DISCOVERY 30TH ANNIVERSARY ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

JAMES L. FANSON
INTERVIEWED BY ERIK M. CONWAY
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CONWAY: This is Erik Conway. It's August 2nd, 2022, and we're both doing work-from-home today, interviewing about GALEX [Galaxy Evolution Explorer] and Kepler. My subject is Jim Fanson. Are you back at JPL [NASA's Jet Propulsion Laboratory, Pasadena, California] full-time or are you still doing Carnegie [Observatories] work?

FANSON: I am the project manager of the Giant Magellan Telescope [Project] for GMTO Corporation, not for Carnegie.

CONWAY: Oh, sorry.

FANSON: Carnegie is one of the founder institutions that is funding the development of the Giant Magellan Telescope. But I'm also an IEP [Interim Employment Program] employee of JPL at present, so I'm doing this from a JPL computer and I have a JPL badge and so on as a retiree.

CONWAY: Okay. I wondered how that worked, because I thought you still worked on GMT, but thanks for clarifying. So, first, Jim, I always ask this question of new subjects. Tell me where you were born and how you were educated.

FANSON: I was born in and grew up in Waukesha, Wisconsin, which was the county seat, in the southeastern portion of the state. I went through Lutheran High School and then entered the University of Wisconsin, Milwaukee campus, and completed my undergraduate at University of Wisconsin, Madison. While I was a student at the University of Wisconsin, I worked to help build one of the instruments that flew aboard the Hubble Space Telescope. They were building that at the University of Wisconsin, the High-Speed Photometer, for PI [principal investigator] Bob [Robert C.] Bless. At that time, the Voyager mission was about to fly by Saturn, and I was assigned to record the broadcast that JPL made with Al [Albert] Hibbs as the voice of Voyager.

I became so enamored with JPL that I decided I wanted to go to graduate school and work at JPL. That's when I discovered that JPL was operated by Caltech [California Institute of Technology], so I applied to graduate school at Caltech and was accepted and did my master's and Ph.D. at Caltech and did my thesis topic on something of interest to JPL. And while a student, I did some work for the Galileo mission, the Jupiter orbiter mission, and when I graduated, continued my research as a technologist at JPL. So that's how I wound up doing what I do.

CONWAY: Who were your advisors at Caltech?

FANSON: My advisor was a man named Tom [Thomas K.] Caughey in the Applied Mechanics Department. My degree from Wisconsin is engineering mechanics, and my degree from Caltech is applied mechanics. In fact, I think Building 157 at JPL has a title on it that says, "Applied Mechanics." So that was a particularly active field back in the seventies and eighties. He also did some consulting work for NASA and was connected at JPL.

What was interesting is that the Wide Field and Planetary Camera was being built at JPL at that time, which also flew on the Hubble Space Telescope. They would meet as part of the Hubble team, and the University of Wisconsin team communicated to the JPL team that I was transitioning to Caltech. I was actually offered a position on the original Wide Field and Planetary Camera team, but I chose instead to work on Galileo, which my advisor thought would be perhaps more interesting.

CONWAY: Oh, that's interesting. But you worked on the second camera after that, the Wide Field and Planetary 2 [WFPC 2] camera, didn't you?

FANSON: That's right. After the Hubble spherical aberration was discovered—who was it at JPL? So the project scientist for the second camera was John [T.] Trauger—Aden [B.] Meinel is the name I was trying to think of. Aden Meinel was working at JPL at that time, the former head of the Steward Observatory [University of Arizona], an optics expert. They quickly determined that the problem was probably in the polishing of the primary mirror for Hubble, and they quickly devised a way to correct the error by polishing the reverse of the error into mirrors in the Wide Field Camera design. It happened to be designed in a way that the image of the primary mirror of the Hubble Telescope was formed on secondary mirrors of repeater optics, and you could turn those mirrors into corrective mirrors if you polished them into the correct incorrect shape of the same magnitude but opposite sign.

But the trouble was you also needed to center very accurately the image of the Hubble primary mirror on this corrective optic or you would make the problem worse than it was to start with, and they needed to be able to steer four optical beams to get the alignment on these corrective optics, and there was no conventional way to do that. They were like 60 percent of the way already having built the second camera as a spare when they went about trying to modify it. John Trauger picked up a journal article about a new technology for solid-state actuation that could be very compact, and he called up the person who wrote the article and said, "Can you build us a mirror that we can do these minute adjustments with?"

And they said, "Sure, we could do that, but you should talk to your own guy at JPL. Jim Fanson is working with us on that technology."

So in through my office door came John Trauger, and they said, "We need this new device. Division 35 [Mechanical Systems Engineering, Fabrication and Test Division] at JPL says it's not possible to do this. Can you adapt this new technology to allow us to do this in the camera so we can fix the spherical aberration?"

And I said, "Sure, I'll volunteer to do that." So I got sort of drafted in by the science team on the Wide Field and Planetary Camera. There was an interesting dynamics there. I think I did an earlier interview for you guys on the WFPC 2 experience.

CONWAY: You might have. I know I interviewed a number of people, but it was quite a while ago. And I've done hundreds of interviews now in my career, so I don't remember everything, but I remember this story. I don't necessarily remember who told it to me. So we might have done this before.

FANSON: Yeah, I think it might have been you that interviewed me. Yes, that was a number of years ago. But that was a very interesting sort of astropolitical situation around the Hubble repair.

CONWAY: Yes. So it was interesting, [Division] 35 didn't think they could do it, so you did it instead.

FANSON: Yeah. I was actually a Division 35 employee at that point, but they went to Section 352 [Spacecraft Mechanical Engineering], which are sort of the nuts and bolts mechanisms guys, and they said, "We can't fit any kind of a mechanism in the space you guys have got available, so it's not possible." But I was in Section 354 [Engineering Research], I was in the Applied Technologies Research Group, and so Division 35 became intrigued by what it is I was setting out to do, because they had never done anything like that before. So it was an interesting experience for the division.

Now those technologies are finding their way into the chronograph imager instrument that's going to fly on the Nancy Grace Roman Space Telescope to do the exoplanet imaging, so now it's state of the art, but at that time it was new.

CONWAY: Interesting. Interesting story. So what do you do after WFPC 2?

FANSON: So after WFPC 2, I worked with Aden Meinel and John Trauger on a proposal for the advanced camera for the Hubble Space Telescope, but we were not selected to build the advanced camera. They gave that job to, I think, Johns Hopkins [University Applied Physics Laboratory].

After WFPC 2, I joined the Spitzer Space Telescope team. I was working for Larry Simmons, so I was transferred over into 7X [Astronomy & Physics Directorate] at that time. I led the design team for the Spitzer Space Telescope for what was called the warm-launch architecture, moving it onto the Delta launch vehicle from a larger rocket. We had to get the mass of the Spitzer vehicle down, what we called SIRTF at that time, the Space Infrared Telescope Facility. We had to get the mass down to fit on a Delta. Johnny [H.] Kwok came up with the idea of the trailing solar orbit, and my job was to re-architect the spacecraft around this warm-launch concept, where the telescope was outside of the cryogenic dewar instead of inside, which had been the conventional way to do things. So I led the design team for what became Spitzer through the preliminary design review and the industry team selection, and then I went off to do the GALEX mission.

CONWAY: So you leave Spitzer before launch and go to GALEX?

FANSON: Yeah. Larry Simmons was looking for a project manager for the GALEX mission that had just been selected in its Step 1 selection, and asked if I'd be interested to do it, and I said, "Sure, I'd be happy to do that," and went down to talk to the PI at Caltech, Chris [Christopher] Martin. He was agreeable for me to serve as the project manager. That would have been in late '97, and I transitioned off of Spitzer onto GALEX.

CONWAY: So you come in right at the beginning of Step 2. So tell me what's the state of the proposal at that point? What are major decisions that have been made and so forth at that time, and what still had to be done?

FANSON: So this was an interesting process by NASA. The typical process is that NASA gets all these proposals and then they do a Step 1 selection, then you do a Phase A, then they do a Step 2 selection down to the mission that they're going to fly. It was a little different this time. They had selected two small explorers in Step 1. There was GALEX and then there was Fiona [A.]

Harrison's x-ray mission [Nuclear Spectroscopic Telescope Array (NuSTAR)] which was later re-proposed, selected, and built and flown. But rather than do a Step 1 and then a Step 2, they selected GALEX as the primary mission and Fiona's mission as the backup.

NuSTAR was considered the backup, so it was like if we somehow failed Phase A, they would then go to Fiona's mission and develop that one. So I don't think they were asked to submit—I could be mistaken, but I don't think they were asked to submit a Stage 2 proposal and go through a down-select. I think it was ours to lose, and if we couldn't get our act together, they would go to the backup.

So we did a very rapid Phase A study, conceptual design review followed by a preliminary design review, a conceptual design review and a requirements review, and then looked into the preliminary design review in Phase B. So it was all very compressed over a short period of time.

CONWAY: And at that point, had the decision already been made that JPL would be building the instruments and a contractor would build the spacecraft? That's what I'm trying to get at, what are also the technical and management decisions that were made by then.

FANSON: Right. So it had already been decided that JPL would manage the project, or I should say this was a little bit nuanced and it might be of interest to you because of this transition at that time in implementation. But the small explorers at that time were the lowest-price-point competed missions for NASA, so they were very small. We're talking the total mission cost for GALEX at that time was like $50 million, including operations, so a very low cost point. It was difficult for JPL, which organized itself to be able to do flagship missions of national importance, starting with the lunar orbiter missions, and moving on to Voyager and the early Mars missions and so on. JPL typically didn't have very many missions in development at any one time, and they would move from one to the next. They organized themselves to be able to do what became very complex large-scale missions for NASA.

But when Dan [Daniel S.] Goldin came in as NASA Administrator—and he came in as NASA Administrator right around the time we were finishing WFPC 2 instrument—he was not interested in doing what he called "Battlestar Galactica" missions. He said if it were his choice, he'd cancel the Cassini mission that was in development at that time because it was just too expensive. He didn't want to do any missions at all that were greater than $500 million, and he really wanted to get "faster, better, cheaper" moving and get these smaller missions and sort of fill the sky with science missions.

So it was a challenge for JPL to be able to span the dynamic range from doing very large, complex, high-reliability Class A missions on the one hand, but still be able to do, in a competitive, efficient way, very low-cost missions that did not have the expectation on reliability and quality and so on. The Small Explorers Program, which had been going on for some time, was most accustomed to working with university-led organizations, and so the program office at the Goddard Space Flight Center [Greenbelt, Maryland] would sort of hold the hands of the university teams, supply the NASA depth and strength and oversight, and work with the university teams, but the universities could operate at a lower price point than a place like JPL.

I think that GALEX was the first of the small explorers that JPL attempted to implement, and JPL's overhead structure and just the way costs are recovered at JPL made it difficult for JPL to really be competitive at this low price point. So what was decided for GALEX, rightly or wrongly, was that the contract for GALEX would be between the Goddard Space Flight Center program office and the Caltech campus, and that JPL would be exercised from the campus through an interdivisional transfers of funds to draw upon the talent needed at JPL as an operating division of Caltech and would operate under the provisions of the prime contract with the approval of the NASA Management Office in that role. So the money that was going to JPL did not flow through the prime contract; it flowed from Goddard to Caltech campus, and then portions of funding went to JPL for project management, for parts of the instrument, for technical expertise, for mission assurance, and things like that.

The original conception was that the instrument would actually be physically built at the campus. Chris Martin, after having not had an earlier proposal for this mission selected while he was at Columbia University in New York, moved out to Caltech and joined the faculty. They gave him a laboratory and equipped it with a vacuum chamber, not a thermal vacuum chamber, but just a vacuum chamber. Chris was active in the suborbital program, launching instruments on sounding rockets, and this was his first attempt to actually get a space flight mission funded by NASA. So he made the shift to Caltech, I think, in order to be able to draw on the experience of JPL, among other things, and so the proposal was organized that way. The detectors would come from the University of California at Berkeley, some of the optics would come from the French in Marseilles [Laboratoire d'Astrophysique de Marseille], the spacecraft would be supplied by Orbital Sciences Corporation under a subcontract from the campus. So we bought the spacecraft bus from the campus.

Then I, as the project manager, moved down to the campus and I co-located with the PI and his team, and managed the project largely from the campus, although I still spent a significant fraction of my time at JPL. I was doing a shuttle between the campus and JPL quite frequently, almost on a daily basis.

So that's how it was structured in order to get the price down to be competitive for a small explorer. Or course, that created a number of challenges for us, which we can go into if you'd like.

CONWAY: Yes, please, because that is an unusual arrangement. I don't know that we've ever done that kind of thing again for a mission. It sounds managerially complex.

FANSON: I think that there might be some similarities in the way the SPHEREx [Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer] mission is being done. There might have been some similarities with how Fiona did her mission, but they probably were not done quite this way.

So the problems on the campus side is that the campus had never built and flown a spacecraft, and they had the university pricing structure and the university infrastructure, so their procurement organization was not really prepared to do the kind of thing that we were asking them to do, like we need to buy a spacecraft from Orbital Sciences Corporation and manage that and do all the cost accounting and so on. So Janester Short, who had been the financial resource manager for Spitzer or for SIRTF, I think she transferred and became an employee of the campus and co-located with me, and she did all the contract work and all of the financial administration work all in one person down there. She's a very capable individual.

We sort of stressed the infrastructure at the campus in doing the financial planning and accounting and reporting, as well as all the contract management. And, of course, it turned out that this vacuum chamber that they had provided to Chris Martin was really not adequate for testing a space flight instrument, and so much of the work that had been planned to be done at the campus had to be done in facilities at JPL.

At JPL, the challenges were a little bit different. I encountered regularly a feeling that somehow we were trying to obtain support from JPL without paying our taxes, because the money didn't come through the prime contract, so they didn't really want to recognize us as anything official that JPL was doing. So from the 7X perspective, this was a mission that was in their portfolio, they reported on it to the director on a regular basis and to the Executive Council, but when we tried to draw from the administrative support areas, I would run into priority issues, because they would say, "Well, this is a campus thing. This isn't a top priority at JPL." It was difficult to get the kind of support that I was accustomed to getting when doing a JPL mission, doing it from the campus for this very low-cost spacecraft mission. So we stressed the system at JPL as well in this model. I have to say at the end of the day, we got excellent support from JPL, but there was some grudging support in certain quarters because the money wasn't flowing through the prime contract and the overheads were not being extracted to support those areas.

CONWAY: I can understand that. So then when this was negotiated between campus and lab, did they attempt to but not succeed at ensuring some of those overheads charges were paid? I mean, it's a little strange that the laboratory would accept that.

FANSON: Yes. Well, I wasn't around when the PI put the original deal together and they submitted their initial proposal. I came in after that proposal had been selected in Step 1. The provision in the prime contract permits Caltech to make use of JPL on sort of a noninterference basis, and you can just transfer money up to JPL and you can have a charge number at JPL that you can assign to people. So it's not like some outside organization that would be trying to do work at JPL.

JPL, being a Caltech division, has a very close relationship, and this kind of mutual support is permitted. So I don't believe that there was any effort to recover overheads. We certainly could provide a charge number for direct support for people who needed to charge, but perhaps people who were typically burden-funded weren't accustomed to getting a different charge number and charging direct labor for that work, although we certainly had an account code that we could use for that and did use for that.

CONWAY: It sounds like what you were attempting to do was essentially buy certain numbers of hours from certain people whose expertise you needed.

FANSON: Right. We paid the direct charge, so we got a mission assurance manager on a part-time basis and they charged their time to an account code that was tethered to money that came from the campus, but it's a different overhead structure associated with money that comes up from the campus. It's not the full majesty of the overhead structure that's applied to things that come through the prime contract.

CONWAY: Fair. Okay, we've talked about management, management challenges. Anything else for management challenges before we go on to talking about technical challenges?

FANSON: I would say other management challenges, there were some challenges in that because our contract from the campus was with the Goddard Space Flight Center, they expected us to comply with the way the Goddard Space Flight Center does business, but because I was trying to manage this from JPL and make use of the JPL means and methods, I was trying to comply with the JPL way of doing business, and the two centers, although they do very similar work, have different ways of doing business. This actually reached a point sometime later that caused Tom [Thomas R.] Gavin, when he was assistant director at JPL, to develop a Memorandum of Understanding between JPL and the Goddard Space Flight Center that tried to clarify which rules of the road were going to be used in which circumstances.

But we were neither fish nor fowl. As far as Goddard was concerned, we were a subcontractor to them, and, yes, they saw this appendage out there called JPL, but from my perspective, I wanted to bring the JPL reliability and systems engineering and instrument knowledge, and so I wanted to let JPL do what we do well the way we do it, and there was a bit of a clash that occurred from time to time along these lines, so that was an interesting management challenge. I suspect there may still be some of that for any explorer that JPL is doing, including the SPHEREx mission, for example. They probably still have a bit of lingering tension there. But we were sort of the first example that had to face into this in this way, so it was a bit of a learning experience for us.

CONWAY: I realize, before we go on to technical challenge, we should talk about the transformation out of "faster, better, cheaper" into the design principle and flight project practices era, which happens when GALEX is being built. So talk about that transition from your perspective.

FANSON: Right. So the idea under Dan Goldin of the Explorer Program was that this would be an opportunity to experiment with more efficient ways of doing space flight missions, so it was viewed as sort of an arena to test innovative ideas and approaches, to do things at low cost. I forget what classification we had for GALEX, but we were like a Class C or a Class D type of implementation, and that's how it was priced and that's how we organized, and that's how we were working at that time, taking advantage of the experience of people to help us know what can we get away with not doing and not paying for, and still get a reasonable confidence level for success.

When the Mars '98 failures occurred, we were already pretty far along in the implementation. There was another explorer mission, a MIDEX, a Medium-Class Explorer called the Far Ultraviolet Spectroscopic Explorer, or the FUSE mission, and they were actually getting very close to launch at the time that this transition occurred. So it was really a scramble on the part of NASA to figure out how we look at everything the agency is doing right now and try to buy the risk down, compared to what these missions were accepting at the time of the Mars '98 failures.

So NASA instituted a series of reviews. They organized sort of—I forget what they called them, but they were like Red Team Review Committees that we then had to present to and explain what our risk posture was, what our implementation assumptions were, and let them, these review committees, absorb that, and then they would make recommendations for what we could do, what the agency could do to buy the risk down. I remember the FUSE team telling us that they had spent a half a million dollars just going through the review process to buy down the risk, just to support that review process. We didn't keep track of how much we spent going through our reviews, but one of the realities is that it's very difficult to buy the risk down late in the game because you've already built the risk in at some point.

So we were allowed an additional budget funding increment based on an assessment of things that we could do that would increase the reliability and the quality for GALEX, not to make it a Class A mission, but in areas that they thought maybe we were taking undue risk, we would try to mitigate those risks and we were allowed additional resources to accomplish that.

CONWAY: So then what were perceived at that point to be the remaining technical risks that needed reduced?

FANSON: The technical risks that we needed to reduce?

CONWAY: Right. You were just saying that you got an increment of money for risk reduction late in the game, so what was it that the red team thought you needed to do?

FANSON: So that's an interesting question. I don't recall off the top of my head what those items were. I have extensive files from that mission. I might be able to pull out the report from that group, if you're interested in that. I could make an effort to track that down.

But what I have to say is that there's kind of a game that is played with these competed missions, and I think NASA has improved in the interval, over time, but NASA has this "no overrun" policy where once the budget is set, after the preliminary design review, they require that you identify descopes that can be taken in an effort to try to prevent the cap from being exceeded. And if you exceed the cap, you're supposed to have a termination review to determine whether you're going to continue to fund it and complete it and fly it, or whether you're going to terminate the mission. In practice, there were very few examples of NASA actually terminating missions. NASA has the organization and the budget structure to allow them to handle cost growth to a degree if it's necessary.

But the incentives at the time GALEX was selected were for PIs to propose very ambitious missions that often involved cutting-edge or advancing the state of the art. NASA has clamped down on that much harder with the technical readiness levels that they require to control risk like that, but back in this era, that was not so aggressively managed. So GALEX had a number of very advanced technologies, so we were running significant technical risk, and when the mission was confirmed after preliminary design review, we carried something like a 5-million-dollar reserve, 10 percent reserve, which is sort of an absurd level of reserve. Why NASA would have confirmed us with a 10 percent reserve, I don't understand.

The incentive was to propose something very ambitious, which caused PIs to make some rather self-serving or optimistic success-oriented assumptions, and then the project manager comes along and has to try to deliver that when it really is going to take more resources to complete it. So we were very much in that mode with GALEX. Looking back, as I said, I'm a little surprised they confirmed the mission with that much risk and that lower contingency, but, again, it was the "faster, better, cheaper" era.

We had no doubt any number of risk areas that the Red Team recommended be reduced, I think particularly in the area of electronic parts and in reliability analyses. Some of the failures that occurred—I should say that GALEX was not the very first small explorer that JPL was involved in. JPL was involved in the WIRE, Wide Field Infrared Explorer. WIRE suffered a catastrophic failure on launch that was with the result of an architectural deficiency in how the pyrotechnic electronics was designed—the arming and firing of the pyrotechnic cover on WIRE was controlled in a field programmable gate array, and the JPL rules are that you separate the arming and firing circuits. And apparently the supplier of this particular part of the WIRE spacecraft didn't appreciate that when you apply power to a field programmable gate array, it can come up in an indeterminate state for a period of time, and this resulted in the premature arming and firing of the cover on WIRE when it was powered up during the launch ascent, and they lost the mission as a result of that. So JPL had some bad experience before GALEX.

So that's why what I said earlier, I was trying to apply the methods and the rigor of JPL in a selective way so that we could avoid those kinds of problems, but that was the kind of thing that the red team review was looking for. Are they doing the appropriate analyses? Are they reviewing the data? Are they investing in reliable parts? So they reviewed us, they gave us recommendations, and we made some adjustments.

CONWAY: What would you say were the major technical challenges you had? You mentioned you had some very advanced components, for example. What did you see as the major technical challenges during development?

FANSON: Well, our detectors were very challenging; we were operating in the ultraviolet part of the spectrum, which is very demanding from a cleanliness perspective. In the ultraviolet you encounter sort of the minimum contamination thicknesses you can tolerate before too many photons of light are absorbed, so the absorption thickness sort of reaches a minimum in the ultraviolet; you can't afford to have any condensable volatiles deposited on optics, so everything has to be clean and prebaked. You need a pretty rigorous contamination control program. So we knew that was going to be technical challenge.

Our detectors were photon-counting detectors, so the arrival of every photon was timed, geolocated on the detector, and the characteristics of the photon that arrived were measured. Of course, many photons are arriving in an avalanche, and we needed very fast electronics to be able to do that. But we had a wide field of view because we were going to do an all-sky survey on GALEX, so we needed physically the largest photon-counting ultraviolet detectors that had ever been built, and they needed to run as the fastest. We had to have the photon-counting rate of the fastest that anything had ever been built on a physical scale that was the biggest of any ultraviolet detector that had ever been built. So this is where I caution people that when you take an existing technology that you've made work on a certain scale and you want to scale it up to something larger, you have to be very careful because the scaling comes with its own risks. We can talk about the challenges we had building the detectors at Berkeley, but we knew we were asking for something that had not been done before. So the detectors were a challenge.

We also needed pretty good pointing stability, or at least smoothness of the motion of the spacecraft line of sight so that we could get the kind of imaging resolution we were looking for. Because we had photon-counting detectors, we reconstructed the images on the ground by determining where the spacecraft was pointed at any given instant and then mapping the arrival of the photons relative to each other, even though the spacecraft line of sight was moving. But it had to move in a very smooth manner, so we needed very good gyroscopes on the spacecraft, and we knew that was going to be a challenge.

Then we had a very high data rate because we're sending back data on every single photon that's arriving. So typically the way you would get data down from a satellite like that would be the S-band part of the spectrum, but that didn't provide enough data rate, so we had to go to the X-band spectrum. There were not very many X-band transmitters available at that time. There were not very many X-band ground stations available at that time. So the mission architecture was arranged around using a venture capital startup company called Universal Space Networks. It was founded by Pete [Charles P.] Conrad, one of the Apollo astronauts. I should say we moved to Universal Space Networks. The original concept was that the University of Puerto Rico would build an X-band ground station and we would get our data down from the ground station at Puerto Rico, but we soon discovered that if a hurricane came across Puerto Rico and blew out the antenna there, how else are we going to get the data down? So I think one of the changes we made to improve the reliability was to move to Universal Space Networks. Still a risk, because they hadn't actually built all their ground stations yet, so we knew getting the data down was going to be a bit of a challenge.

We flew a half-meter-aperture telescope, which may sound small, but at the small explorer scale, building a half-meter optical telescope that would work at the ultraviolet was also viewed as a technical challenge, and indeed it turned out to be a technical challenge. As events unfolded, we basically had difficulty beyond our expectations in every one of these areas, so it was quite a learning experience to develop the GALEX spacecraft.

CONWAY: So you went in knowing you had a number of challenges, and those came true. Were there challenges that you didn't expect that came up?

FANSON: There were challenges that we didn't expect, and let me give you a couple of examples. I told you that we needed good quality gyroscopes for the mission, and so the spacecraft supplier, Orbital Sciences Corporation, had baselined ring-laser gyroscopes from a manufacturer, and fairly late in the game, the manufacturer began to experience failures of their product on other spacecraft, and their reaction was to say, "We no longer certify these for use in a space environment, except for very short durations on launch vehicles."

So now we're facing a supplier that will no longer stand behind their product for the application for which it's intended on our mission, and there were no other gyros available that we could contemplate that would have the performance that we were looking for, so we started dumpster diving for gyros. We discovered that the serial number 1 Hemispherical Resonator Gyro [Gyroscope, HRG] that was developed for the Cassini mission—that was sort of their development unit—was still in bonded storage somewhere, but it involved quartz crystal resonators that were filled with helium gas—I think with helium gas—and once that gas diffuses out, they become contaminated. So the unit would have to be refurbished.

Now we're trying to figure out how do we take this gold-standard gyro developed for Cassini, get it refurbished, get the electronic interface changed so that we can somehow mount it on the spacecraft as the primary gyro, then we'll put these ring laser gyros in as backup if we have to use them in flight and take lower performance, we'll do that.

So I remember at this time I was working for Gary [L.] Parker. I forget how GALEX wound up in Gary Parker's directorate, but Gary was a private pilot. And turns out the hemispherical resonant gyro was built by Litton [Guidance and Control Systems] out in Goleta [California]. He was a pilot, so we climbed in his private plane, which we were not supposed to do, and flew out to Santa Barbara and drove over to Litton, and they said, "Yeah, we can take this apart and refurbish it and test it and get it back to you on the time scale that you need." So we actually flew a Cassini-class gyro on this small explorer GALEX mission in order to get the performance that we needed. So that was one example. We didn't expect that to happen.

Another example had to do with the X-band transceiver. In order to save cost, the spacecraft supplier had sourced their X-band equipment from—I'm trying to remember the name of the company in England. They had gotten far enough along that they had built the hardware and were in the final stages of tuning the RF [radio frequency] electronics when the company went bankrupt. We got a call, and they said, "We've got your almost-finished hardware here. If you want to make a final payment and come and pick it up, we'll meet you at the loading dock."

So Orbital Sciences Corporation flew to Britain and picked up the unit and brought it back to the United States, but in consulting the experts at JPL and elsewhere, it became clear that you really needed to have the designer do the tuning of the RF equipment. That's not something that a Division 33 [Telecommunications] was willing to do at JPL. They couldn't guarantee any kind of an outcome for that.

So we tracked down the designer in England, who was now working for a different company because the company he had been working with went bankrupt, and his new employer was not really keen to allow him to come and work for us. Well, they were not willing for us to ship the unit to them. We got into a very tight corner from export control, so it turned out that once we had taken delivery of the unit, once we had brought the unit back into the United States, we were not permitted to export it to have the original designer do the tuning work in it, because we didn't have an export license for this hardware that we had just imported. So the only thing we could think of was, well, maybe we can bring the designer into the United States to do the tuning, but he couldn't bring any equipment with him, so it would be an ITAR [International Traffic in Arms Regulations] violation to assist him to do any work on the unit.

So Orbital Sciences Corporation found a laboratory or a room in a building that was under construction, that didn't have anybody in it, they set up a table, they gave him a soldering iron and an oscilloscope, they had their export control officer stand there and their security person stand there, and said, "All right, go and tune the circuits on this unit, and we're not giving you any technical assistance." And, of course, the designer was not a flight technician and he was not able to do this tuning work on the electronics and result in a flight-quality piece of hardware. So our X-band transponder became a doorstop at that point.

Now we're searching for where can we get an X-band piece of radio equipment. This was very late in the game. And that's when we realized that there was a satellite sitting at the Goddard Space Flight Center that was originally called GoreSat. This was the Triana that [Vice President] Al Gore wanted to fly [later became Deep Space Climate Observatory (DSCOVR)]. And because the Republicans were in control of politics at that point in Washington, I think this mission was sort of grounded, even though they had built the spacecraft. I think they had another technical problem with the instrument. I think that was the issue. It was not a political problem; it was a technical problem.

So they had a spacecraft there that didn't have anything to do while they fixed this problem on the science payload side of Triana. So we went in saying, "Can we take your X-band transceiver? We'll replace it for you at some later time." Well, they were not really keen to do that, but here's where the Goddard Space Flight Center became very helpful. They managed to get us the X-band equipment. So we did surgery on the Triana spacecraft and boosted their X-band transceiver and put it on GALEX, paid them to build another one for their own spacecraft.

There were a lot of things like that that happened on GALEX that had never happened on any other mission that I've worked on, that were completely unexpected.

CONWAY: It sounds like somewhat of an unusually challenging development, though not because of anything that specifically went wrong, I guess, but because you had contractor issues.

FANSON: Yes. Another thing that happened that was a bolt from the blue, Orbital Sciences Corporation had also built the spacecraft bus for the FUSE mission, the Far Ultraviolet Spectroscopic Explorer, and they had just finished that spacecraft bus. They had their own facilities. They were located in Germantown, Maryland. They were formerly in Fairchild, then they became part of Orbital Sciences Corporation.

They had a thermal vacuum chamber that dated back to the 1960s, and they would do what we call in-process backout. So they'd put the spacecraft hardware in the vacuum chamber, heat it up, drive off all the condensable volatiles that can be very harmful in the ultraviolet, and they'd just successfully done that for the FUSE spacecraft. And they took the GALEX spacecraft and they put it in the same chamber and they were doing the same in-process bakeout, but a malfunction occurred. They had an old-fashioned diffusion pump pulling the vacuum on of the vacuum chamber, and they wound up accidentally back streaming diffusion pump oil into the vacuum chamber and depositing it completely on and inside the spacecraft bus.

Now we're faced with, well, what do we do? We've got this diffusion pump oil. It's silicone diffusion pump oil, which is a really bad actor. In the end, we decided we have to clean the spacecraft bus. So Orbital took it all apart, and we developed a cleaning solution, sort of a degreasing cleaning solution, to clean the oil off of everything on the spacecraft, including the wire harness, and then bake out the wire harnesses separately to clean them up. We wound up shipping some of the wire harness from Maryland to JPL to use JPL vacuum chambers in parallel with vacuum chambers at Goddard, I think, to get all the wire harnesses cleaned and baked out. So that was an unexpected malfunction in their vacuum chamber that had a big impact on us.

CONWAY: That has to have taken a lot of your schedule time.

FANSON: I think it took six months, basically, to recover from that, yes.

CONWAY: So did you launch in the original schedule or were you delayed? That's a big time loss.

FANSON: Yes. We were delayed quite a bit. Personally, having left the Spitzer project in between preliminary design review and critical design review, and then starting at the beginning on GALEX, I was in a personal race to see if I could beat Spitzer off the launchpad. So we wound up being down at the Cape [Canaveral, Florida] at the same time, and there were periods of time where we were going to launch first, then Spitzer was going to launch first, and then I forget which Mars mission was launching.

CONWAY: In 2001?

FANSON: 2003, I think it was.

CONWAY: The MERs [Mars Exploration Rover missions]. Both MERs were launched in '03, landed in '04.

FANSON: That's right. So those were there as well. It was launch vehicle jockeying around, who was going to launch first. In the end, we did launch before Spitzer did, because there was an issue discovered in the nozzles on some of the strap-on boosters on the delta rocket that Spitzer was going to launch on, and they decided to take them off and replace those rocket motors. So we wound up launching before Spitzer on the Pegasus winged rocket.

CONWAY: So that flew—I'm always confusing GALEX with the launch campaign that was in Kwajalein [Atoll, Marshall Islands]. There was also an orbital. That was a different mission.

FANSON: So we were the first mission that integrated to the Pegasus rocket at the Kennedy Space Center. The typical program was to integrate at Vandenberg [Air Force Base], and then they would ferry to wherever they were going to launch, then they would launch it from that point. So they would integrate it at Vandenberg, then fly to Kwajalein or integrate at Vandenberg and then fly to Kennedy and launch it. We wanted to integrate at Kennedy. When you're integrating to a solid rocket, which the Pegasus is, it's a hazardous process, so they had to find a payload hazardous processing facility, which they dedicate for us, and they wheeled the Pegasus rocket in there and we integrated at Kennedy. So that was the first time that was done. It was an interesting experience to do that.

CONWAY: Who were the other major players on the GALEX project? We've mentioned Chris Martin, but who else?

FANSON: Well, Ozzie [Oswald] Siegmund at the University of California, Berkeley, at their Space [Sciences] Laboratory. They delivered the detectors and the associated electronics. There were a lot of failures of power supplies back in that time frame, and so we cannibalized power supplies that were the spares for the university detectors that were on an instrument on the SOHO [Solar and Heliospheric Observatory] mission, the European Space Agency mission that had been built, I want to say by Steve [Steven J.] Battel.

But, anyway, Goddard basically GFEd (Government Furnished Equipment) those to us and said, "Here, use these." So that was part of the deliverable ultimately from University of California.

We had scientists in France at the astronomy laboratory in Marseilles. They changed their name during the course of the mission, I think. But they delivered—so here's another unexpected thing that happened. So GALEX flew two cameras. There was a Far Ultraviolet Camera and a Near Ultraviolet Camera, and the conventional way of splitting the light is to build what's called a dichroic. A dichroic is like a beam splitter that has a very special multilayer coating on it that reflects light that's shorter of a certain wavelength and transmits light that's longer than a certain wavelength. So you can split the beam into two spectral ranges by placing this dichroic in the beam. Because we were doing a spectroscopic type of mission, our beam splitter was a grism, so it was both a grating and a prism; it had a ruled grating in this piece of calcium fluoride, which I think was calcium fluoride, not magnesium fluoride. I can't remember which it was, but it was a UV [ultraviolet] transparent material, so that the longer UV wavelengths would transmit through it. Then the coating would reflect the shorter wavelengths.

This was a very, very advanced technology optic. There was really only one place that we knew of in the world that could make it, and that was going to be supplied by the French and it was going to be manufactured—the ruling was going to be done by a company in Paris that was located in an address that was on Rue du Canal. So it turns out their factory was right next to a canal that ran through Paris, and their ruling engines are in the basement of the building bolted to bedrock to make them extremely stable for the ruling of these gratings.

They were midway through manufacturing our grism when the storm of the century, basically a hurricane, passed over Paris, and everything flooded in Paris. The canal overflowed, it flooded the basement of this building, it submerged the ruling engine and our optic underwater, and so we had to recover from that as well. We had a weather event that we hadn't predicted that hit Paris and affected us.

CONWAY: Heavens. Were you able to use the same optic after cleaning it, or was it ruined?

FANSON: I think it was ruined. I think we built a second one. I think we had a spare substrate, and I think they ruled the spare substrate after that, but it took them some time to recover. They had to get their laboratory dried out and they had to get their ruling engines up and running again. So all of these things conspired to stretch our schedule out quite a bit from what it had originally been.

CONWAY: Understandable. What else would you say about GALEX before we talk about Kepler, if we have time? If we don't have time, we can do this again.

FANSON: Yes, we can do another time if you need to come back later. So I would say that with all the trials and tribulations that we faced on GALEX, we maintained a good esprit de corps, we had a good working relationship with Goddard Space Flight Center, we had a good working relationship with the Jet Propulsion Laboratory. In the end, we pulled it all together and the mission was a tremendous success.

Just like every other telescope mission that I've worked on, when you look at the heavens with a new tool in a new way, you see things that you had not even anticipated that you might see, and so we knew that GALEX would produce these beautiful images. I think I emailed you the image of the Andromeda galaxy that we'd taken with GALEX. But because we were measuring individual photons that were arriving, we had exquisite timing, so we could do interesting photometry, so we could measure very rapidly-changing brightness in objects, so things like novas and what sort of the gravity wave people are measuring in the gravity wave space, we were able to make some discoveries about objects that had been speculated about, but for which there was no very precise timing data.

Quite by accident, when the scientists were looking at the data for an observation one day, they found a curious feature in the corner of the image. They took some additional data of the star Mira, which is one of the stars that's been studied for the longest in human history, and discovered that streaming behind Mira was this long, spectacular tail that was showing up in the ultraviolet. There was this huge streaming tail with a shockwave out in front of Mira. Mira's plowing through the interstellar medium at high speed, and the outer layers of the star being shed as it ages, and so there's this beautiful shock front and its glowing tail behind Mira that nobody had ever seen before. So it was just a spectacular success, even though it was done for this very low budget, so it was really gratifying.

CONWAY: You got a feeling of accomplishment out of that, it sounds like.

FANSON: Yes, it was glorious. One of the things that you do when you're at the very low price point, we didn't have a budget for a focus mechanism for the telescope, and so you're always wondering did you get it right when you aligned it and tested it, and has it been disrupted from the launch experience and all the gravity release when you go to zero gravity in space. So we were all wondering, when we got the first image down, was it going to be in focus. And it was gratifying that it was in focus, because we couldn't adjust it. So it all worked out very well.

CONWAY: It sounds like you'd rate it as a good experience. Where do you go next?

FANSON: After GALEX?

CONWAY: Yes.

FANSON: After GALEX, I was asked to manage the Keck Interferometer, which was a technology experiment. It started out as a technology experiment for NASA. I came in years into the development of it, to get it finished and get first fringes and start doing exoplanet science to characterize the habitable zones around nearby stars and see how much dust is out there so you would know how to design exoplanet imaging missions. So we were linking the two 10-meter telescopes together, Keck telescopes together on the top of Mauna Kea [Hawaii] , and wanting to add outrigger telescopes so we could do synthetic aperture imaging. In addition to just the two 10-meter telescopes we could do two-dimensional imaging.

This is when we encountered the opposition in Hawaii of the Native Hawaiian groups who were opposed to further development. In fact, they were opposed to the existing development on the top of Mauna Kea, so NASA decided to do a full Environmental Impact Statement for Mauna Kea, the first that had ever been done, looking backward to the first telescope that was put on Mauna Kea and looking forward to anticipate the 30-meter telescope, which is still struggling with those same issues. So it was interesting to do the full Environmental Impact Statement and do the public scoping meetings and listen to the arguments of the varied Native Hawaiian groups that were opposed to what we were doing. In the end, NASA decided not to pursue the outrigger telescopes, but we did get the two 10-meters linked and were able to do exoplanet science from that perspective.

CONWAY: And I thought the outriggers were built and stored. Were they ever put to use?

FANSON: I believe that the outrigger telescopes, one of them was in use in Australia. I think they were using it for space situational awareness. But I think all the outrigger telescopes ultimately were donated to the Navy and are out at the naval interferometer in New Mexico, I believe.

CONWAY: That's what I thought too. I thought they had gone there. Then after the Keck interferometer, what's next for you?

FANSON: So after the Keck interferometer, I think after the Keck interferometer must have been the Kepler mission.

CONWAY: Timing's about right, because you would have finished GALEX in 2003 and then gone on to Keck for probably two or three years.

FANSON: Right. So I think Kepler came next. Kepler was another really fascinating astropolitical situation.

CONWAY: So what stage was the mission when you come into it? I know it had a couple of different project managers.

FANSON: Right. So they basically had, I think, done their critical design review. I didn't know we were going to talk about Kepler, so I haven't boned up on Kepler.

CONWAY: Okay. We can stop and pick another session if that's better for you.

FANSON: Yes, that might be better. I can refresh my memory and give you better information on Kepler. But I believe that they had just finished their critical design review, but they were hemorrhaging money and they were clearly going to run out of money on Kepler, and this was triggering a reaction from NASA, so JPL organized sort of a landing party to descend on them. So let's say Gentry Lee, me, a couple of others reviewed them in detail, and then it was decided that Leslie Livesay would become the project manager, I would become the deputy. Later I became the project manager when we were getting closer to launch. But that was a near-death experience for the Kepler mission.

CONWAY: Okay, so let's talk about that some other time.

FANSON: Sounds good, Erik. Thank you.

CONWAY: Thank you for your time. It's been great.

FANSON: Always a pleasure to talk to historians. I'm an amateur historian myself, so—

CONWAY: Well, thanks, thanks. It's great. Take care. See you soon.

FANSON: Bye-bye.

CONWAY: Bye.

[End of interview]