JWST Master Class Workshop

MOS hands-on

Elena Puga for the ESA JWST Science Operations Team

NIRSpec MOS hands-on

- **Multi-object spectroscopy of distant galaxies**

- In this hands-on session you will be asked to use
  - The Astronomer's Proposal Tool (APT)
  - More specifically, the MOS Planning Tool (MPT) which is part of the APT

- The same science case was already part of the ETC hands-on, so much of the observation planning is assumed to have been completed

Thinking about strategies

Shutter planning constraints

- Slit loss is a function of the relative location in the shutter
- MPT allows adjustment of the constraint on where sources can be placed in shutters

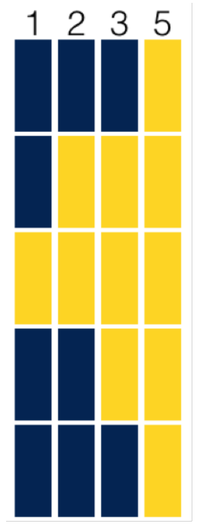
	Unconstrained *(source may be behind the bar)*	**Entire open shutter area** *(default)*	**Midpoint**	**Constrained**	**Tightly constrained**
					
Minimum relative flux transmission at 2.95μm	12%	30%	62%	75%	85%

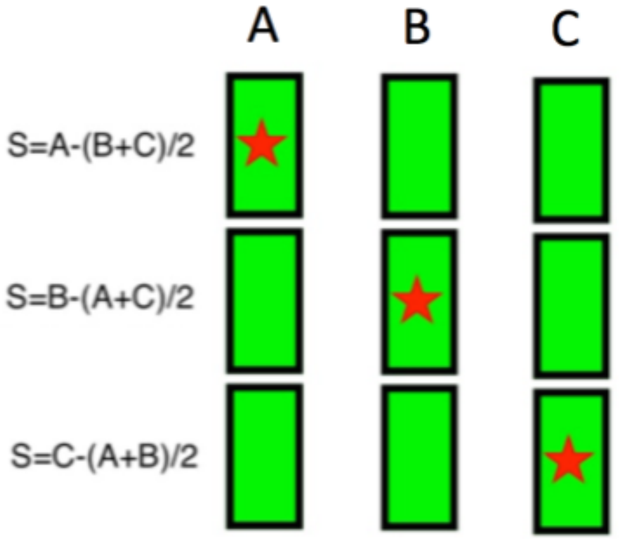
Nodding

- Open **slitlets** in cross-dispersion direction
- There are four selectable slitlets in MPT: 1, 2, **3**, 5

- Telescope is repositioned slightly between exposures
  - No MSA re-configuration
  - Background subtraction between nodded exposures
  - Improves PSF sampling and bad pixel mitigation

- The spectrum from a slitlet will be segmented, with bar shadows between the individual shutters

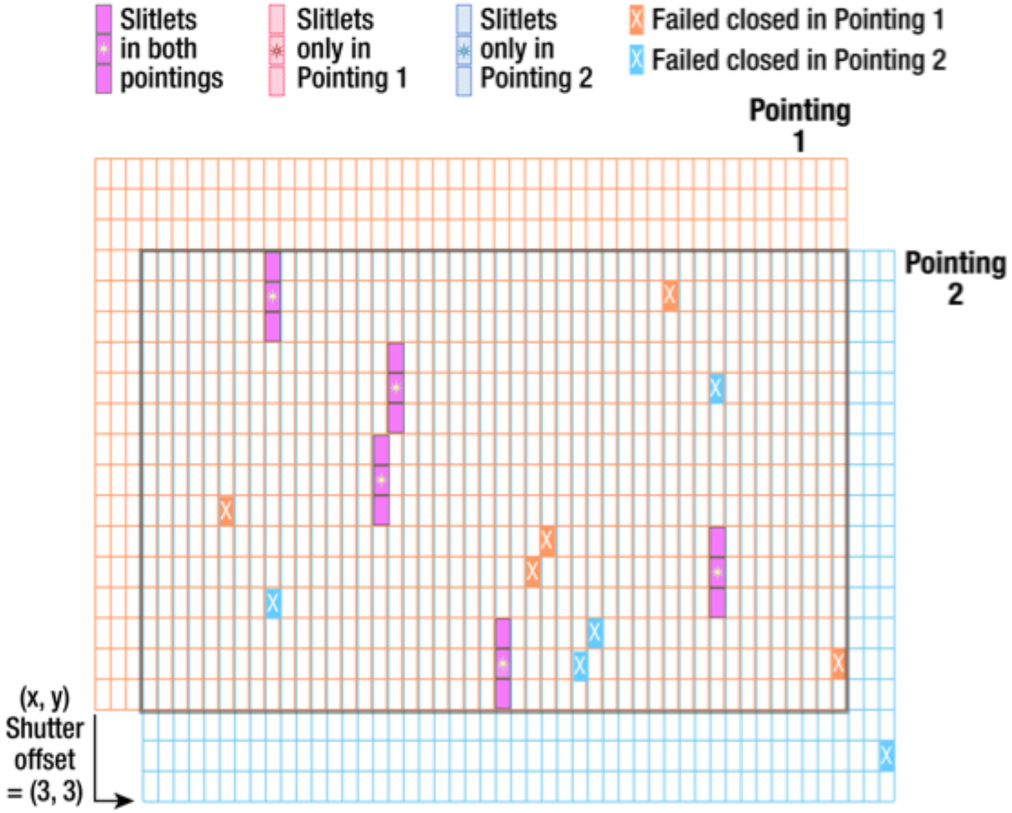




Dithering (fixed dither)

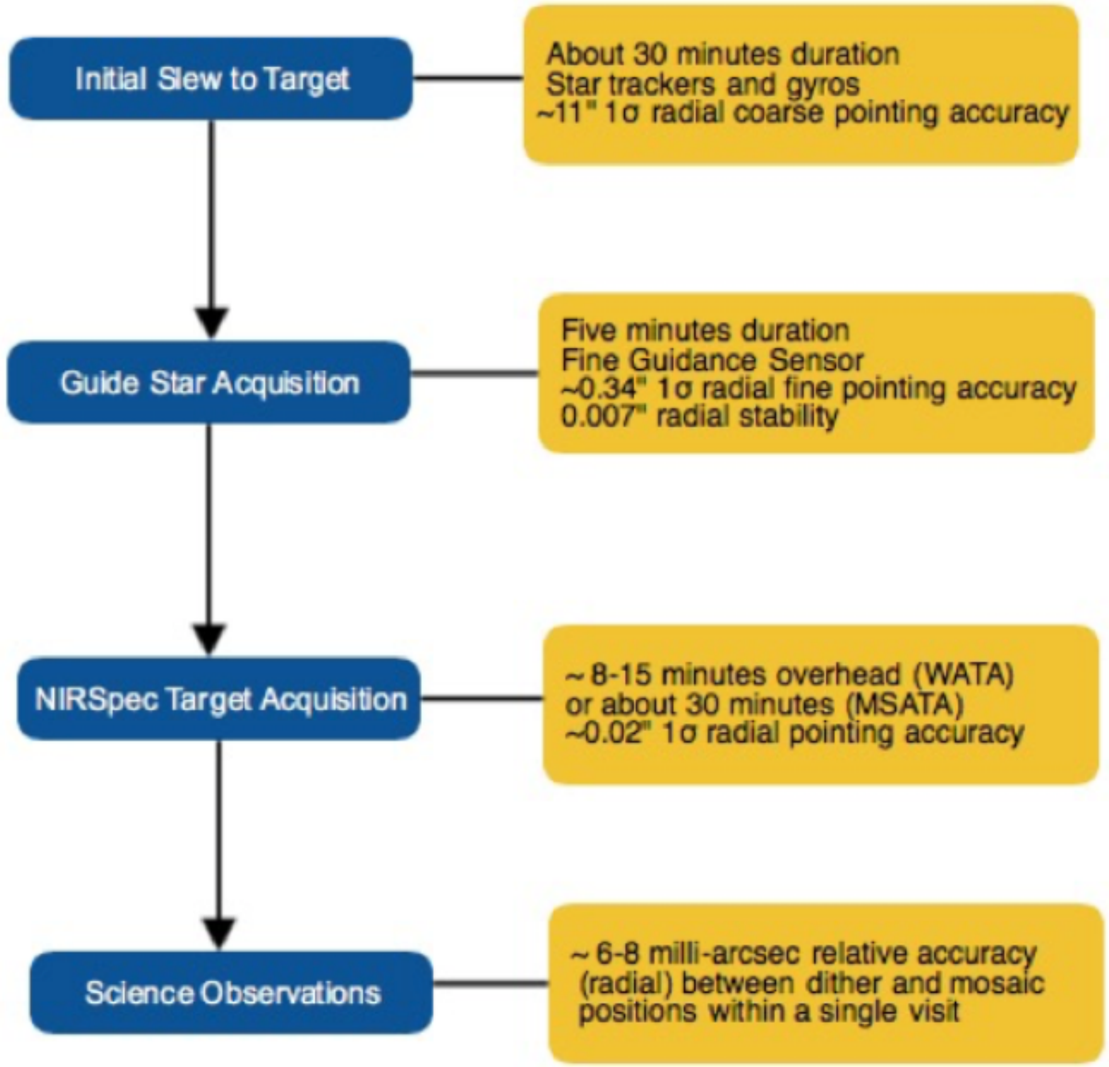
- Telescope repointed and MSA re-configured so many of the same sources fall in different shutters
  - Can be used to cover the wavelength gap
  - Improves PSF sampling and mitigates bad pixels
  - Allows observation of additional sources e.g. those behind shutter bars or the MSA mounting plate
  - Can mitigate effects of light leakage through MSA

- During optimisation, MPT will attempt to observe as many sources as possible at all dithers
- **Nodding and dithering can be used alone or together**



Target acquisition

- **MSATA** is expected to be the usual TA method for the MOS
  - uses 5-**8** reference stars over the entire MSA FoV
  - 8 chosen as a trade-off between TA accuracy and overheads
- MPT used to select reference stars at the assigned APA that will not be behind MSA bars or in failed shutters. This vetting is done at the Visit level at the first pointing in the Visit



Pre-imaging with NIRCam

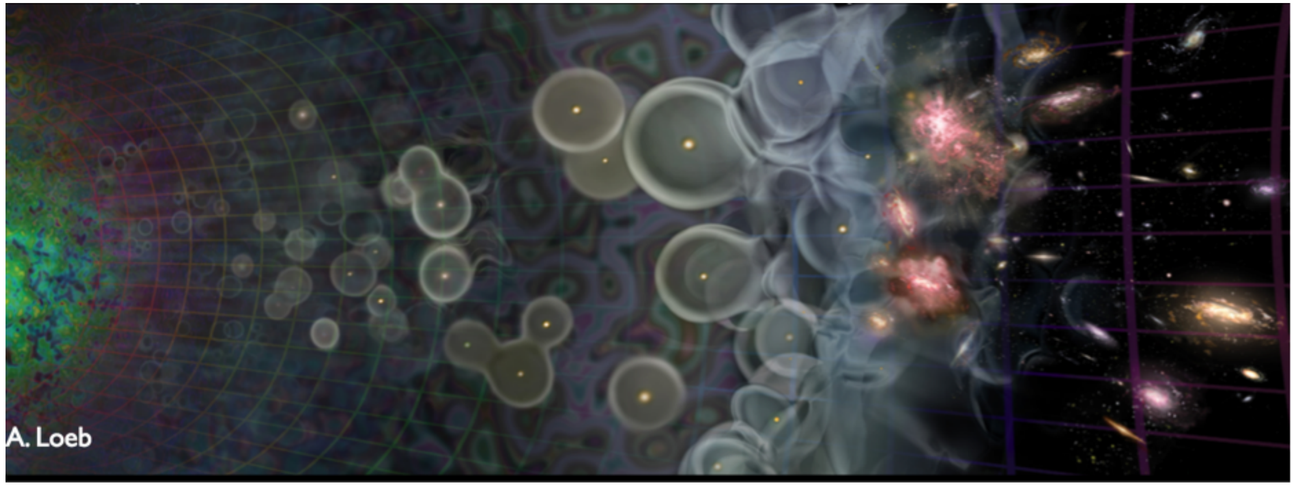
- Is imaging available with
  - deep enough to identify sources?
  - wide enough to fill the MSA and plan reference stars?
  - accurate enough astrometry to plan MOS?

- If not, request **NIRCam pre-imaging** in your proposal
  - accurate enough astrometry to plan MOS?
  - NIRCam image should be large enough to allow for any NIRSpec APA
    - Ideally 5x5 arcmin
    - typically a 2x1 mosaic + dithers to cover gaps
  - NIRCam observations must be flight ready at proposal submission

The science case

Science overview

- **Goal**
  - This program aims to study the evolution of galaxies from the early Universe (z>10), through the end of the dark ages (z=7-9), to the epoch of galaxy assembly (z=2-6)
    - Understanding very early stages of galaxy formation
    - Probing the epoch of re-ionization and the role of galaxies
    - Constraining the build-up of stellar mass and metals through time
    - Understanding the role of AGNs.
    - And looking for surprises…



Observation methodology

- **Methodology**
  - An in-depth program of this type would typically combine deep imaging (NIRCam) and follow-up spectroscopy (NIRSpec MOS)
  - In the following, we will use a much simpler example:
    - deep NIRSpec MOS observations at a single location
    - input source catalog derived from existing HST imaging

- **Spectral configuration**
  - MOS at low and medium spectral resolution
- **Type of sources**
  - Galaxies over a wide range of redshifts handled as compact (point-like) objects
- **Observation strategy**
  - Combination of nodding (1x3 slitlets) and dithering

Instrument configuration

- **Low spectral resolution (CLEAR/PRISM)**
  - sensitivity to continuum
  - wavelength coverage (0.6-5.3 μm at once)
  - higher-multiplex MOS thanks to the shorter spectra on the detector
  - Main drawback: lack of spectral resolution…

- **Medium spectral resolution (F100LP/G140M, F170LP/G235M, F290LP/G395M)**
  - clean separation of emission lines
  - allows accurate centroid calculation for the lines
  - Main drawback(s):
    - 3 configurations required to cover 1.0-5.2 μm
    - high multiplex only possible if spectra allowed to overlap

- Configurations give complementary information: **include all 4**

Getting started

Getting started

- Follow the steps on the handout

  - Plan your observation strategy
  - Open APT
  - Load the catalogue
  - Set-up the MPT Planner
  - Generate the plan
  - Create the observation

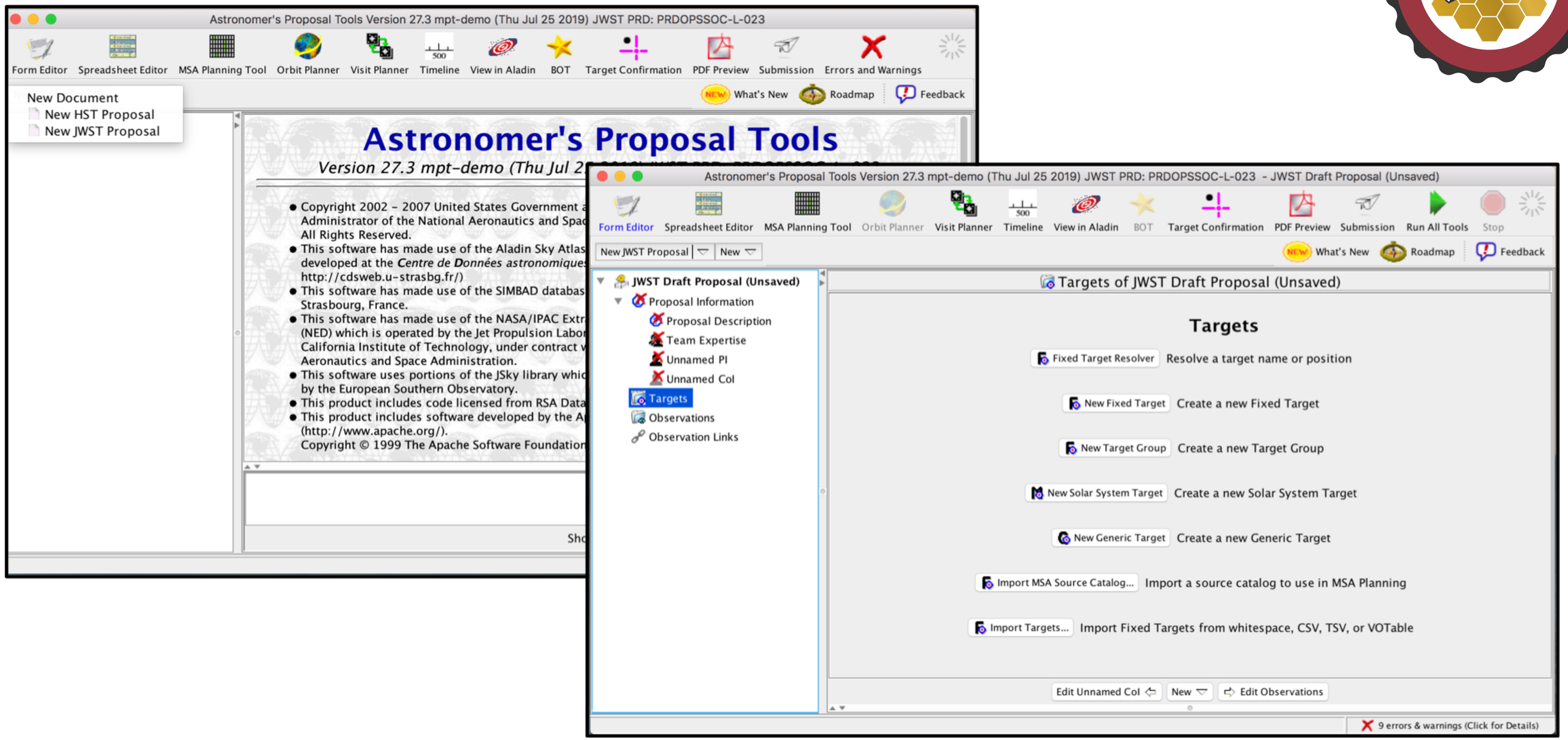
Cheat screenshots…

Plan your observation

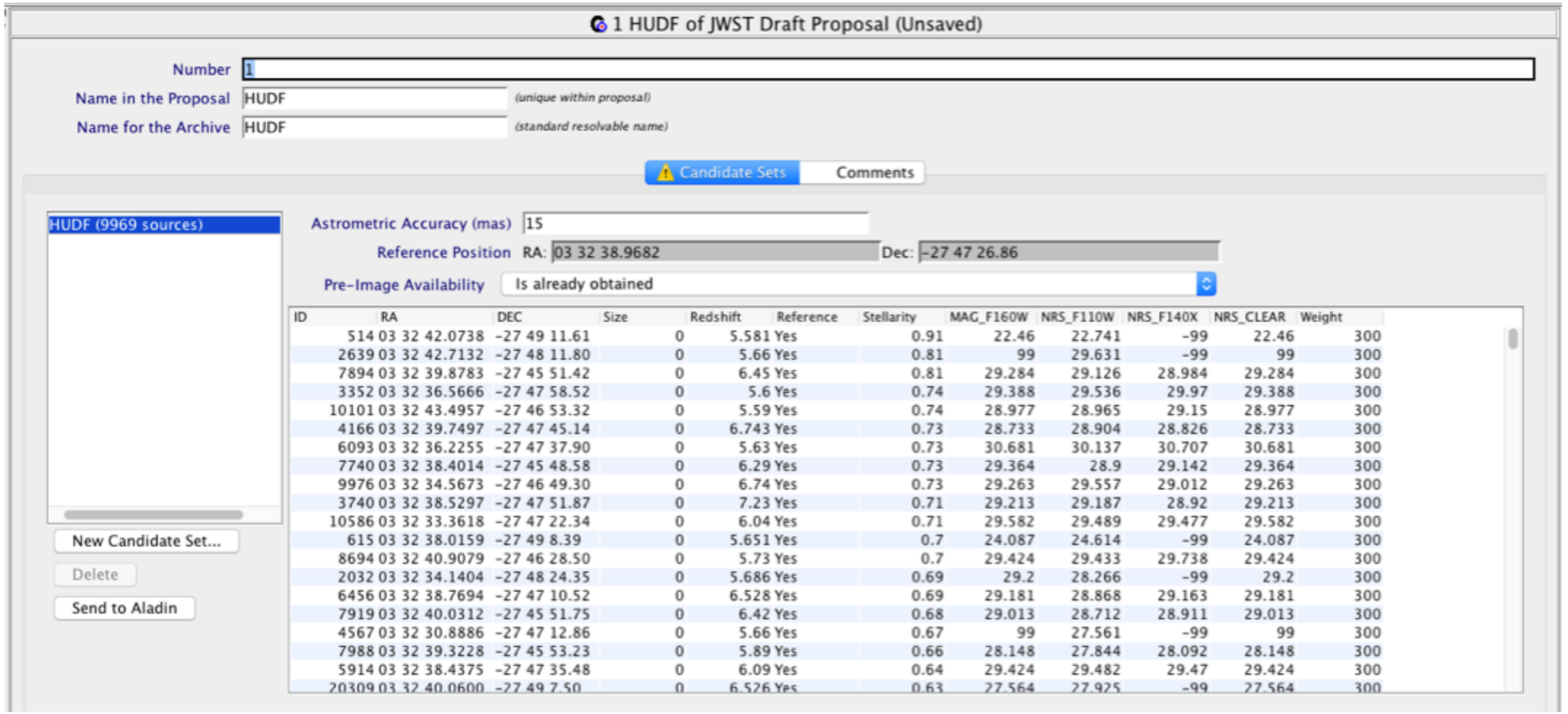
Dither	Nod	CLEAR/PRISM	F100LP/G140M	F170LP/G235M	F290LP/G395M
1	1	8	3	3	3
	2	8	3	3	3
	3	8	3	3	3
2	1	8	3	3	3
	2	8	3	3	3
	3	8	3	3	3
3	1	8	2	2	2
	2	8	2	2	2
	3	8	2	2	2
TOTAL Exps		**72**	**24**	**24**	**24**

- NOTE: for simplicity, create a program with **27** exposures per medium-resolution grating

Open APT

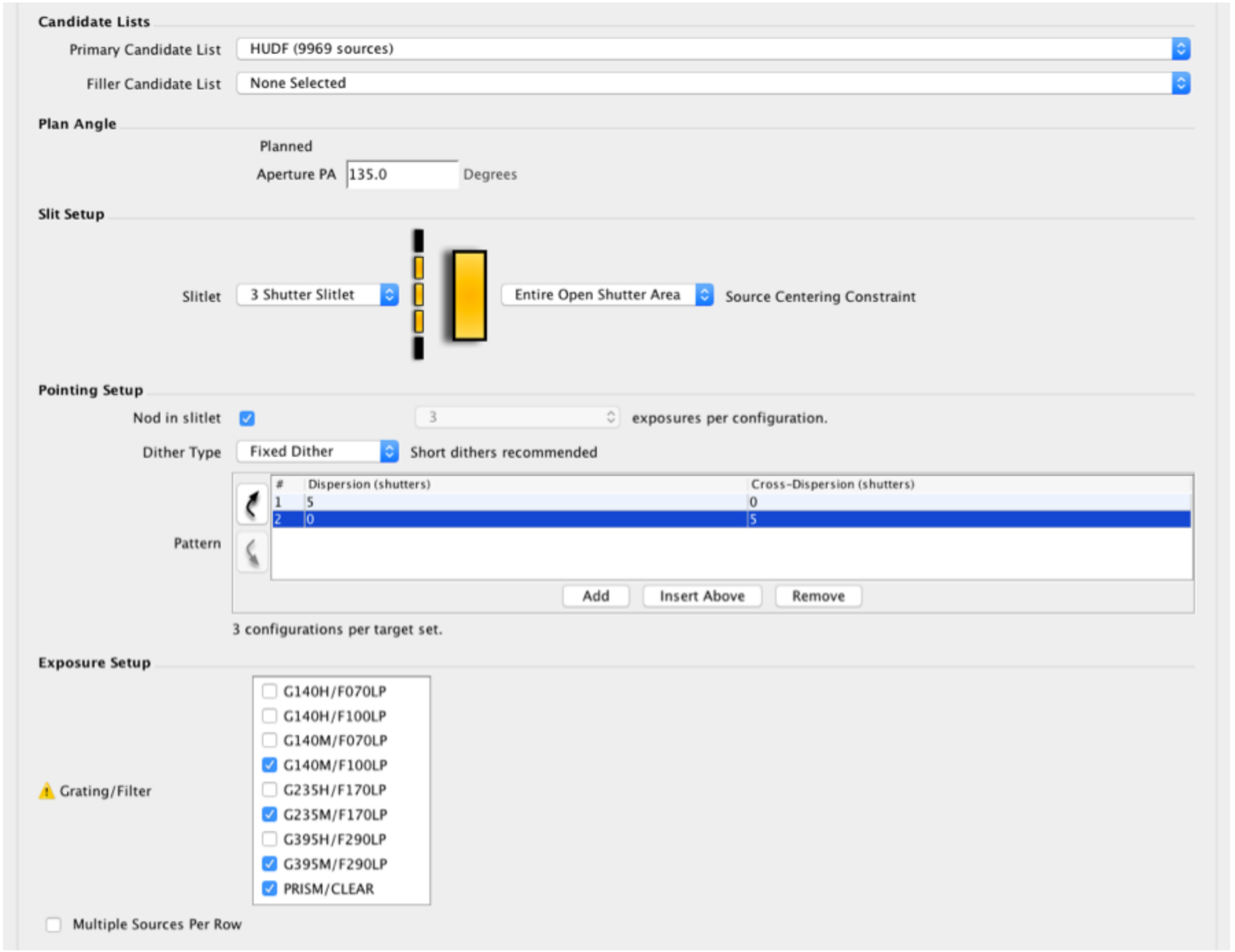

Astronomer's Proposal Tools Version 27.3 mpt-demo (Thu Jul 25 2019) JWST PRD: PRDOPSSOC-L-023
Form Editor
Spreadsheet Editor
MSA Planning Tool
Orbit Planner
Visit Planner
Timeline
View in Aladin
BOT
Target Confirmation
PDF Preview
Submission
Errors and Warnings
What's New
Roadmap
Feedback
New Document
New HST Proposal
New JWST Proposal
Astronomer's Proposal Tools
Version 27.3 mpt-demo (Thu Jul 2
Copyright 2002 - 2007 United States Government
Administrator of the National Aeronautics and Spac
All Rights Reserved.
This software has made use of the Aladin Sky Atlas
developed at the Centre de Données astronomiques
http://cdsweb.u-strasbg.fr/)
This software has made use of the SIMBAD databas
Strasbourg, France.
This software has made use of the NASA/IPAC Extr
(NED) which is operated by the Jet Propulsion Labor
California Institute of Technology, under contract w
Aeronautics and Space Administration.
This software uses portions of the JSky library whic
by the European Southern Observatory.
This product includes code licensed from RSA Data
This product includes software developed by the A
(http://www.apache.org/).
Copyright © 1999 The Apache Software Foundation
Sho
Astronomer's Proposal Tools Version 27.3 mpt-demo (Thu Jul 25 2019) JWST PRD: PRDOPSSOC-L-023 - JWST Draft Proposal (Unsaved)
Form Editor
Spreadsheet Editor
MSA Planning Tool
Orbit Planner
Visit Planner
Timeline
View in Aladin
BOT
Target Confirmation
PDF Preview
Submission
Run All Tools
Stop
New JWST Proposal
New
What's New
Roadmap
Feedback
JWST Draft Proposal (Unsaved)
Proposal Information
Proposal Description
Team Expertise
Unnamed PI
Unnamed CoI
Targets
Observations
Observation Links
Targets of JWST Draft Proposal (Unsaved)
Targets
Fixed Target Resolver
Resolve a target name or position
New Fixed Target
Create a new Fixed Target
New Target Group
Create a new Target Group
New Solar System Target
Create a new Solar System Target
New Generic Target
Create a new Generic Target
Import MSA Source Catalog...
Import a source catalog to use in MSA Planning
Import Targets...
Import Fixed Targets from whitespace, CSV, TSV, or VOTable
Edit Unnamed CoI
New
Edit Observations
9 errors & warnings (Click for Details)

Load the catalogue

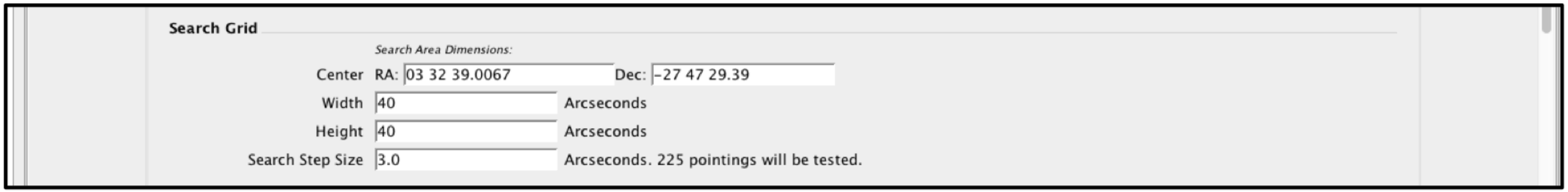


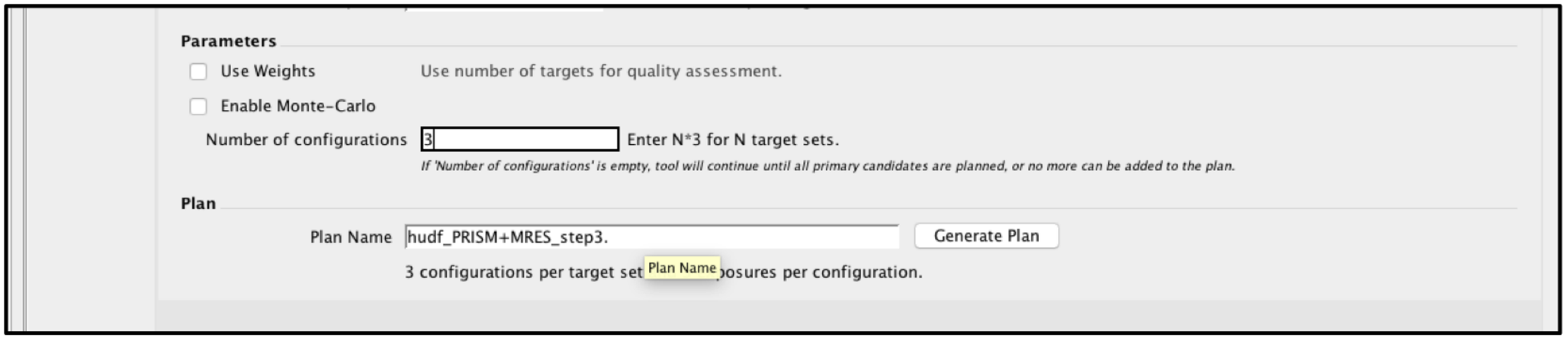
ID	RA	DEC	Size	Redshift	Reference	Stellarity	MAG_F160W	NRS_F110W	NRS_F140X	NRS_CLEAR	Weight
514	03 32 42.0738	-27 49 11.61	0	5.581	Yes	0.91	22.46	22.741	-99	22.46	300
2639	03 32 42.7132	-27 48 11.80	0	5.66	Yes	0.81	99	29.631	-99	99	300
7894	03 32 39.8783	-27 45 51.42	0	6.45	Yes	0.81	29.284	29.126	28.984	29.284	300
3352	03 32 36.5666	-27 47 58.52	0	5.6	Yes	0.74	29.388	29.536	29.97	29.388	300
10101	03 32 43.4957	-27 46 53.32	0	5.59	Yes	0.74	28.977	28.965	29.15	28.977	300
4166	03 32 39.7497	-27 47 45.14	0	6.743	Yes	0.73	28.733	28.904	28.826	28.733	300
6093	03 32 36.2255	-27 47 37.90	0	5.63	Yes	0.73	30.681	30.137	30.707	30.681	300
7740	03 32 38.4014	-27 45 48.58	0	6.29	Yes	0.73	29.364	28.9	29.142	29.364	300
9976	03 32 34.5673	-27 46 49.30	0	6.74	Yes	0.73	29.263	29.557	29.012	29.263	300
3740	03 32 38.5297	-27 47 51.87	0	7.23	Yes	0.71	29.213	29.187	28.92	29.213	300
10586	03 32 33.3618	-27 47 22.34	0	6.04	Yes	0.71	29.582	29.489	29.477	29.582	300
615	03 32 38.0159	-27 49 8.39	0	5.651	Yes	0.7	24.087	24.614	-99	24.087	300
8694	03 32 40.9079	-27 46 28.50	0	5.73	Yes	0.7	29.424	29.433	29.738	29.424	300
2032	03 32 34.1404	-27 48 24.35	0	5.686	Yes	0.69	29.2	28.266	-99	29.2	300
6456	03 32 38.7694	-27 47 10.52	0	6.528	Yes	0.69	29.181	28.868	29.163	29.181	300
7919	03 32 40.0312	-27 45 51.75	0	6.42	Yes	0.68	29.013	28.712	28.911	29.013	300
4567	03 32 30.8886	-27 47 12.86	0	5.66	Yes	0.67	99	27.561	-99	99	300
7988	03 32 39.3228	-27 45 53.23	0	5.89	Yes	0.66	28.148	27.844	28.092	28.148	300
5914	03 32 38.4375	-27 47 35.48	0	6.09	Yes	0.64	29.424	29.482	29.47	29.424	300
20309	03 32 40.0600	-27 49 7.50	0	6.526	Yes	0.63	27.564	27.925	-99	27.564	300

Set-up the MPT planner

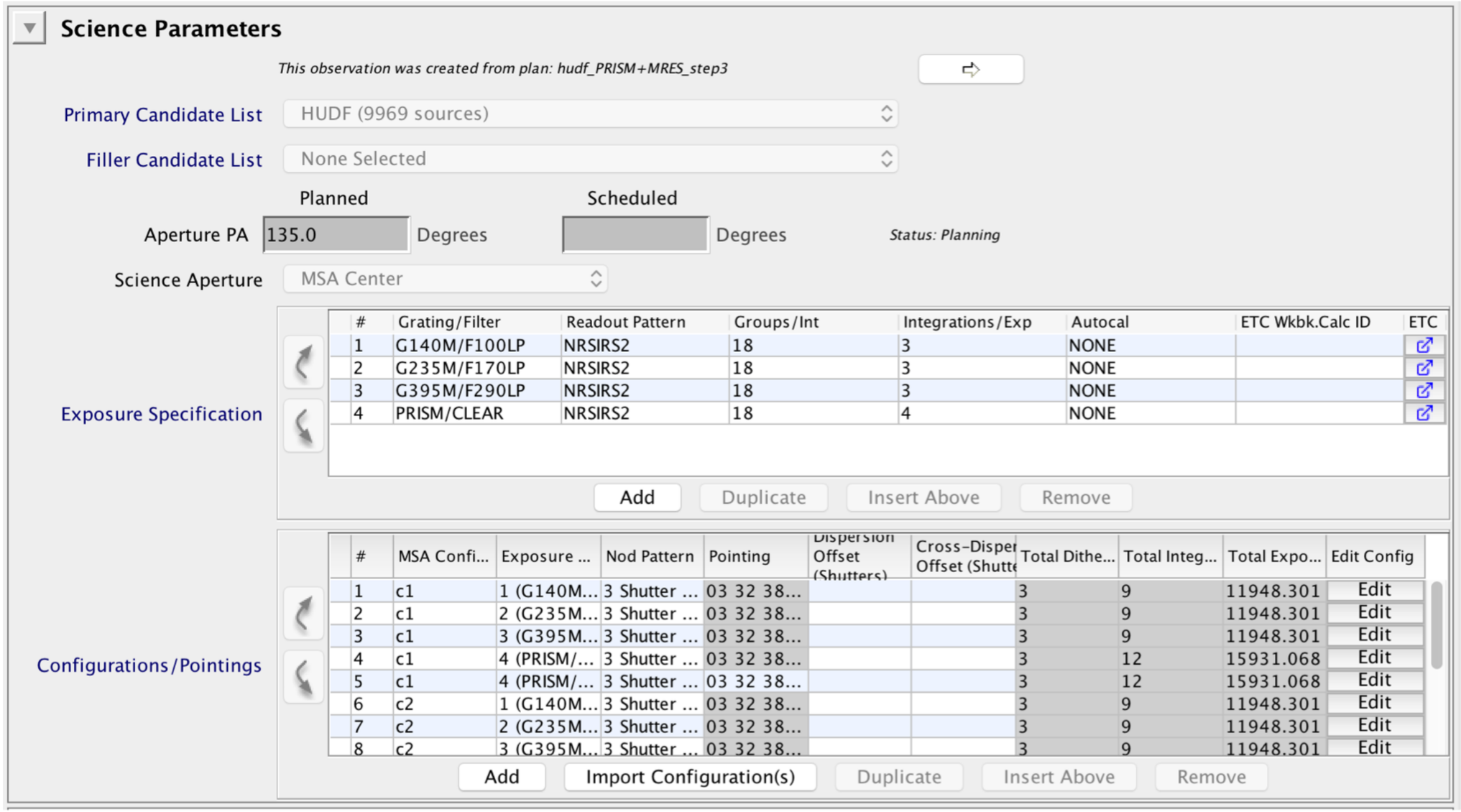


Planner parameters





Create the observation



Further reading

MOS/MPT Help and JDox

- **JWST Help Desk:** https://jwsthelp.stsci.edu

- **JDox Home page:** https://jwst-docs.stsci.edu/
  - Updated for the new version of APT/MPT

- Specific MOS/MPT materials:
  - MOS Roadmap
  - Multi-Object Spectroscopy
  - NIRSpec MOS Observing Process
  - NIRSpec MOS Operations
    - Catalogues and Images
    - Pre-Imaging Using NIRCam
    - Confirmation Images
    - Slit Losses
  - **NIRSpec MOS Recommended Strategies**
  - MOS APT Template