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May 22, 2015

Dr. Kathryn Flanagan, Interim Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Re: JSTAC assessment of GO funding levels for JWST

Dear Director Flanagan:

One of the reasons for the success of the Great Observatories has been NASA's practice of providing direct data analysis funding to General Observer (GO) investigators who have obtained observing time on NASA missions. GO funding has been highly effective in maximizing their scientific productivity. The combined publication rate from the Great Observatory missions (HST, Chandra and Spitzer) is nearly 2000 refereed scientific papers per year.

These remarkable returns have been done for an extremely small incremental cost relative to the overall mission lifecycle cost. The marginal cost of providing GO data analysis support is typically less than 1% annually of the cost-to-launch. The extraordinary science return from NASA's support of GO data analysis has shown that providing GO funding at a well-justified level will be an excellent investment.

GO Funding Importance for JWST: GO funding will be even more important for JWST that it has been for missions such as Chandra and HST. Like Spitzer, JWST is a limited-lifetime mission. Opportunities for follow-up observations depend crucially (1) on the rapid availability of data (dealt with in prior JSTAC letters regarding the exclusive use/proprietary period), and (2) on the ability of investigators to publish the early science results as quickly as possible. The JWST instruments and observing modes will be new to all investigators and include additional complexity compared to the current suite of available space-based instruments on the Great Observatories. This complexity makes it imperative to provide sufficient GO funding to maximize the overall scientific productivity of JWST. A highly-important and related aspect is to ensure that the data from the early cycles (Cycles 1 and 2) are analyzed and published quickly so as to provide results that can be followed up in the cycles close to the nominal end-of-life (Cycles 3 through 5). If JWST's life goes beyond its required 5 years, as we all hope, the decision to have an appropriate level of GO funding, particularly in its early phases, but also throughout its lifetime, will continue to be rewarded by substantially increased science productivity.

Prior Discussions of Factors/Metrics: The JSTAC has discussed GO funding for JWST on a number of occasions, with very thoughtful presentations from the Science Mission Office at STScI on the factors that they considered to be key to assessing the level of GO funding. The JSTAC discussion of GO funding was motivated also by a question to the JSTAC at its Dec 10, 2012 meeting from the Astrophysics Division Director Paul Hertz. Director Hertz asked in a list of *Questions for JSTAC: What are metrics for determining appropriate level of GO funding in context of lessons learned from Spitzer, Hubble, etc.?* As a result of the discussion that followed the Dec 10, 2012 meeting the JSTAC wrote a letter to the Director on July 28, 2013 regarding the methodology for estimating the level of GO funding. That letter can be found here: GO_Funding-JSTAC_recommendations

The JSTAC noted in the July 28, 2013 letter a number of considerations that framed the discussion at subsequent JSTAC meetings. They are repeated here, given their relevance to the current letter:

In summary the JSTAC:

1) *clearly felt that an augmentation of GO funding for JWST relative to that for HST and Spitzer was needed;*
2) *endorsed the factors that had been chosen to evaluate the degree of augmentation;*
3) *was concerned that the current augmentation factor for Complexity was too low;*
4) *suggested that consideration be given to the crucial aspect of "time criticality" that results from the five-year mission lifetime; this could be accommodated within this set (under Learning curve?) or by augmenting the number of factors;*
5) *understood that the overall augmentation would come from multiplying the above factors, adjusted for any changes resulting from the JSTAC discussion.*

GO Funding Subcommittee: During further consideration of this topic at its December 2014 meeting, the JSTAC decided to form a subcommittee of three of its members (Neta Bahcall, Roger Brissenden and Lisa Storrie-Lombardi) with extensive experience in dealing with HST, Chandra and Spitzer GO funding to review in detail all of the factors and metrics, and to derive actual estimates of the funding needed. The subcommittee was supported by Neill Reid and Rachel Osten of the STScI Science Mission Office, and was asked to assess the robustness of the values assigned to the factors and to carry out any additional analysis required to provide a more robust estimate for the level of GO funding needed to carry out data analysis, scientific analysis and scientific publication for JWST.

The JSTAC subcommittee charter: *Work with STScI to derive a robust, well-justified recommended level for the NASA science data analysis support for JWST General Observers with the goal of maximizing the scientific return from the mission.*

GO Funding Subcommittee Findings: The JSTAC subcommittee reviewed the materials that had been developed and discussed with JSTAC. The subcommittee estimates were made using both top-down and bottom-up approaches. The recent data for HST data analysis funding levels provided a well-defined starting point for estimating the level for JWST GO funding. The details are provided in the attached JSTAC GO Funding Subcommittee report.

The subcommittee assessment resulted in the following levels of funding from the two approaches: (1) $61 million ($FY19) per cycle from a top-down estimate for data analysis funding (including GO, Archive, and Theory); and (2) a range from $53 – 65 million/cycle (GO only) from a bottom-up estimates The higher value in the latter estimate came mainly from Cycle 1 where many more smaller programs are expected from GOs utilizing the new capabilities available with JWST. For Cycle 1 the bottom-up estimate for GO funding alone is $61 million. Given these estimates, ***the JSTAC recommends an annual GO funding level of $60 million.***

The subcommittee noted that Archival and Theory programs were funded at a level of ~$3 million in HST Cycle 18, while Spitzer also provided $2-3 million/cycle in AR and Theory support during its cryogenic mission. Given the success of both these programs, ***the JSTAC recommends annual support for AR and Theory programs at an inflation-adjusted level of $4 million.*** It is expected that the Archival funding will play a key role in Cycle 1 since the JSTAC has recommended, and STScI is planning for, a substantial Early Release Science (ERS) program very early in Cycle 1. This will enable the science community to climb the steep learning curve of JWST capabilities prior to the Cycle 2 proposal submission. Archival funding is a critical element for enhancing the effectiveness of the ERS program in readying GOs for Cycle 2, and so ***JSTAC also recommends that the above level of AR and Theory funding be provided in Cycle 1.***

The scientific value of archival research is widely recognized. Yet the scale of its contributions to the overall science productivity of the Great Observatory missions is probably not widely appreciated. More than half of the HST, Spitzer, or Chandra papers published each year now utilize archival data. The subcommittee analyzed the publication rates from archival data and concluded that funding archival research after the JWST mission is completed will yield a significant number of additional publications. Based on current experience, post-mission archival research is expected to provide a very cost-effective scientific return. Archival research provides significant scientific enhancement for a very small marginal cost to the overall lifecycle cost. Given this, ***the JSTAC recommends an appropriate scaling of post-mission funding to support archival research.***

In summary, the JSTAC would like to convey its recommendations for the level of funding needed for JWST GO data analysis, scientific analysis and scientific publication, based on the analysis provided by its subcommittee, as follows:

JSTAC assessment regarding GO, Archival and Theory funding:

1. ***We recommend an annual GO funding level of $60 million ($FY19).***

2. ***We recommend an additional $4 million in annual funding for the Archive and Theory programs starting in Cycle 1 and continuing through the life of the mission.***

3. ***We recommend substantial funding of post-mission archival research for a minimum of 2 years.***

The JSTAC recognizes that there are other constraints that will influence, and could potentially reduce, the budgeted funding level for GO science support, including the Agency estimate of the lifecycle cost of JWST of $8.835B through its prime mission. Nonetheless, the basis for the annual $60 million level of GO funding appears to be well-founded, as does added funding for Archival and Theory programs. The high scientific productivity over the lifetime of the Great Observatory missions provides an excellent rationale for having a robust GO program, as exemplified by that of HST (which was used by the JSTAC GO Funding Subcommittee in their analysis). JSTAC would encourage those concerned to approach the level above as a very desirable goal.

The JSTAC would appreciate it if you could provide our consideration of the level of funding for GO data analysis, scientific analysis and scientific publication for JWST observations to those at NASA responsible for the support of the JWST program during the operational era.

Sincerely yours, on behalf of the Committee,

Garth Illingworth
Chair, JSTAC

JSTAC members:

Roberto Abraham	University of Toronto
Neta Bahcall	Princeton University
Stefi Baum	Rochester Institute of Technology
Roger Brissenden	Smithsonian Astrophysical Observatory
Timothy Heckman	Johns Hopkins University
Malcolm Longair	Cavendish Laboratory, University of Cambridge
Christopher McKee	University of California, Berkeley
Bradley Peterson	Ohio State University
Joseph Rothenberg	JHR Consulting
Sara Seager	Massachusetts Institute of Technology
Lisa Storrie-Lombardi	Spitzer Science Center, Caltech
Monica Tosi	INAF – Osservatorio Astronomico di Bologna

JSTAC Ex-officio observers from the Agencies:
(whose contributions to this letter were limited to factual input)

Hashima Hasan	NASA HQ
John Mather	NASA GSFC
Mark McCaughrean	ESA
Alain Ouellet / Jean Dupuis	CSA
Eric Smith	NASA HQ

23 March 2015

Report from the JSTAC JWST GO Funding Level Sub-Committee

JSTAC Members: Neta Bahcall, Roger Brissenden, Lisa Storrie-Lombardi
Support from STScI was provided by Neill Reid and Rachel Osten.

Sub-Committee Charter: Work with STScI to derive a robust, well-justified recommended level for the NASA science data analysis support for JWST General Observers with the goal of maximizing the scientific return from the mission.

Background: NASA's practice of providing direct data analysis funding to investigators that are successful in obtaining observing time on NASA missions has been highly successful in realizing the science from the missions. In particular, the data analysis funding provided with General Observer (GO) time on NASA's Great Observatories has led to a combined sustained publication rate from these missions of now close to 2000 refereed scientific papers per year.

JWST is a limited-lifetime mission, therefore opportunities for follow-up observations depend on the ability of investigators to publish the early science results as quickly as possible. The astronomical community is now well-versed in utilizing the instruments on the Great Observatories. The JWST instruments and observing modes will be new to all investigators and include additional complexity compared to the current suite of available space-based instruments. The mean time from data to publication for HST, Chandra and Spitzer is ~ 2.5 years, therefore providing sufficient funding to get data from Cycles 1 and 2 analyzed and published is key to providing results that can be followed up in Cycles 3 through 5.

The Science Mission Office at STScI has studied the factors to take into account in determining the appropriate GO funding level, including the complexity of instrument modes and the observatory efficiency. They have also researched how each of the Great Observatories have determined individual funding levels for their GOs. Estimates have been prepared and discussed with the JSTAC on a number of occasions. At the December 2014 meeting the JSTAC formed a subcommittee to review in detail all of the materials that have been presented, the robustness of the estimates, and do any additional analysis required to determine the most robust estimate for recommended JWST GO funding levels.

Committee Findings:

The sub-committee reviewed the prior materials and made estimates using both top-down and bottoms-up approaches. Using the recent data for HST data analysis funding levels provides a well-defined starting point for estimating the necessary level for JWST GO funding. The details of how the estimates were determined are summarized in Appendix 1.

The top-down estimate for data analysis funding (including GO, Archive, and Theory) is $61 million ($FY19) and the bottoms up estimates (GO only) range from $53 – 65 million/cycle, depending on the distribution of proposal sizes in Cycle 1. The first cycle is likely to see more smaller programs that are 'skimming the cream' with the new capabilities available with JWST. Given the likely program size distribution in Cycle 1 the bottoms-up estimate for GO funding alone is $61 million/cycle, which is the average of the values determined from model A (program size distribution for HST Cycle 18) and model B (program size distribution favoring small programs) in Appendix 1.

Archival and Theory programs were funded at a level of ~$3 million in HST Cycle 18. During the cryogenic mission Spitzer also provided $2-3 million/cycle in AR and theory support. The committee recommends that support for AR/theory programs be provided at a level of $4 million/cycle, which just scales the number up for inflation.

Based on an analysis of use of archival data and publication rates (see Appendix 2), we conclude that funding archival research after the JWST mission is completed will yield a significant number of additional publications. More than half of the HST, Spitzer, or Chandra papers published each year now utilize archival data. In order to maximize the investment in JWST, we recommend an appropriate scaling of post-mission funding to support archival research.

Recommendations Summary:

1. We recommend an annual GO funding level of $60 million/cycle ($FY19).

2. We recommend an additional $4 million in archive/theory program funding starting in Cycle 1 and continuing through the life of the mission.

3. We recommend funding post-mission archival research for a minimum of 2 years.

The marginal cost of providing direct data analysis support to the community is less than 1% annually of the cost-to-launch. The extraordinary science return from NASA's direct mission data analysis support has shown that this will be an excellent and well-motivated investment.

Appendix 1: Quantitative estimates of the appropriate funding level for JWST GO, AR & Theory programs

Context

Both top-down and bottoms-up methodologies have been used to estimate the likely requirements to adequately fund JWST science programs. These estimates are based on data regarding grant/contract funding by NASA's Great Observatories, Chandra, Spitzer and Hubble.

Top down budget estimate

This approach bases the JWST Cycle 1 estimate on scaling the total HST Cycle 18 budget, combining all observational and archival programs:

HST proposal funding for Cycle 18 was $27.6 million (FY11) – this includes funding for all GO, AR and Theory programs in that cycle, including the Multi-Cycle Treasury progams.

Four scaling factors are used:

- Observing efficiency – JWST 70% vs. HST 45%, factor = 1.56
- Inflation – 3% to FY 19, factor = 1.27
- Observing complexity, estimated as a factor of 1.5*
- GO observing time in JWST Cycle 1: JWST time is allocated in wallclock hours (8,766 hrs/cycle) we anticipate ~2200 hours allocated to GTO time, reducing the available time by a factor 6,566/8,766 = 0.75

Overall: JWST Cycle 1 GO funding = 2.23 * HST Cycle 18 funding = $61 million

*JWST will include complex instrumentation including multi-object spectroscopy, integral field unit spectrographs and coronagraphs.

Bottoms up budget estimate

These estimates are based on the actual resources used by HST Cycle 18 observing programs

-- *Observing programs*

HST Cycle 18 observing program data are taken as reference, combined with data for large programs from Cycle 19 and 20 to improve the statistics for those programs. HST Cycle 18 was the second cycle following SM4, so the instrumentation was relatively new to the community; approximately 800 orbits was allocated to the Multi-Cycle Treasury programs; the remaining time in Cycle 18 was ~2600 orbits and this was allocated to 155 observing programs. Fourteen of the 155 programs had no US investigators and therefore received no funding. The statistical analysis is based on the remaining 141 programs.

Analysis shows that 80% of the funding in those programs is devoted to personnel; analysis shows that the resources available to Chandra observers are distributed in the same manner. Table 1 shows the distribution of funding among senior researchers (faculty, research staff), postdoctoral fellows and graduate students; these three categories account for 76% of the total budget. Table 1 also lists the average loaded costs per FTE for each category in FY11 dollars.

Table 1: Hubble Cycle 18 Observing Programs - Personnel Support

Category	% funding	$/FTE (FY11)
Senior personnel	33%	$212K
Postdoctoral fellows	29%	$104K
Graduate students	14%	$54K

We adopt the assumption that the HST and JWST programs of similar size (1 HST orbit ~ 50 minutes on-sky observing time) require similar resources. We therefore use the average resources allocated to HST programs (Table 2) to estimate the appropriate resources for JWST programs as a function of size:

Table 2: Average resources for HST programs

Size Orbits/hours	Senior personnel	Postdocs	Grad students	Personnel costs (FY11)	Total costs (FY11)	Total costs (FY19)
1-10	0.14 ftes	0.14 ftes	0.2 ftes	$62K	$79K	$99K
11-20	0.2	0.25	0.25	$94K	$120K	$150K
21-40	0.2	0.6	0.6	$166K	$213K	$213K
41-100	0.5	0.6	0.5	$225K	$288K	$360K
>100*	1.0	1.2	1.4	$471K	$603K	$754K

Allowing for GTO programs, JWST Cycle 1 is likely to include ~6,566 hours for GO programs. Assuming 70% efficiency, this corresponds to ~4,600 hours of on-target science observations. A typical HST orbit provides ~50 minutes of on-target science observation. Consequently, the 2600 orbits available in HST Cycle 18 correspond to ~2170 hours of on-target science observation. Thus, JWST Cycle 1 is likely to offer approximately twice as much observing time as HST Cycle 18, and we have scaled the program number estimates accordingly.

We adopt 3 models for the distribution of program size (Figure 1).

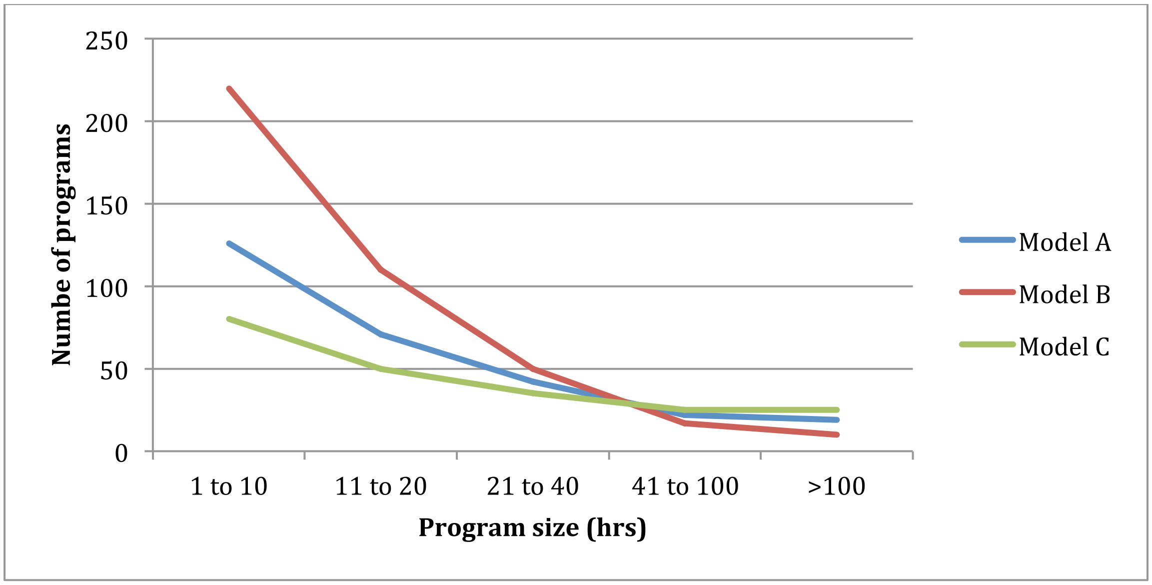

Figure 1: Estimated program size distributions (hours) for JWST Cycle 1.

Model A follows the same program size distribution as HST Cycle 18, with a total of ~280 funded programs; the total funding required is $57 million.
Model B emphasizes small programs, with 410 funded programs – the total funding required is $65 million.
Model C favors large programs, with 215 funded programs – the total funding required is $53 million.

The JWST Cycle 1 GO size distribution is likely to fall between Model A and Model B, since JWST instrumentation will offer the opportunity for high-impact, small-scale programs.

-- *Archive and Theory programs*

Individual resource assignments are not available for Archival and Theory programs; consequently we have scaled the overall allocation to those programs in HST Cycle 18. Those programs account for ~40 programs in a typical HST cycle and were funded at a level of ~$3 million in HST Cycle 18. Both Archival and Theory programs will be available from Cycle 1, with ERS data available for AR programs. Scaling by inflation indicates an allocation of ~$4 million.

-- *Total funding*

To summarize, the funding required to support JWST Cycle 1 observing programs is estimated to lie between $53 million and $65 million, depending on the program size distribution; the expectation is that a high proportion of Cycle 1 JWST programs will be relatively small, leading to required funding levels in the upper part of that range, ~$57 – 65 million.

Additional funding is required to support archival and theory programs; if those programs are supported at the same level as current HST programs, additional funding of ~$4 million is required in JWST Cycle 1.

The total funding likely required to ensure high science productivity for JWST Cycle 1 is therefore estimated as between $61 and $69 million.

Appendix 2: Post-mission archive funding for JWST

In assessing the importance of post-mission archive funding for JWST we found an assessment of publication rates and archive data usage from the Chandra X-ray Observatory to be instructive. Where feasible we made comparisons with the experience from Hubble and Spitzer. Chandra was launched on 23 July 1999.

1. Publication rate and time to publication

The number of refereed papers based on Chandra data published per year is shown in Figure 2. The number of papers increases rapidly in the first 4 years from ~50 to ~400, then to ~450/yr by year 6. After the first 6 years, the average rate of publication has remained at ~450 papers/year. The rate of increase is largely due to the time needed by Observers to perform analysis and write the paper. For Chandra, the mean time from data receipt to publication is 2.5 years.

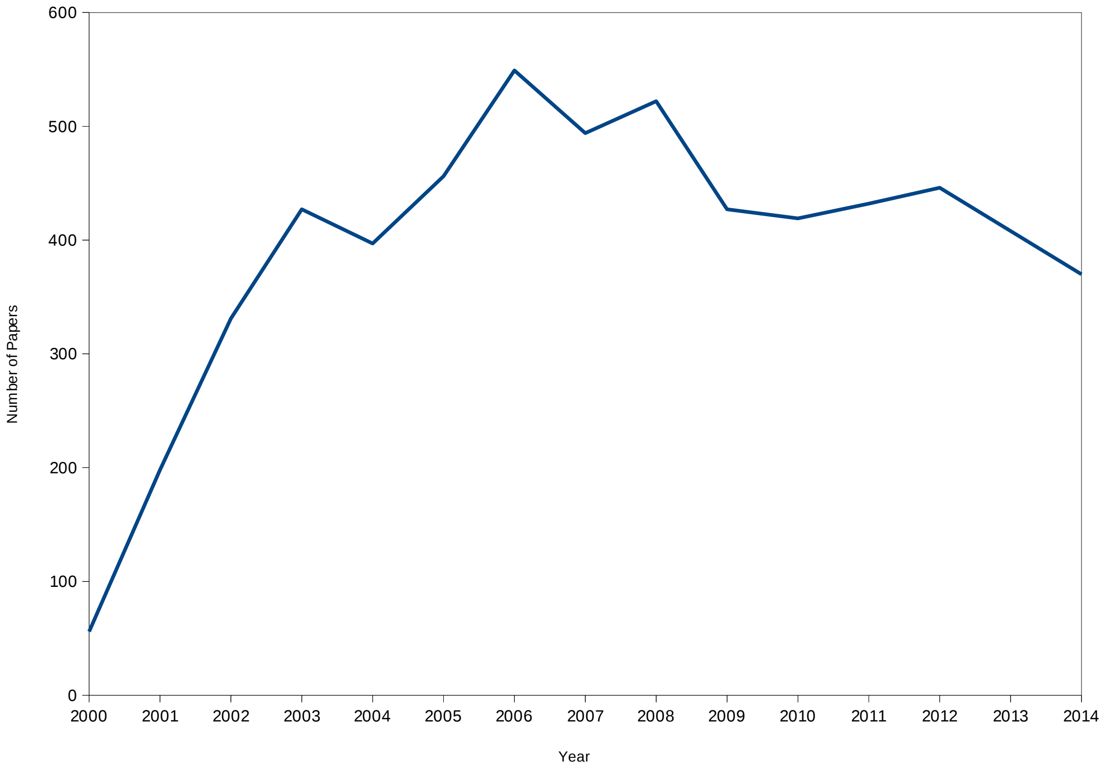

Figure 2: The number of Chandra Science Papers per year (2014) partial.

Both Hubble and Spitzer experienced similar increases in publication rates and mean time to publication, and we should expect the same for JWST. Since the timescales of these two factors are significant compared with the expected minimum lifetime of JWST, and the availability of prior data and publications inform new proposals and publications, steps to reduce these factors will positively impact science productivity. Steps such as minimizing the proprietary period and providing early funding to Observers, are discussed elsewhere.

Given these factors, we will now examine the use of archival data.

2. Use of Archival Data in Chandra Science Papers

In Figure 3 we show the use of data in three categories for those papers that present observations:

- Papers using only new data (bottom band)
- Papers using only data that had been published previously (middle band)
- Papers using a mix of old and new observation data (top band).

The papers in the second and third categories are considered to "contain archival data."

Figure 3 shows that papers using only new data fall to 30% by year 5 of the mission, with a corresponding increase in use of archival data. Papers using archival data increase to 70% by year 5 with an average of 72% thereafter (though year 15) for Chandra. The 70% is comprised of ~50% using only previously published data, and ~20% using a mix. The figure shows the importance of the archival data after 5 years.

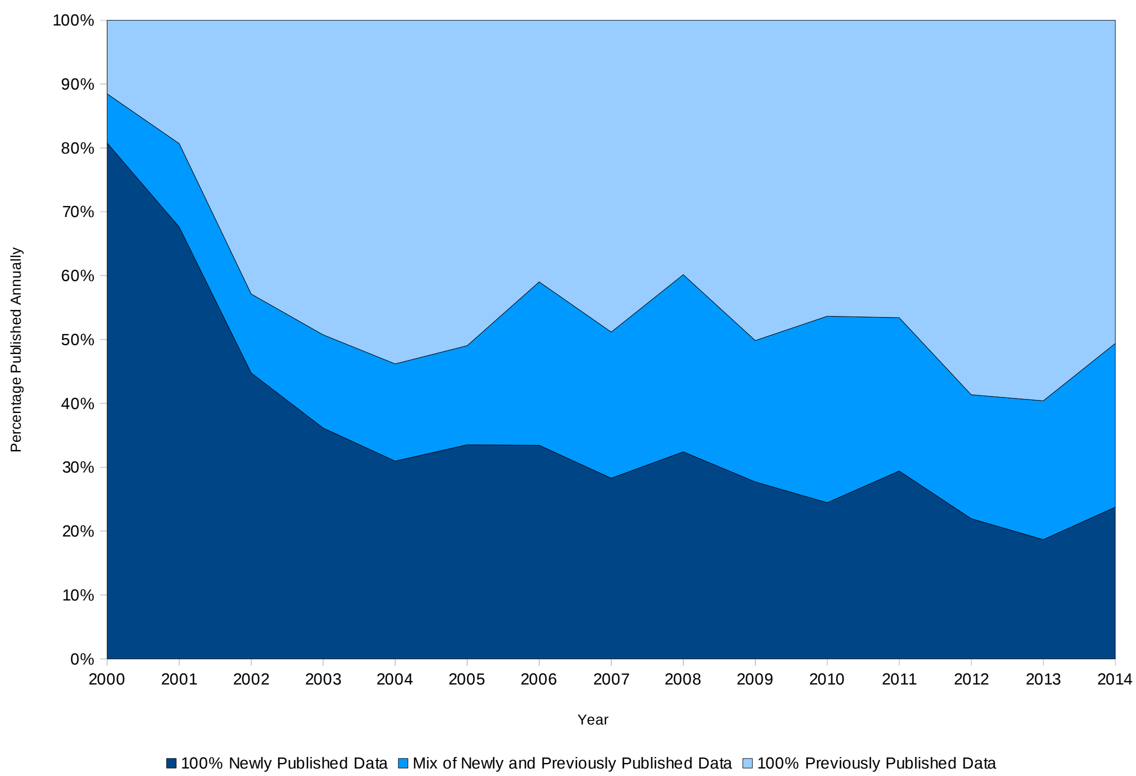

Figure 3: Percentage of new (bottom band) and archival data (combination of middle and top bands) used in Chandra science papers.

3. Publication and Data Age

Given the expected 5-10 year lifetime of JWST, we examined the use of Chandra data in publications from the first 5 years of the mission. Figure 4 shows the percentage of available observing time, for observations using >50% of data from the first 5 years, published once, twice, thrice and >3 times, as a function of the time since the data were released. We have chosen observations with >50% of data as an indicator of the trend if Chandra had ended its mission after 5 years, i.e., the papers would likely have been published even in the absence of additional observations since the majority of the data came from the first 5 years.

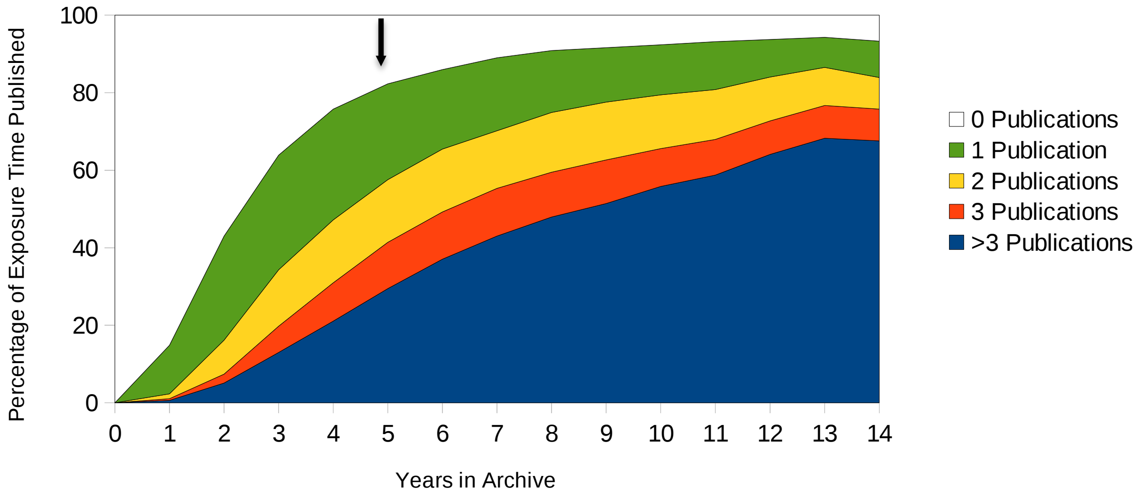

Figure 4: The percentage of available exposure time, for observations with >50% of data from the first 5 years, published once, twice, thrice and >3 times as a function of the time since the data were released. The simulated end of mission is indicated with the black arrow.

Figure 4 shows that after 4 years in the archive, 76% of the data in the archive have been published once and 21% have been published in more than 3 publications. After 7 years (5 year mission +2 years), 89% of the data have been published once and 43% in more than 3 publications. This demonstrates the impact of the archive data in the years immediately following the observations, and in general the heavy use of the archive in addition to the activity of the original proposers.

In the case of a 5-year mission, there would be significant impact from work done using archival data after the completion of the mission, in addition to work completed under funded observing programs from the last year. For JWST, this argues that providing funding to the community post launch to support use of the archive data, will have a direct impact on the overall science return of the mission.

4. Conclusion

Figures 1-3, combined with a mean time from data receipt to publication of 2.5 years, suggests that funding the community for at least 2 years after the JWST is completed will yield a significant number of additional publications, and increase the use of JWST data in multiple papers. The detailed analysis in this appendix is based on the Chandra mission but similar trends in the growth of archival publications throughout the mission are seen for both HST (Figure 5) and Spitzer (Figure 6).

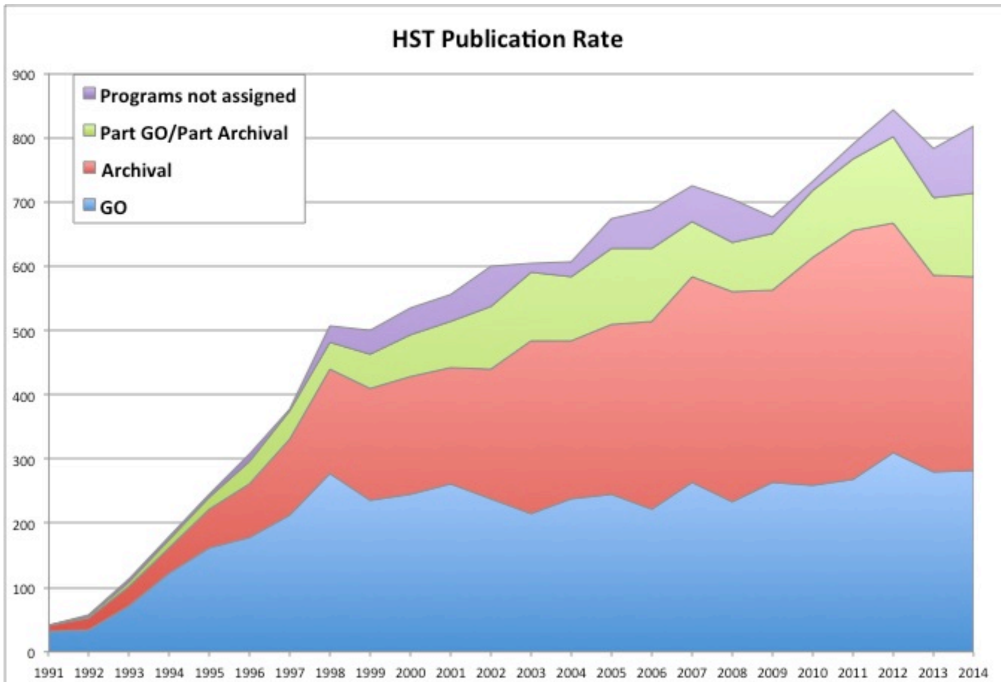

Figure 5: The number of HST publications per year since launch. The areas are color-coded based on the primary source material for the papers, ie. GO for those published by the original investigators versus data taken from the archive.

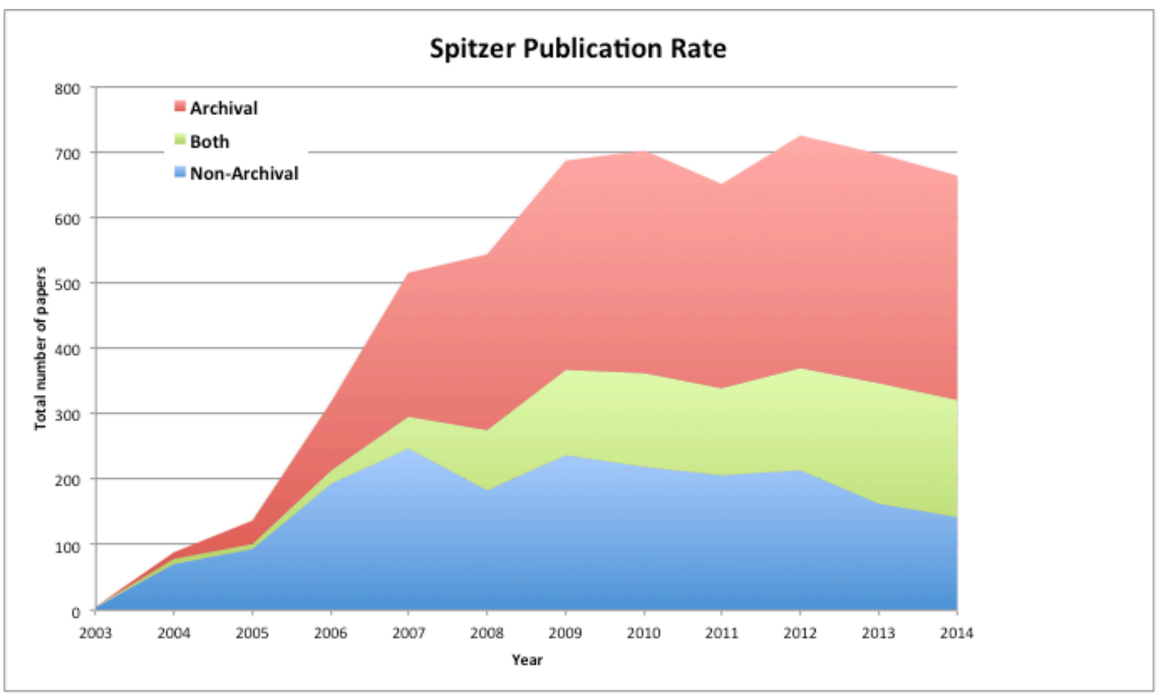

Figure 6: The number of Spitzer publications per year since launch. The areas are color-coded based on the primary source material for the papers, ie. Non-Archival for those published by the original investigators versus data taken from the archive. This includes all papers based on the cryogenic mission (observations through May 2009) and the warm mission (July 2009+).