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JWST Pure Parallel Implementation Review

Revision A

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Table of Contents

Executive Summary 1

1 Introduction1

2 Pure Parallel Program Submission Process.....1

3 Pure Parallel Slots and Group Slot2

4 Pure Parallel Slots Assignments3

5 Pure parallel programs completion status.....4

6 Main Limitations to Pure Parallel Implementation4

7 Findings and associated actions.....5

Table 1: Approved pure parallel programs completion status. The charged time takes into account the visits listed in APT, including the ones that are not yet executed. Note that some programs have APT charged time over the allocated program hours. The S&OC allows the PI to add more hours than the allocated hours to facilitate scheduling. It does not necessarily mean all of the hours will be observed since some pure parallel observations do not get executed due to them causing scheduling issues with the primes (i.e., data volume issues)..... 4

Figure 1: Schematic representation of a JWST visit structure for a prime program (blue) with available slots where a pure parallel exposure can be attached (orange). The instruments mechanisms configuration occurs sequentially, whereas the detectors configuration for both instruments is simultaneous. Each pure parallel slot corresponds to a single exposure; all slots are associated with a dither pattern position and form a group slot. 2

Figure 2: Schematic representation of pure parallel calibration slots attachment. If only a fraction of a slot group is used, the entire slot group will be not available for science. 3

Executive Summary

The STScI S&OC supports the implementation of JWST parallel observations, where two or more instruments are simultaneously used to obtain science and/or calibration data. This is primarily done to enhance the efficiency and science return of the JWST mission.

The JWST Mission Office (JWSTMO) and the STScI Director's Office (DO) established a Working Group in summer 2024 to review the current status of implementing pure parallel programs. The charter for the Working Group is included as Appendix A. In response to that charge, this report presents the current implementation of JWST pure parallel observations by the Space Telescope Science Institute (STScI) Science and Operations Center (S&OC). In particular, it presents the current pure parallel program submission and slots assignments process, and the completion status for all Cycle 1 through 3 pure parallel programs. Input was solicited from the PIs of Cycle 1 and 2 programs, and their feedback has been included, as appropriate, in the discussion. It also discusses the main limitations to pure parallel implementation, as well as some mitigation strategies. Finally, a summary of all findings and recommendations is presented.

1 Introduction

There are two categories of JWST parallel observations: coordinated and pure.

- **Coordinated parallel observations** are crafted within the APT template used for the primary instrument mode, and are approved by the Telescope Allocation Committee (TAC) as part of the same observing proposal.
- **Pure parallel observations** are proposed as entirely separate programs of investigation. They use parallel observing "slots" created by exposures from other accepted programs that do not already have parallel observations specified. *As per [JWST's policies](#), pure parallels are not allowed to influence the dither patterns or other aspects of the observing strategy of the primary observations to which they are attached, since the primary observations belong to different science proposals/investigator teams.* In actuality, pure parallels will add a small additional overhead for setting up the instruments (see Fig. 1). This is handled by the scheduling system and is not assigned as an overhead on the primary observations.

This report presents the current JWST S&OC pure parallels implementation, its performance and limitations, and identifies areas of improvement that should facilitate the implementation of future pure parallel observations.

2 Pure Parallel Program Submission Process

Pure parallel proposals do not follow JWST's standard [single stream](#) process. Instead, the submitted proposal only specifies example observations in APT, and requests a certain number of hours to achieve the scientific objectives.

In Cycle 4, the following 5 observing modes can be requested as pure parallel observations:

- MIRI imaging
- NIRCам imaging
- NIRCам wide field slitless spectroscopy (WFSS)

- NIRISS imaging
- NIRISS WFSS

and the following APT templates are allowed to have pure parallels attached:

- MIRI imaging
- MIRI LRS slit
- MIRI MRS
- NIRCам imaging
- NIRCам WFSS
- NIRISS imaging
- NIRISS WFSS
- NIRSpec fixed slits
- NIRSpec IFU
- NIRSpec MOS

Observation techniques/templates that require significant telescope stability, such as coronagraphy, time series observations or NIRISS Aperture Masking Interferometry, are not allowed to attach pure parallels. This is because their impact on the primary science performance has not been evaluated.

After the TAC reviews the proposal and approves “up to” a certain number of hours, pure parallel observations are crafted by the observer based on their example observations and sized to fit the pure parallel slots assigned to them. In this process pure parallel PIs work closely with the STScI Program Coordinators (PCs).

3 Pure Parallel Slots and Group Slot

A parallel **slot** corresponds to a single exposure of a prime program (typically a single dither position, see Figure 1). A slot includes instrumental overheads; however mechanism moves are not included in the parallel slot, and the slot is not constrained by them. A **group slot** is a set of slots/exposures that are part of the same dither pattern. We have noticed that, in proposals, observers use the term “slot” as a substitute for “group slot”.

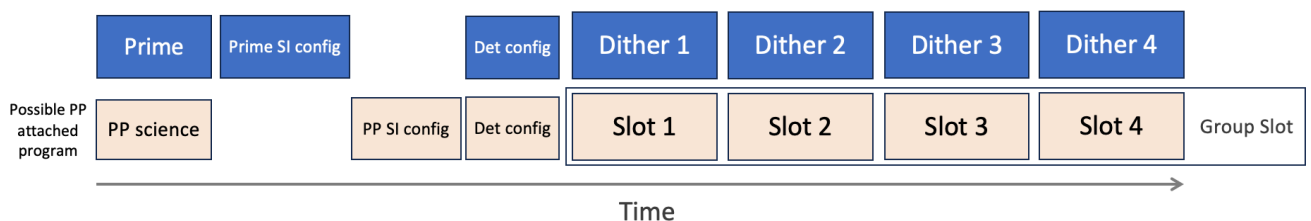


Figure 1: Schematic representation of a JWST visit structure for a prime program (blue) with available slots where a pure parallel exposure can be attached (orange). The instruments mechanisms configuration occurs sequentially, whereas the detectors configuration for both instruments is simultaneous. Each pure parallel slot corresponds to a single exposure; all slots shown are associated with a 4-point dither pattern position and form a group slot.

4 Pure Parallel Slots Assignments

The process currently followed to assign pure parallel slots is as follows:

- The Long Range Plan (LRP) team builds the observing plan based on the pool of proposals approved by the TAC.
- The JWST Pure Parallel Operations (JPOPs) tool is used to generate a list of available science and calibration slots; this list is then provided to the STScI JWST instrument teams to reserve pure parallel calibration slots.
- The instrument teams run an independent SQL query¹ on the Proposal Planning System (PPS) Database, and reserve pure parallel group slots for pure parallel calibration activities (primarily darks). Because dark parallel exposures can extend over several prime exposures, planned pure parallel calibration slots will block the entire group slot, not just the “reserved” individual slots (Figure 2).
- All group slots reserved by the instrument teams are removed from the JPOPs list.
- The remaining science slots are distributed to the pure parallel science programs. A pool of available slots is assigned to each program in APT, so there is no conflict between programs.
- At this point PIs can begin assigning remaining slots to their programs.
- It is noted that darks are currently not executed as a 3rd parallel instrument with a pure science parallel.

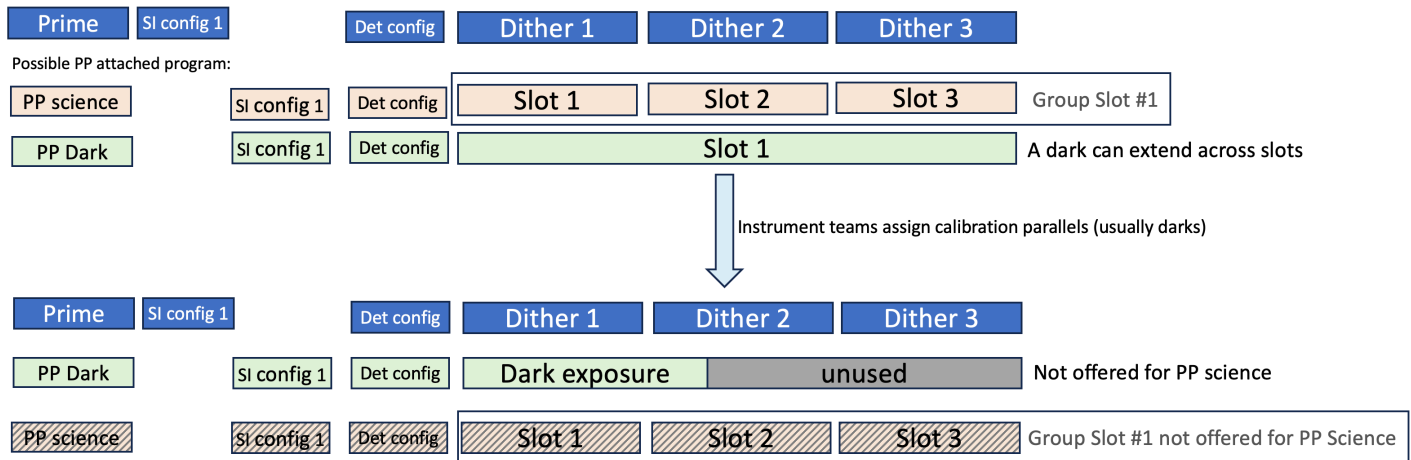


Figure 2: Schematic representation of pure parallel calibration slots attachment. Even if only a fraction of a slot group is used, the entire group slot will be not available for science.

¹ The suitability of the parameters of this search, and how it compares with the JPOPs list, are aspects currently under evaluation.

5 Pure parallel programs completion status

In JWST Cycles 1 through 3 a total 8, 4, and 8 Pure Parallel programs were submitted per cycle, and 3, ² and 2 were recommended by the TAC. All these submitted programs made use of NIRCcam and NIRISS. This corresponds to an oversubscription of ~1:3, 1:2 and 1:4 per Cycle, respectively. Finally, the Cycle 4 call for proposals saw 10 pure parallel programs submitted, including, for the first time, a program that uses MIRI.

Table 1 presents the current status of all JWST pure parallel programs. At the time of writing this report, 100% of the Cycle 1 have been completed, and 53 and 330 Cycle 2 and 3 visits, respectively, remain to be executed. Note the S&OC allows the PI to add more hours in APT than the allocated hours to facilitate scheduling. This does not mean all of the APT charged time will be observed.

Cycle	PID	Approved hours	Status
1	1571	Up to 591.0	COMPLETED
1	2211	Up to 38.0	COMPLETED, however, visit 48:1 was recently SKIPPED due to the prime 1266 visit 7:1 being SKIPPED. Schedulers waiting on the prime to be repeated so that the parallel visit can be repeated as well
1	2514	Up to 150.0	COMPLETED
2	3383	Up to 205.0	7 visits remaining to be executed; APT charged time: 192.0 hours
2	3990	Up to 600.0	25 visits remaining to be executed; APT charged time: 612.2 hours
2	4681	Up to 410.0	21 visits remaining to be executed; APT charged time: 332.3 hours
3	5398	Up to 400.0	70 visits remaining to be executed; APT charged time: 53.7 hours
3	6434	Up to 600.0	260 visits remaining to be executed; APT charged time: 709.3 hours

Table 1: Approved pure parallel programs completion status as of November 1st 2024. The charged time takes into account the visits listed in APT, including the ones that are not yet executed. Note that, to facilitate scheduling, some programs have APT charged time over the allocated program hours.

To date, these observations have resulted in the publication of one science paper (Williams et al, 2024 arXiv:2419.01875).

6 Main Limitations to Pure Parallel Implementation

Mechanisms moves: the number of mechanism moves/available spectral configurations in pure parallels is determined by the prime programs. In short, if a prime program only uses three filters, the parallel program will not be able to use more than 3 different spectral configurations.

Each visit file uploaded to the spacecraft contains the critical timing window for which the observation is valid, momentum management data, guide stars information, dither pointing information, target acquisition and a series of science activities. *Each science activity includes only*

² One of the approved programs was separated into two.

one prime mechanism and dither patterns; therefore, the attached parallel can only have one spectral configuration per science activity in the visit.

This scheme is part of the architecture of the Onboard Script Subsystem (OSS): any modification to this concept would be a fundamental change in the S&OC operations.

Observers have suggested ways to allow more mechanism moves, for instance to make every single dither position a separate activity hence allowing one spectral configuration per dither position. Implementing such change would be resource-consuming, and would come with a significant overhead increase, hence impacting the prime program and its efficiency. In addition, only limited testing has been done on the impact of a mechanism move (e.g. pointing stability and cross-instrument electromagnetic interference, EMI) on the prime observation.

Data volume: the [nominal data allocation](#) for a visit is the sustainable downlink rate (0.87 MB/s) times the visit duration, where visit duration is slew time plus scheduling duration. Data excess for a visit is data volume minus the nominal data allocation. If a visit exceeds its nominal data allocation attaching pure parallel slots may be challenging; if data excess goes over a certain threshold the parallel may be pulled out. This data excess will depend on the number of detectors and configurations used in the prime visits.

Prime program observing mode: There are certain science modes/templates that do not allow the attachment of parallels. This is because the science modes require extremely precise pointing stability throughout the visit (see Section 2), and there are additional concerns about the impact of cross-instrument (EMI). To allow for additional pure parallel opportunities the S&OC could consider expanding the list of observing modes that allow their attachment; this would require thorough on-orbit testing to evaluate potential impact on the prime observations.

7 Findings and associated actions

- Finding #1: For planning purposes pure parallel observers would find it very useful to understand the slots duration, group slots, and number of spectral configurations available for pure parallel programs in Cycles 1 through 3. Only part of this information is already available in JDox.
 - Recommendation #1: S&OC to gather these details and make it available in JDox. In particular observers want to know, for parallel-eligible prime-instrument visits: the number of group slots and slots within the visits; the distribution of total integration times; the distribution of mechanism moves (i.e. number of spectral configurations).
- Finding #2: Often pure parallel programs would like to have additional spectral configurations. However, as per current JWST's policies, pure parallels are not allowed to influence aspects of the observing strategy of the primary observations
 - Recommendation #2a: At this point we do not recommend a design change on the observatory operations to accommodate additional mechanism changes(filters/gratings) on the parallel instrument that may have an impact on the prime science program. Implementing such change would require: (1) A thorough on-orbit testing plan to ensure the mechanism change does not impact the science quality of the prime program. (2) Rewriting sections of OSS, which would require extensive

- testing first unit-testing by the individual developers, and then verification and validation testing in simulators. (3) A re-writing of the Observation Plan Generation System (OPGS) rules, to ensure a seamless handshake among different group subsystems and a proper on-board execution. (4) A reevaluation and change of the overheads model. (5) A review of the JWST science policies, that currently state that pure parallel programs will not impact the prime (see also Action #2b). To mitigate the uncertainty of the available number of mechanisms moves at the time of writing a proposal, pure parallel PIs are encouraged to design a primary/optimal program, and also to consider and describe in their proposals how to achieve/adjust the proposed science objectives with a reduced number of spectral configurations.
- Recommendation #2b: We also do not recommend requiring prime programs to adjust their observations to accommodate pure parallel programs. Besides the potential impact on the science of the prime program, this would require extensive coordination between multiple observing teams that would necessarily double or triple the workload for the community and STScI program support staff and schedulers.
 - Finding #3: The terms slot and group slot are confused by users is generally confused by users.
 - Recommendation #3: Update JDox to further clarify the terminology.
 - Finding #4: The assignment of STScI's instrument team's calibration pure parallels may not be optimized, thus reducing the available pool of science pure parallel slots.
 - Recommendation #4: The S&OC is investigating the assignment process and will take steps to optimize it (e.g. by ensuring the length of darks are well matched to the used slots and group slot).
 - Finding #5: Darks could be attached as a third instrument in parallel with a pure science parallel.
 - Recommendation #5: Under investigation by systems engineering.
 - Finding #6: The S&OC could expand the list of modes that allow attached pure parallels.
 - Recommendation #6: Investigate the cost/benefit of testing the impact of attaching pure parallel observations to currently non-allowed modes. For instance, in the case of TSO exoplanets transits it will typically allow only two spectral configurations, one for the (generally short) target acquisition process, the other for the (generally long) single exposure no-dither activity. This may not be useful for pure parallel programs.

Appendix A

Pure Parallel Working Group: Charter

The JWST Mission Office is convening an internal group to review the implementation of pure parallel observations on JWST. The working group will consider the following questions:

- What are the main limitations on scheduling pure parallel observations with JWST as currently implemented?
- What are the statistics on how Cycle 1 and 2 programs are using the available slots? How well do those slots match the parameters described in the original proposal?
- What mitigating strategies could be employed to add flexibility for scheduling pure parallel observations?
- What work is required to implement those mitigating strategies – actions, fte support, risk to observatory?
- What issues could limit those mitigating strategies – eg data volume, complex implementation?
- What science results are being achieved by the current JWST pure parallel programs? How do those results compare with HST pure parallel programs?
- What actions should be taken to implement pure parallels in Cycle 4 and subsequent cycles? Continue as is, implement mitigations, or cancel pure parallel programs?

STScI will also contact the Principal Investigators of Cycle 1 and 2 Pure Parallel programs and ask them for feedback on two questions:

- What science questions from their original proposals will be addressed by the data that have been acquired?
- What science questions cannot be addressed and what changes in operational procedure would be required to address those questions?

The Working Group will submit a report to JWSTMO/DO by October 31 2024

