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Observation Planning and Scheduling for the Hubble and James Webb Space Telescopes: Insights and Strategies

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Abstract

The Space Telescope Science Institute (STScI) manages science and mission operations for NASA's Hubble Space Telescope (HST) and James Webb Space Telescope (JWST). Within STScI, the Observation Planning Branch (OPB) oversees the end-to-end implementation of observation programs, from proposal acceptance through execution. Program Coordinators (PCs) act as technical liaisons between scientific teams and mission operations, leveraging specialized tools to validate targets, configure observations, secure guide stars, and resolve scheduling constraints. This presentation outlines the full lifecycle of an observation program, with a focus on the operational tools and engineering challenges involved in executing complex space-based observations.
Keywords: JWST, HST, space operations, observation planning, mission scheduling

Acronyms/Abbreviations

STScI (Space Telescope Science Institute), HST (Hubble Space Telescope), JWST (James Webb Space Telescope), OPB (Observation Planning Branch), PCs (Program Coordinators), PIs (Principal Investigators), TAC (Telescope Allocation Committee), GO (General Observer), SNAP (Snapshot), CAL (Calibration), DDT (Director's Discretionary Time), ToO (Target of Opportunity), APT (Astronomer's Proposal Tool), TTRB (Telescope Time Review Board), CS (Contact Scientist), LRP (Long Range Planner), MAST (Mikulski Archive for Space Telescopes), HOPR (Hubble Observation Problem Report), and WOPR (Weekly Observation Problem Report)

1. Introduction

The STScI oversees science and mission operations for major space observatories, including NASA's JWST and HST. Within STScI, the Science Operations & Engineering Division (SCOPE) focuses on building tools and systems that support efficient planning and execution of astronomical observations for HST and JWST. A key branch within this division, the OPB, is responsible for preparing science, engineering, and calibration programs for both near- and long-term scheduling.

Once a research proposal is awarded telescope time, OPB assigns a Program Coordinator (PC) to manage its operational execution. PCs serve as the primary technical point of contact between the science team and STScI, translating scientific objectives into executable spacecraft commands. This includes validating target selection, configuring exposure parameters and instrument modes, and incorporating special requirements through mission planning tools. PCs also identify viable guide stars, determine scheduling windows, and resolve conflicts with other observatory activities. Internal technical reviews and close coordination with investigators ensure all details are finalized before execution.

Given the variety of program types and constraints—ranging from orbital dynamics to instrument-specific limitations—the planning process is inherently complex. This paper provides the space operations community with a detailed overview of how science programs are implemented on JWST and HST, emphasizing the planning workflows, tools, and operational challenges involved.

2. Material and Methods

Securing observation time on HST and JWST involves a highly competitive, dual-anonymous, peer-reviewed proposal process. This process includes technical evaluations, scientific merit reviews, selection by the Telescope Allocation Committee (TAC), and subsequent implementation. Central to this process, the TAC evaluates and prioritizes proposals with the goal of maximizing scientific return within the technical, operational, and scheduling constraints of each observatory. The OPB plays a key supporting role during the TAC process, serving as the technical liaison between the science review panels and STScI operations.

HST and JWST support a diverse array of science program types designed to optimize observatory usage and meet a wide range of scientific objectives. General Observer (GO) programs are the primary mechanism for community-driven science and are competitively selected through the TAC during the annual proposal cycle. Snapshot (SNAP) programs consist of short, flexible observations that can be inserted into otherwise unused gaps in the schedule, thereby increasing overall operational efficiency. Calibration (CAL) programs are internally managed by STScI to monitor instrument performance, verify system health, and ensure the continued accuracy and consistency of scientific data products. Director's Discretionary Time (DDT) programs provide a mechanism for rapid-response observations outside of the standard review cycle, enabling time-critical investigations of transient or high-priority phenomena. Collectively, these program types enable the observatories to support both long-term scientific goals and dynamic, time-sensitive opportunities, while maintaining the efficiency and integrity of mission operations.

2.1 Observing Program Implementation

Once a proposal is approved through the TAC process, the program enters the implementation phase. This phase is initiated through close collaboration between the PC and the Principal Investigator (PI), with the shared goal of translating the proposed scientific objectives into a technically sound, executable observation plan. This collaborative effort includes selecting the appropriate instruments and observing modes, configuring exposures, ensuring accurate target acquisition, and incorporating any special observational constraints such as timing constraints, roll angles, or guiding considerations.

The PI is given a submission deadline by which they must finalize and submit the observation plan via the Astronomer's Proposal Tool (APT), which provides an interface to build, configure, and validate observations. Upon receipt, the PC ingests the program into the STScI database and begins a detailed internal validation process. This step includes a series of technical and policy compliance checks to ensure the proposed observations conform to both operational and scientific guidelines. These include verifications that the program does not duplicate past or current observations, adheres to instrument-specific configuration rules, and remains within the limits of its approved allocation—such as the number of orbits, targets, instrument modes, filters, and any special requirements or constraints.

Programs that include unapproved elements—such as additional or modified targets, new timing requirements, or expanded resource requests—must undergo formal change control. In such cases, the PC works with the PI to submit a change request to the Telescope Time Review Board (TTRB). The TTRB is responsible for adjudicating proposed deviations from the original TAC-approved program. It evaluates whether the changes are scientifically justified, operationally feasible, and fair within the context of the peer-review process, ensuring that the integrity of the mission's scheduling and allocation framework is preserved.

To support this workflow, PCs utilize a suite of mission-specific tools in conjunction with APT. These tools enable in-depth evaluation of the program's technical feasibility, including detailed modeling of target visibility, guide star acquisition, slewing constraints, instrument buffer and memory usage, and orbital dynamics. These planning resources allow the PC to refine observation parameters to ensure compatibility with observatory operations and optimize the use of limited observing time.

PCs support a broad spectrum of science program types on both HST and JWST, including GO, SNAP, CAL, and DDT programs. In addition to these core categories, PCs also manage highly complex, time-critical, and coordinated observations that introduce unique operational and engineering challenges. These include multi-observatory campaigns requiring precise alignment with other space and ground-based observatories such as Chandra, ALMA, and XMM-Newton, often involving narrow and non-recurring scheduling windows that demand careful long-range planning and inter-agency coordination.

Programs targeting solar system objects or other moving targets introduce an additional layer of complexity, as they require dynamic ephemeris tracking and real-time updates to maintain accuracy in targeting. Precision-timing programs, such as those aimed at capturing exoplanet transits or eclipsing binary events, impose strict constraints on execution timing and demand high-fidelity modeling of spacecraft visibility, buffer capacity, and instrument readiness to ensure success.

One of the most operationally demanding program types PCs support is the Target-of-Opportunity (ToO) program. These observations are designed to respond rapidly to transient and unpredictable astronomical events, such as supernovae, tidal disruption events, gamma-ray bursts, or electromagnetic counterparts to gravitational wave detections. ToO programs must be technically pre-defined and scientifically justified at the proposal stage but require rapid activation and dynamic integration into the existing observation timeline upon trigger. When a ToO is invoked, the PC must work in real-time with the PI, mission planners, and scheduling teams to insert the observation without violating other scheduling constraints or compromising ongoing science programs. In some cases, existing observations must be rescheduled or reprioritized, requiring careful impact assessment and conflict resolution across mission planning systems.

These highly constrained and dynamically managed programs showcase the operational agility and technical depth required of PCs. They must not only maintain a thorough understanding of the observatories' technical capabilities and limitations, but also exercise strategic judgment in navigating trade-offs between schedule stability, scientific responsiveness, and overall mission efficiency. Successfully executing these challenging programs underscores the critical role of science operations engineering in enabling frontier science while preserving the integrity and throughput of space observatory operations.

In parallel with PC review, each program is assigned a Contact Scientist (CS), a subject matter expert in the relevant scientific field and instrument. After the PC validation checks and once the program is error-free, the CS conducts an independent science and instrument review to verify that the proposed observation strategies are scientifically sound, instrumentally appropriate, and aligned with the capabilities and constraints of the telescope. This includes detailed assessments of target selections, observing configurations, and special requirements, with a focus on identifying scientific risks or inefficiencies. If the CS identifies significant technical issues, configuration warnings, or policy violations, these must be resolved by the PI prior to the program being cleared for further processing. The CS provides expert guidance throughout this process and ensures that the scientific integrity and feasibility of the program are preserved.

2.2 Planning and Scheduling

Once all internal reviews are complete and the observation visits are nearly ready for flight, Program Coordinators (PCs) perform a test scheduling step to confirm that the visits can be scheduled as-is with their current constraints and ephemeris files. If a visit does not schedule, the PC investigates the issue—this could be due to constraint conflicts, target visibility limitations, or other scheduling restrictions. The PC then works to resolve the issue, which may require adjusting the visit timing to fit within a specific, often narrow, observability window. In these cases, the PC coordinates closely with the Long Range Planner (LRP) and Calendar Builder to ensure these constrained visits are included in the long-range planning timeline and not overlooked.

After the PC identifies a workable spot in the calendar, they inform the LRP and short-term scheduling teams to make sure the visit is held in its assigned window. Once this is confirmed, the PC sets the visit to Flight Ready so that it can be formally incorporated into the scheduling pipeline.

Each week, science and engineering activities are reviewed and prioritized by the LRP and short-term scheduling teams to build a balanced observation schedule that supports both operational efficiency and scientific goals. Once the weekly schedule is finalized, the operations team compiles an Operations Package that includes command loads, timelines, and all necessary materials for the Mission Operations Center to prepare for uplink. Once uploaded, the observatory carries out the observations, completing the transition from planning to execution on orbit.

2.3 Execution, Data Processing, and Archive

If the observations execute successfully, the resulting raw science data and associated engineering telemetry are downlinked from the observatory and processed through automated calibration pipelines. These pipelines are responsible for applying instrument-specific corrections, generating high-quality calibrated science products, and extracting relevant metadata. The resulting data products are then ingested into the Mikulski Archive for Space Telescopes (MAST), where they are indexed, classified, and made accessible to the community through advanced search and retrieval tools. This entire process is not performed by the OPB.

However, in the event that an observation fails—due to issues such as guide star acquisition failures, loss of lock, or onboard anomalies—the OPB becomes directly involved. The PC works closely with the PI to assess the failure and prepare a formal Hubble Observation Problem Report (HOPR) and/or Weekly Observation Problem Report (WOPR) for JWST, which is submitted to the TTRB for evaluation. If the TTRB approves the request to repeat the observation, the PC, in coordination with the CS, proceeds to re-implement the affected visits. This process ensures that the observation is rescheduled and executed successfully, while maintaining adherence to the program's scientific and technical requirements. The OPB's role in this phase is critical to preserving scientific return and upholding the integrity of the observatory's scheduling and resource management framework.

3. Discussion and Conclusions

PCs, as part of the OPB, serve as the primary liaison between the STScI and PIs throughout the lifecycle of an observation program. Their role is critical not only in translating scientific objectives into executable observation plans, but also in navigating the technical, operational, and scheduling complexities of space-based observatories. The sustained interaction between PCs and PIs ensures that scientific goals are met while adhering to mission constraints, technical standards, and the peer-reviewed allocations approved through the proposal process.

The successful execution of scientific observations with HST and JWST is a technically sophisticated, interdisciplinary effort. It demands seamless integration of science operations, engineering constraints, and mission planning. From the moment a proposal is accepted, through detailed program development, technical reviews, flight readiness validation, scheduling, and final execution on orbit, OPB staff play a central role in ensuring that each observation is both scientifically productive and operationally feasible. PCs apply mission-specific planning tools, perform complex constraint analyses, and lead internal reviews to validate that all program elements are consistent with observatory capabilities, rules, and resource limits.

PCs also support dynamic program elements, such as ToO triggers, coordinated multi-observatory campaigns, and time-sensitive constraints, which add additional layers of complexity to scheduling and execution. By collaborating with instrument experts, mission planners, and the PI, PCs manage these challenges while maintaining the integrity of the broader observing schedule.

References

This paper is not directly sourced from a specific external reference, but rather represents a synthesized summary based on established operational practices by the OPB team at STScI. The workflows outlined are well-documented across several key resources, including:

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