping it alive into the future.
Fraser: Right, but it's not just going to be space missions, there's also going to be some scientific questions that can be answered from the ground.
Pamela: Right. The planet's surface still has a role to play. We don't have to put everything in space. This is where instruments like the Large Synoptic Survey Telescope (LSST), a giant telescope people have been talking about as the mother lode coming, it finally got the blessing of the entire field that it needed to start getting the funding that it needed. This is a multi-meter telescope that is going to be able to observe the entire visible sky every three nights. It's going to produce terabytes and terabytes and terabytes of data. It's goal is primarily... well, it's getting justified as something that will find the next asteroid that might wipe out the planet Earth in time so that we can deter it... but along the way, while it's looking for these killer asteroids and mapping out everything in the inner solar system, it's also going to be mapping the entire universe. It's going to be helping us find new classes of variable stars, new classes of flickering objects of every type from active galaxies to comets that have jets turning on and off. It's going to pick up on all of these different events happening across the sky. The follow-up targets, we're going to be using every telescope on the planet to follow up on the new discoveries. They're saying there might be on the order of tens of thousands of things found each night flickering on and off in the images coming from this telescope.
Fraser: It's funny... we have talked about this. It's interesting that there just isn't a really comprehensive survey to just see how the sky changes from night to night, so this is actually really important.
Pamela: It's following on... we've had ???? project that discovered so many different asteroids and satellites. We've had things like the Palomar Sky Survey which in its time surveyed the entire sky, slowly but surely. But the rapidity that's allowed by having robotic telescopes... this is something we've never seen before. It's going to be fantastic to see what comes from this specially-directed telescope.
Fraser: So, we're going to have faster telescopes... but I'm sure we're going to have bigger, right?
Pamela: Right. And this is where we start looking at things like the Giant Segmented Mirror Telescope. Lots of different people have come up with lots of different giant sizes... pick your giant tens of meters size of choice... Exactly which one we end up going with is still going to be decided, I think.
Fraser: Thirty meters...

Pamela: Yeah... something obnoxious is coming... So here, it's two different ways of looking at the sky. With the Large Synoptic Survey Telescope (LSST), we're going to be looking at the entire sky over and over and over with an 8-meter mirror... giant survey telescope. But it's not going to be sitting down and looking at one galaxy for four days to be better able to understand what was going on in the first few hundred thousand... first few million years of the universe. The Giant Segmented Mirror Telescope... here we're looking at tens of meters, and it'll have specific calls out... ok, tonight... everyone tell us what you want to look at tonight... it's more sophisticated than that with telescope allocation committees... but we're still going out to the community and looking for calls for specific science questions. So on one night they might be looking at the light echo of a quasar, and on another night they might be looking at the very first galaxies forming in the beginning of the universe and answering specific questions... resolving planets, perhaps, around other stars and observing their light from the surface of the planet. It depends on what kinds of optics they have. So two different ways of doing science outlined with these two different giant telescope missions.
Fraser: Now, the decisions have been made... the proposals have been made, but it's a long way to go from idea for a space mission to the actual thing launched. So let's talk a bit about the development process.
Pamela: Now we have two different sides here... ground-based and space-based. And this is where governmentally we divide things... sorry, we're being U.S.-centric... apologies, apologies, apologies. Strategies vary in other nations. Here in the US what we have is the National Science Foundation on one side is funding things that are ground-based, and NASA on the other side is funding things that are space-based. So with NASA, programs like the Explorer missions... they'll actually put out calls to the community and say ok, we want individual PIs... individual investigators to put together a team, to put together a set of mission goals, and put together a budget. Then submit, in a lot of crazy documentation that makes you pull your hair out, all of the things you want to do and how the things you want to do align with the long-term goals of NASA, which get aligned, in turn, with the decadal survey in a lot of ways. Then committees are put together. Everyone in the astronomy community at one point or another sits on a committee of a varying level, and you decide the fate of the community when you sit on these panels. You read through the documents, you try to figure out can these people actually do what they say they're going to do. Are their science questions as important as they say they are? Then you pick what missions are going to get funded. It's often with satellite missions a 2-tiered system where first there's the general call for proposals. Then it gets narrowed down to a smaller set. The narrowed-down set then has to go through a new round of documentation of what they're planning to do. Then the final decisions get made. With the giant missions, where we say... Dear community, we're going to build the Hubble Space Telescope. In that case, NASA says we have a defined program, and they put things out for bids. So, it's a different way of doing things.
Fraser: It's put out to aerospace companies for bids?
Pamela: It varies because you have instruments getting built. Instruments come not just from corporations but from universities. For instance, Cornell has built a whole variety of different instruments for different things all over the surface of the planet and on their way to other planets. You also have companies like Boeing and Ball Aerospace and Lockheed... they're all involved in building a variety of satellite missions as well.

Fraser: Right, and then the proposal is chosen and the spacecraft is built. About how long does it take for a spacecraft to be built?
Pamela: The aim with the smaller missions is to actually do full turn around in no more than 36 months. So that's pretty impressive to think about. Now the bigger missions, the Chandras, the Hubbles, those can, from conception of idea to launch, take decades. But the smaller missions you're looking at the course of one graduate student's lifetime. You can actually get from conceiving the idea to getting data on hand. And that's pretty awesome to think about.
Fraser: And then they put the mission into their launch schedule.
Pamela: And then you schedule a rocket and hope and pray that the rocket works.
Fraser: Yeah... it doesn't explode and you have to go back from scratch and build it all over again... which has happened... a few times.
Pamela: It does... part of my dissertation was eaten by an x-ray satellite. These things happen and you learn to move on. My lesson to all graduate students out there... having learned this the hard way... is do not write a dissertation proposal that relies on satellites that aren't launched and telescopes that aren't commissioned.
Fraser: And then, once the spacecraft is launched, then they spend a few months testing everything out... making sure it's all working. Then finally they open it back up to the scientists and start to schedule their time to start making the observations that they had planned out ten years before...
Pamela: Right, or if they're lucky and it's a smaller mission... two years before.
Fraser: Or if they're unlucky and it's the Hubble... 20 years before.
Pamela: Right. As a side note, one of the reasons it takes so long to go from launch to first light is they actually, for some of the missions, have to wait for them to outgas. So you get to orbit and you have to wait for everything to stabilize after exposing your spacecraft to vacuum. But once the mission is launched and once you start taking data, then the scientists get first crack at everything. Typically they get anywhere from a few months to 6 months, sometimes you can beg, borrow, and steal extra time beyond that, to get first chance to publish the results of the mission. No one's hiding data, and this is something you may have heard a debate about with Herschel, is Herschel is actually holding on to some of its best data for the team scientists. This is simply a matter of these people have gone sleepless nights getting their missions put together, pulling all-nighters now and again just trying to get that last bit of something done. Part of the payback of the blood, sweat, and tears... and there's always tears... there's not always blood, but there's always tears involved in building a mission... part of the payback is you get first crack at the data. Everyone else is told hands off, you can't see until that waiting period is over.
Fraser: Right. Cool. So when might the first spacecraft get launched from decisions that the committee made just this year?
Pamela: Well, it's hard to say specifically, because when you have things like augmentation to the Explorer program... these are recommendations made by the decadal survey, and now we have to wait and see if Congress agrees. We have to wait and see when does the funding make itself out of the National Science Foundation. One of the things that people don't realize is how long it just takes to push things through the U.S. government. When I get grants... I went through this last year... I got a phone call from my NASA program officer. He made my day one day in October. The check finally came through mid-January, processed to my university. So it takes a lot of time to get

everything processed through, but they're also running background checks on you, on your university, on everything else to make sure you're not going to run with the money. So a lot of checks and balances are put into place. And all of those checks and balances slow things down. Which is basically my way of saying that due to Congress and bureaucracy it could be three months... it could be six months... it could be a year before we see the first drop of funding that results directly from a recommendation from the survey.

Fraser: Right, and then depending on the complexity of the mission... three years to ten years after that for the actual mission to be launched. Cool. Well, thanks a lot for that, Pamela.

Pamela: It's been my pleasure, Fraser.

Fraser: We'll talk to you next time.

Pamela: Ok, bye-bye.