HUBBLE SPACE TELESCOPE OPERATIONAL ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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The questions in this transcript were asked during an oral history session with Thomas Ayers. The text has been amended for clarification and for publication on this website.

GAINOR: So, it's September 23rd today, 2015, and I'm at the University of Colorado in Boulder with Dr. Tom Ayres who is going to tell me about his work on Hubble [Space Telescope, HST].

AYRES: What little I can remember, owing to encroaching senility.

GAINOR: [laughs] Right. I know that sometimes I think I could hide my own Easter eggs. Maybe you should just start off by telling me generally about the type of work you do, and then, I imagine you were well along with that when Hubble finally got going, and then we can get into that.

AYRES: That's certainly correct. My main area of interest is in stars: cool stars that are much like the Sun, in many cases; and in some extreme cases, quite a bit different from the Sun.

I started out in the business back in the days of the International Ultraviolet Explorer [IUE]. I did my thesis work supported by pre-launch money provided from IUE, and my advisor at the time was Jeff [Jeffrey L.] Linsky, who is another big Hubble person.

GAINOR: Who I spoke to Thursday, I think.

AYRES: Nice.

GAINOR: Thursday or Friday.

AYRES: Yeah, Jeff was my thesis advisor, and together we were on the commissioning team of the IUE satellite. In fact, he and I took the very first scientific observations during the commissioning of IUE, when I was a post doc. (I had finished my thesis by that time.) So, the IUE satellite ran for many years, for decades after that. It was very successful. It did ultraviolet spectroscopy, of relatively bright objects, and at relatively high spectral resolution for the day, considering it was one of the very early NASA satellites. And it also pioneered the idea of having a Guest Investigator Program. And all these things, high resolution, UV [ultraviolet] spectroscopy, Guest Investigator Programs later became a major part of Hubble, and so that's why I mention it.

I worked for many years on this IUE satellite, many programs. There were lots of papers based on IUE data, and so when the idea of Hubble came along, many of us were pretty excited, because it was going to do much, much better than IUE, using certainly a larger telescope, but more importantly, state of the art instruments (state of the art at the time, of course) using much better detectors. IUE had, basically, relatively primitive TV cameras, although they worked reasonably well, and for 17 years, until the satellite was eventually turned off [about 7 years after the launch of Hubble].

GAINOR: Correct.

AYRES: Which is amazing. But Hubble was going to have these fancy, new, electronic detectors, and we were all really excited about that. Having dealt with all the cosmetics and the vagaries of IUE data, there were a lot of things that one had to be very careful about to tease any useful information out of the IUE spectra. Although it was really transformative in that day. So, we all were really looking forward to Hubble, and its fabulous detectors, and to be able to get high resolution spectra of all our favorite stars on which we had done a lot of preliminary work with IUE. It was quite an exciting time, back in the '80s, when this possibility of a Hubble was coming to fruition.

And I got involved in the earliest years of Space Telescope when, thanks to some prodding by Jeff, I put together a small team to write one of the initial proposals to Hubble. It was called, "Sleuthing the Dynamo," of all things. Unfortunately, many of my titles are kind of mixed metaphors. But in any event the basic idea was to observe sunlike stars in young open clusters. Open clusters are groups of stars that have recently formed, and it's possible to age-date these clusters pretty accurately, and so you know the age of these sunlike stars in the clusters. Then, these clusters vary in age from older ones, as much as 600 million years old (still quite young compared with the Sun), to the very youngest ones, which are around 50 million years old (and there are actually even younger ones, but then you get into the realm of pre-main sequence stars).

In any event, we were interested in the evolution of solar-like magnetic activity, which is generated by a "dynamo" process deep inside the star. This surface activity is what produces all the ultraviolet and X-ray emission from these young stars. We were interested in the evolution of the activity over time, and, for example, the influence of enhanced UV radiation and X-rays, and a perhaps stronger solar wind as well, on developing planetary systems around these young stars, including the early history of our own Solar System. For example, it's thought that Mars had much of its atmosphere blasted away by a young and unruly Sun. It turns out that stars are much more active in their youth. The dynamo-inspired magnetic activity depends on how fast a star is rotating, and stars start out their lives very fast, thanks to spin-up by the collapsing gas cloud from which the star is born. But then they lose their spin over time, due to shedding of angular momentum in their coronal winds that are magnetically tied back to the surface of the star and drag on the stellar rotation.

So we were very interested in this whole prospect of being able to measure ultraviolet and X-ray emissions from these young sunlike objects using Hubble to get the ultraviolet part and what was then a relatively new X-ray satellite called ROSAT [Roentgen Satellite, a cooperative program between the Germany, the United States, and the United Kingdom.] to get the X-ray part. So, I banded together a group of whatever colleagues I could scrape up to cobble together a proposal to observe something like 15 solar-like stars in three young clusters, five in each, with Hubble. We submitted that proposal in year one, and by some miracle it turned out to be successful. However, there was quite a hiatus, because the [Space Shuttle] *Challenger* [STS-51L] tragedy in 1986 seriously delayed the launch of Hubble, and so it was a number of years before we were actually able to carry out the observations. Our project utilized the low-resolution far-UV grating of GHRS [Goddard High Resolution Spectrograph], and it's very sensitive Digicon camera, to measure important emission-line spectra in the solar-type cluster stars. And then, after HST was finally launched in 1990, and we were all set to go, the Side 1 electronics of GHRS failed, because of a bad power supply, and the low-resolution channel we were going to use was crippled as a result. So almost immediately our project kind of ground to a halt. Thankfully, the folks at Space Telescope [Science Institute] let us change our program to the other Hubble UV instrument, the Faint Object Spectrograph [FOS].

Unfortunately FOS had problems observing solar-type, relatively cool objects, because its cameras were susceptible to long wavelength scattered light. This overwhelms the faint far-UV emissions. The "solar-blind" GHRS Digicons were immune to this effect, which is why my team originally selected that instrument for our project. FOS was designed specifically to look at flat spectrum quasars, very distant objects that had non-solar spectra. So, it was not the optimum instrument for our purposes. But nevertheless, we went ahead and took the Sleuthing observations with FOS, and they ended up being quite illuminating, after all.

We had arranged the FOS orbits on these young solar-type stars in a series of short exposures, and practically every object we looked at displayed intermittent bursts of energy, which are called flares on the Sun, during each observation. They'd have these sort of impulsive, short bursts in the highly ionized carbon and silicon emissions [C IV and Si IV, both three-times ionized] that were in our observing bandpass. And this was quite an unexpected behavior. Nowadays we recognize that these young sunlike stars are basically just flaring all the time. In fact, these frequent high-energy outbursts create a rather hostile environment around these very young stars, for any planets that might be orbiting there. And it was also quite illuminating as to how the activity on these objects actually works: it just is completely dominated by flares all the time. Even the "quiescent" level of the stars is a superposition of a blizzard of low-level flares.

So we had tremendous insight into the operation of this magnetic activity on the young solar-type stars. And this research thread has continued to the present day, with Hubble and its ever more sophisticated spectrographs and cameras and particularly now the Cosmic Origins Spectrograph [COS], which in some ways is analogous to the Faint Object Spectrograph of the first instrument complement, but is hugely more sensitive, and plus it has actual spectral resolution, whereas the original FOS had really terrible resolution. But, again, FOS wasn't designed to do the particular project I had wanted to do back in the day.

GAINOR: Did you work with STIS [Space Telescope Imaging Spectrograph] when it came in?

AYRES: Absolutely! So STIS was, for everybody who had worked on IUE, going to be their favorite instrument, because it was in many respects quite familiar to us. To explain this, I need to step back. When we started using GHRS for the high-resolution channels not affected by the Side 1 failure, it in some respects was a step backward from IUE. Instead of having a panoramic 2D [dimensional] camera like IUE had, which could record a whole spectrum of many Echelle orders (if you're familiar with how the Echelle spectrum is set up), the GHRS Digicons were 1D linear arrays that could capture only a short piece of the spectrum in a single exposure. So IUE was able to observe basically an entire spectrum of an object in the far ultraviolet, for example, with a single exposure, because it could put the 30 or so Echelle orders, neatly stacked on top of one another, on its 2D detector all at once.

GHRS, on the other hand, made it very difficult to explore, say, the whole spectrum of a given object, because you could only record the spectrum in snapshots, small little chunks. To build up an entire spectrum was extremely laborious and required a lot of precious HST time, which the TAC [Telescope Allocation Committee] was almost always unwilling to provide. Thus, although GHRS was extremely sensitive and had much higher resolution than IUE, in that one aspect of not being able to capture the whole stellar spectrum, GHRS was really kind of a disappointment to many of us. Although of course we all ended up doing a lot of really good science with it.

And then STIS came along. STIS basically sort of harkened back to the IUE design by having a compact Echelle with a two-dimensional detector. The difference was—thanks to Bruce Woodgate, a great, great instrument designer who designed STIS—the marriage of a very efficient, though actually quite complex, multi-mode Echelle design with these extremely sensitive, very high-quality MAMA [Multi-Anode Microchannel Array] detectors, which were built over here at Ball [Aerospace & Technologies Corporation]. And these MAMA cameras are absolutely amazing. Nothing really like them has flown since. The latest generations of detectors in some respects are more sensitive, but they lack certain important characteristics of the MAMA detectors. The main one is that the MAMAs have physical pixels, so the photons always end up in specific locations [pixels] on the detector, and those pixels aren't wandering around. In the more modern detectors, such as are used in COS, on the other hand, the charge clouds produced in the gain stage of the detector basically are located by centroiding, rather than being collected in a specific pixel. There are a lot of details.

It's fixed pattern noise, and things like that, that's not always being sampled uniformly by the new cameras, and this also was the case for the IUE TV-type cameras, where the dynamic pixels were always kind of moving around because of stray magnetic fields in the instrument housing. So STIS was really a tremendous advance in that regard: solid-state detectors with addressable physical pixels. STIS also had something else that was pioneered by IUE: platinum arc lamps to provide extremely precise wavelength calibrations. I've done a lot of work with STIS, and I've got to tell you, that it's just an absolutely beautiful instrument. I mean, the characteristics of it are just so good that you can easily go back and recalibrate the data and do even much better than the specs, and much better than the routine data that's produced by the normal pipeline, which nevertheless still is quite good. But Bruce, bless his heart, designed a really good instrument, very sensitive, great resolution, perfect for bright object spectroscopy.

So STIS was the second generation of UV spectrographs on Hubble, installed in '97. After that, STIS became a real workhorse for UV astronomy, mainly for UV stellar astronomy, I should say. And even for looking at relatively faint objects, with a low-resolution channel paralleling what GHRS had; extremely useful for looking at distant quasars, and that sort of thing.

So I've had several dozen programs with STIS, and in the last few years, what I've been trying to do, basically, is carry out what I would call the "no regrets" policy, which is someday HST won't be around anymore, and it'll be a long time before we have any instruments that are at all comparable, so what observations would we really regret not having in the archive, in that future day? We have an ability to collect these data right now and should be doing so. What would we really regret not having? And, actually, I wrote a proposal with that title back in 2004, just before STIS failed, and it was basically to build up these sort of specialized observations for the archive so that they could then be analyzed by future generations of spectroscopists. But if you don't get the data, you'll never have the possibility of carrying out the analysis. Unfortunately, then STIS failed in 2004, so the "no regrets" really became sort of prophetic.

GAINOR: You didn't get to make many of them?

AYRES: I didn't get to make any of them.

GAINOR: Oh, okay.

AYRES: And so STIS failed in 2004. However, miraculously, it was revived in 2009—you know the whole story—it's unbelievable, because Story Musgrave had to remove all the machine screws in the cover of STIS.

GAINOR: It was somebody else by then, Mike [Michael J.] Massimino.

AYRES: Oh, I'm sorry, it was Massimino, yeah. Yeah, Story was early, that's right. But Massimino had to remove all those machine screws, and you know whenever you do anything like that, you get to the 105th one, and it strips out. So Massimino actually had to break off a handhold on the STIS casing, in order to put on that cover that the screws were captured in after he removed them. But that was absolutely a miraculous recovery. So after that, I got together with some folks and we decided to really press hard on this "no regrets" philosophy. We proposed a program several years ago to create full coverage UV spectral atlases of bright cool stars, things like Betelgeuse and Procyon, objects with vaguely unpronounceable names, all sorts of alphas and betas and a few gammas thrown in, but all bright stars.

Our program was approved, a large project with 146 orbits [Advanced Special Library, ASTRAL], and we carried it out in Cycle 18, which was pretty much just a couple years after STIS was revived. And two years after that, or actually almost three years later, in Cycle 21, I got together with another cast of characters (some were the same as in the earlier project) to do the same thing, but this time for early-type stars, so-called hot stars. And that project, ASTRAL-II, as well, was approved, this time for 260 orbits. It was the largest Guest Observer project in Cycle 21, and was completed this past January [2015], so I've been working very diligently processing that data and getting it onto the ASTRAL Project website, for my collaborators, and others, to analyze, and that's been on-going.

So for me, personally, that was really exciting, because I was able, finally, after all those years (I mean, 2004 seems a long time ago), to go after those objects that I thought were really important—for my own personal, selfish, scientific analysis reasons, but also for posterity's sake—to get them into the archive, where they would be available for future analysis. So, my objective the last five years since the Servicing Mission 4 has been to get as many observations as possible in the ultraviolet with Hubble, and I hope to continue doing so in the future for as long as Hubble is operating.

GAINOR: That's right.

AYRES: And I can sit back and analyze these data and write all the papers some other day, but getting the data right now is the key thing.

GAINOR: People have been accommodating for that, I hope?

AYRES: Well, yeah. We've been fortunate. I think in the early years of Hubble, it was really difficult to get stellar observations approved, because everyone was talking about the edge of the universe and quasars and active galactic nuclei, and the Cosmic Web, and supernovae, and not only the expansion of the universe, but also its acceleration. All that sort of stuff. And I think the way the TAC review panels were constituted was, in some respects, biased against what some of the folks considered to be rather pedestrian science. "We already know everything about stars." That sort of thing.

However, for those of us in the trenches, the one lesson the Sun has taught us—we have this array of fabulous solar observatories, some of which parallel Hubble in their capabilities, but now looking at this very bright object with high spatial, temporal, and spectral resolution—the one thing that solar physics has taught us is we don't really understand all that much about sunlike stars, even rather, sort of run-of-the-mill objects like our own Sun. And I can tell you there are some sunlike stars out there that actually are extraordinary, especially these very young objects that are magnetically hyper-active and flaring all the time, which are rather extreme in their behavior.

There are a lot of important physical mechanisms that we don't understand, simply from observing the Sun, and furthermore, by observing that one single object, we don't get the full context of what a star like the Sun is like, either in its youth or in its old age. The hope is that by carrying out observations at these different stages of evolution of a sunlike star, we can gain insight into these physical mechanisms that so far have been elusive.

GAINOR: Just going back a little bit. I somehow managed to miss it, or maybe I forgot it, but you mentioned that a big part of GHRS failed early on.

AYRES: Yes.

GAINOR: Could you just tell me a little bit about what that was, and when it happened? Was that something that maybe got lost in all the excitement of this spherical aberration?

AYRES: Yeah, it certainly got lost in a lot of that excitement. I don't remember when actually it did happen, but there was a fix to it at some point. It was in one of the servicing missions, perhaps when COSTAR [Corrective Optics Space Telescope Axial Replacement] was installed.

GAINOR: Right.

AYRES: There was some kind of a fix to the—

GAINOR: Because it was in until '97.

AYRES: Yeah, it was in.

GAINOR: So, there was that one servicing mission that they could have put something in.

AYRES: Yes. Because eventually we did get that Side—I guess they were able to cross-strap somehow the two electronic Sides—but we were able to get the low-resolution mode of GHRS back, and that was really helpful, particularly since COSTAR had been installed, and we were now getting good imaging, which is important for the spectral purity of the observations. So previously, before COSTAR was in, you could still use GHRS.

It had two apertures, the Large Science Aperture [LSA, 2 arcsecond by 2 arcsecond] and the Small [SSA, .25 arcsecond by .25 arcsecond]. As you recall, the spherically aberrated point spread function for a point-like star was quite blurred, but through the GHRS LSA, which actually is very close to the size of the COS aperture, you could get most of the light through, although at the cost of some degradation in spectral resolution. If you really wanted the highest spectral resolution, and you had a relatively bright object, you could still use the SSA, but you would lose a lot of light in the process.

That all changed when COSTAR went in, because now you could gather almost all the light, even with the SSA, and sensitivity improved quite a bit. But somehow (and I've forgotten the details), the low-resolution mode of GHRS was brought back, because I observed a number of objects with it. However, as I recall, that opportunity was relatively short lived because GHRS had to be removed from Hubble when STIS was installed. So, and there were only a few Cycles where we were actually able to make use of that low resolution mode.

GAINOR: I guess a couple of questions ago, I asked, "Were they generous?" I was thinking in terms of more recent times when they know that after Hubble stops, it's going to be a bit of a dry spell for ultraviolet astronomy.

AYRES: Ultraviolet and optical astronomy as well. Same thing, pretty much, because the new James Webb Space Telescope isn't really going to help us in either of those areas, since JWST primarily is an infrared facility.

As I usually do, I get sidetracked.

GAINOR: That was an interesting answer you gave, by the way.

AYRES: But, in recent years there's been something called the UV initiative. So, there was a meeting at the Institute three years ago, in fall 2012, and the idea of this meeting was to get together a lot of people who had been working in UV spectroscopy and identify areas where Hubble would have potentially large impact if observations were approved in those particular areas. A sort of hidden agenda was to try to get folks together to form consortia to actually make these proposals. So, it was a kind of two-sided thing. On the one hand, the Institute was going to come out with this UV initiative, which for the past several Cycles has basically instructed the TAC panels to give somewhat higher weight to proposals that use the unique, irreplaceable capabilities of Hubble, basically the UV and high-resolution spectroscopy.

A lot of the optical stuff by Hubble can, in some respects, be done from the ground. Not everything, certainly, and not yet. I mean there are a lot of things like a multi-conjugate adaptive optics that you can't buy off the shelf yet, and the next generation Extremely Large Optical Telescopes on the ground are a bit far off as well. So, for doing wide field, high-spatial resolution observations of objects or collections of objects, Hubble still is unparalleled. But for doing narrow field, high-spatial resolution observations of certain objects, adaptive optics from the ground with large telescopes is quite competitive. In fact, contemporary 10-meter class telescopes can actually outperform Hubble, in some respects, especially in the near-IR.

So we're most worried about the UV, which can't be done, of course, from the ground, and there's just nothing on the books that's going to be able to replicate the Hubble capabilities in the near future (and by near future, I mean two decades). Like sort of the professional lifetimes of graduate students who are getting their PhDs right now. It's going to be a long time.

So, the UV initiative was put into place, but then the meeting also created these consortia of individuals to get together and write big proposals to try to make the best use of this UV initiative. And I think that's been fairly successful over the last few years. There certainly have been many more proposals for doing stars, and, actually, extra-galactic objects as well. And for the UV, COS has been a big hit; it's really fueled kind of a revolution in observing distant faint objects, quasars, AGN [Active Galactic Nuclei], that sort of thing, and particularly looking for intergalactic absorption lines that are characteristic of gas that's loaded onto the Cosmic Web, as they call it. It's the cosmological scaffolding that pervades the Universe. In any event, I think that program's been pretty successful.

Also, there's been a concerted effort, by the people that run the TAC, to make smaller, more focused peer review panels. Previously (and I've served on many of these panels over the years, so I've seen the evolution), there were typically very large panels—many people on them—with a very diffuse subject matter, like "Galactic Astronomy," which was intended to cover everything from neutron stars, high mass x-ray binaries, solar-like stars, nebulae, cataclysmic binaries, interstellar medium, to even stellar populations in not-so-nearby galaxies. Given the broad range of fields, typically only one or two people on the panel might know anything, or know enough, about a given topic to properly evaluate a proposal, and usually they were kicked out of the room for the discussion due to a conflict of interest because they were a Co-I [co-investigator], or at the same institution, that sort of thing.

I thought it was a very ineffective process then, but I give a lot of credit to the people that are running the show now, for creating the new smaller, more topical panels. I think the more focused collection of expertise allows a fairer evaluation of proposals, and as a result, the allocation of time has gone more in the direction of things supported by the UV initiative, so I view that as very helpful.

GAINOR: That's good. I was going to ask about what you thought about this process, and maybe I will a little bit, because if you were on IUE, that'll sort of, it harkens back to an earlier time in astronomy, and you know when it was done a little bit, it's not quite the guy with the beard and the coffee in the observatory and writing it down and shuffling off to his own room. But I am asking people about what they think about the process that goes on at the Institute, especially because you get to see it from both sides usually, and just how that whole change has changed astronomy.

AYRES: That's exactly a very interesting thought. Because, back in the IUE days, at least early in the mission, you as an astronomer had to actually travel to Goddard Space Flight Center, sit in a little control room for eight hours, in some cases for a double shift of 16 hours, and carry out your observing program in real time. And the way you did that was you would fill out a target name and coordinates, and exposure time, on a piece of paper—the observing script—and hand it to the telescope operator (TO) next to you. The TO, in turn, would hand the script to the Resident Astronomer. He (or she) would look it over and see if it was okay, and if so, the TO then would slew the spacecraft to the target by real-time commanding, take the specified exposure, and read it down. Then, you had the chance to look at the raw science image on a big TV screen and decide what to do next. It was really more like ground-based observing, where you get a program approved, and you get a certain number of nights at the telescope, and you go to the telescope and carry out observations, but you have a lot of latitude in what you can do.

So for example, if you did an exposure of an object, and it came back basically blank, you'd say, "Well, I have two choices here. I can either increase the exposure time by a factor of 50," (if it's a 3-second exposure, you go up to several minutes) or if it didn't look like that target was going to be observable, no matter how much time you threw at it, say, "Well, I'm going to go to the next object and give that one a try."

Now, Hubble is quite a bit different from that. And so, you're familiar with the process.

GAINOR: Yeah.

AYRES: You write a proposal, some months later it's evaluated by the TAC, a month or so after that you get notification that your program is approved or not. If it was approved, then you have another month and a half or so to prepare a Phase 2 program, which is the detailed specification of how the observations are meant to be carried out. Then you submit that Phase 2 program, and there are a bunch of iterations, perhaps, or it's just accepted. And some months later, you get a notification that your target or targets have been put on the long-term schedule. Then you feverishly track the weekly schedules to see when, actually, the target is due to be observed, and you pace up and down, waiting for that observation time to come, but you know exactly when it is supposed to happen. And then as soon as the observation is predicted to be finished, you begin checking the archive to see when the data actually hits.

Then about a day later, or two days later, you get a notification from HST that says your observation has been carried out, but you don't have to wait that long, because the data goes into the archive almost immediately and you can access it and see what happened.

So this is like a year after you made the original proposal. And then you get your observation and it's blank. So now what do you do? There are a number of things that could have gone wrong that are not necessarily your fault. There might have been a spacecraft anomaly, like a bad gyro reading, and the guide stars weren't acquired properly, so your target was never in the spectrograph aperture. In this case you likely would have an opportunity to repeat the observation after filing a Hubble Observation Problem Report, HOPR, although probably not for several months and perhaps longer.

But say you put in the wrong target coordinates or put in the proper motion (the space motion of the object on the sky) in the wrong units, so that when the scheduling system tells HST to look for the star over here, it's really way over there, so the target acquisition fails. Well, that's your fault, as the observer. Or maybe you completely mis-underestimated the exposure time that's necessary to capture the target spectrum with reasonable signal levels, so your feasibility assessment was somehow in error.

Well, if you messed up in either of such cases, you're very unlikely to be allowed a re-observation going through the HOPR process. So, if it was your fault, more likely than not, they'll deny your re-observation request. And especially if it was that your feasibility was way off, and the object was just way too faint for the specified exposure time. So now what do you do?

Well, if it's a really important observation, and you think it absolutely has to be done, and after all, it was approved by the TAC originally. You can go back to the TAC the next Cycle and reapply for more time. However, your chances of getting time in the extremely competitive review under any circumstances is small, especially in this situation where the panel likely is thinking, "Well, your feasibility was way off. You really messed up. Unless you can super strongly justify a new observation, you're just never going to get it." So, the whole process—and the way you carry out the science—with HST is very different from the ground-based observing experience, or the historical IUE model. It's very hands off. You have to make sure everything is right at the beginning, and then kind of hope for the best. But that hope really has to be tempered with a lot of upfront work.

GAINOR: And I suppose before you press the send button, you pass it around to your colleagues, "Make sure I didn't screw this up, did I?"

AYRES: Yeah, well, I typically don't because I'm experienced enough. And also, over the years, the Institute has developed tools to help the observer get it right. So, they have this thing called APT, the Astronomer's Proposal Tool, which allows you to create an observing program—fill up the allocated orbits with exposures—and it tells you whether you've done that correctly. It also shows you when the observations are schedulable over the observing year, which is a big help if you want to put in constraints, say, "Well, I have to have a certain roll angle of the spacecraft, because you know my object is a binary, and I want a certain orientation on the spectrograph slit." Or, "I have to observe in the Continuous Viewing Zone, because then I can get a full orbit's worth of observation without losing 40 minutes to the Earth occultation."

[The Continuous Viewing Zone (CVZ) is a region of the sky that varies over the year, where if an object is in that region, you get really efficient observations. So that kind of time is highly prized, but there are relatively few objects that happen to sit up in those zones at any given time. And most of them are only accessible a few times a year, and usually only for a day or two.]

Anyhow, if you put a lot of constraints in your APT script, and after you press the button there are no little black boxes that tell you that it's schedulable, it's just blank, that's a bad sign. You've put in too many constraints. So, you have to relax those constraints until the observation is doable.

A lot of people interact with APT only after their proposal's been accepted, when they create their Phase II program, because many people feel that it's a real chore, particularly if they don't have a lot of experience. But if you have enough experience doing this stuff, you can just create the observing script in advance during the Phase I stage of proposal submission, and then you know exactly what to ask for and whether it's feasible or not. So it's actually a great tool and a very powerful one. And it's meant to be used for James Webb and other future missions as well.

GAINOR: Right. Okay.

AYRES: But it used to be really bad, I mean trying to do HST planning, because all you had were little tables that said, "Well, there's this much overhead for this mode, and that much overhead for that mode," and you had to write everything down on paper, and in Year One, it was pretty grim.

GAINOR: That's right, yeah, because there was no internet really.

AYRES: No, Al Gore hadn't invented the Internet by then.

GAINOR: That's right. Oh well, he got his satellite up there recently.

AYRES: Oh yeah, he did, yeah, that's awesome.

GAINOR: So [laughs]

AYRES: The old Triana [Deep Space Climate Observatory].

GAINOR: Well, I think that's pretty good. Was there anything you think I missed, or that you think should be said?

AYRES: There's probably a lot we missed, but I don't remember it anyway, so I'm sorry. But I guess what I can say is that the beauty of Hubble is that it's lasted for 25 years now, and that's a good fraction of somebody's career, like my own, for example. So there are many of us in this kind of cohort that started off with IUE, and then hit the ground running with the Space Telescope, and it has evolved, and we have evolved, and there's been this important synergy between HST and the science we're able to do, and the real key to this evolution was the fact that the HST instruments were upgraded periodically, and repaired if necessary, and so at the end of the day (it's the end of the day now) we have a really nice complement of extremely useful instruments. Whereas, if the original instruments were still in there, they would basically not be useful anymore, because, for example, the CCDs [charge-coupled devices] in the original Wide Field Camera would be completely dead because of cosmic ray damage and that sort of thing.

At the beginning the technology was so primitive, compared to what we have now. I think it makes a lot of sense to have these situations where you can replace instruments on a still-viable telescope. It works great on the ground, it's just a little expensive when you have to do it in space. But the Hubble experience, I think, has been really instructive in that regard, and certainly terrific for the science.

GAINOR: Yeah. And even if it conks out tomorrow, you've got plenty of work to do.

AYRES: Don't say that.

GAINOR: With the data, with the data.

AYRES: Please don't say that. I have four new HST programs this year. Three of them are relatively small, and actually those three programs came from the Chandra X-ray Observatory. This is one thing I didn't mention. Even though back in the day it was difficult to get HST time through Space Telescope itself, because review panels were just so big and unwieldy, and they just sort of ignored stars and that sort of thing. But, on the other side of the street, the Chandra X-ray Observatory started off having what HST has now, small topical panels dealing with stars or X-ray binaries, AGN, and that sort of thing, and allocating observing time to these panels according to the proposal pressure. So, if a lot of people were proposing to observe stars, then there would be more stellar panels and there'd be more time allocated to them, or conversely, if more people proposed to observe AGN, then you'd get more AGN panels.

But shortly after the Chandra mission began, in the early 2000s, HST and Chandra got together and decided to offer joint observing opportunities. So Space Telescope gives 100 orbits or so to Chandra each year, and HST time can be requested in connection with a Chandra proposal. And similarly, Chandra provides some of its time (I think its 200 kiloseconds) that can be applied for in the HST process. It's meant to avoid the sort of double jeopardy of having a program where you want to make use of both observatories, but then have to submit separate proposals to each observatory.

GAINOR: And maybe get turned down on one and not the other.

AYRES: Yeah. So the idea here is that it's one-stop shopping, and you avoid the situation where you otherwise would have to confront two very low success rate competitions simultaneously. And the consequence of that was back in the first decade of the 2000s, there were a lot of joint proposals on stars that were approved on the Chandra side, which produced a lot of really good HST STIS UV spectra stars, but the approval process was completely different. It was coming from the Chandra side and those panels because they were explicitly stellar panels, were more in tune with the kind of science that was being proposed, and also the synergy that you can get doing joint X-ray and ultraviolet observation, which is basically looking at different, complementary aspects of the high-energy emissions of these magnetically active objects.

So personally, I, and also many of my colleagues, got a lot of HST time through the Chandra route, back in those days, which was quite valuable.

GAINOR: And who runs Chandra?

AYRES: The Smithsonian Astrophysical Observatory [SAO], much like AURA [Association of Universities for Research in Astronomy].

GAINOR: I knew it wasn't AURA, but I couldn't think of who it was.

AYRES: Yes, it's different. But, like AURA, SAO is under contract to NASA.

GAINOR: Yeah. Okay. Well, thank you very much.

AYRES: Sure, you're very welcome.

[*End of recording*]