

# Exposure Time Calculator for the Roman Coronagraph Instrument



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# CGI Perf: overview

- Excel spreadsheet<sup>1,2,3</sup> to calculate exposure time to reach SNR accounting for
  - Contrast stability
  - Coronagraph performance
  - Throughput
  - Detector QE
  - Albedo
  - Stray light
  - Exozodi
  - Observing scenario

$$t = \frac{\text{SNR}^2 C_b}{C_p^2 - \text{SNR}^2 C_{sp}^2}$$

- $t$  – Exposure time
- SNR – Signal to noise ratio
- $C_b$  – Background electron noise count rate
- $C_p$  – Planet signal electron count rate
- $C_{sp}$  – Residual speckle count rate



# CGI Perf: overview

- Great for testing, but not very extensible

Roman Coronagraph Brightness Dependent Errors

575 nm

Possible sources of contrast and C stability

Contrast Source	C (avg raw)	ΔC (stab)
CG Design Perf	2.74E-09	5.48E-10
Dist x Sens Model	9.16E-09	2.87E-09

δC

Time Margin 99%

pl Thput 1.48%

Planet Flux Ratio 100.0 ppb

SNR target 5.00

2.9E-09 seIDC

93.6 mpi

0.0006 lpk

1.7E-10

total FRN 3.70

Current Target: EB Fiducial Target

Coronagraph Type: CGPERF\_HLC\_20190210b

Critical SNR	45.43
Critical FR	10.0 ppb, SNR=5.0
Critical fpp	142.5% SNR=5.0
Critical pl radius	7.88 @max elong
Hrs to SNR	0.05 hrs
tSNRraw	0.05 hrs
seconds to SNR	1.94E+02 sec
frames to SNR	97 frames
frame exp time	2 s

Threshold IMG NF B1

time to SNR 0.05 hrs EB Fiducial Target

Variance rates for det. noise sources

planet shot	2.1E-01	e/SR/s
speckle shot	3.0E-02	e/SR/s
zodi shot	3.8E-03	e/SR/s
dark noise	2.5E-03	e/SR/s
CIC + RNLeak	3.0E-02	e/SR/s
Stray light	4.7E-03	e/SR/s
read noise	0.0E+00	e/SR/s
noise var rate	3.46E-01	e/SR/s

Miss 33%

QE 69%

$$\xi_{crit} = SNR \frac{\sigma_{\Delta C}}{k_{pp}} \left( \frac{\tau_{pk}^{int} \tau_{mpix} \tau_{sp}}{\tau_{arc}} \right)$$

Error Category	Rollup	NEFR	native	Units	Comments	Equal Error Integration Time
Calibration	2.17					31314 seconds 8.70 hrs
Star Phot	1.41	ppb	1.41%	fractional		*instrument stray light needs attn
CTI	1.10	ppb	1.10%	fractional		
core thrupt	0.69		0.69%			
flat field	0.71		0.71%			
Image Correction	0.71		0.71%			

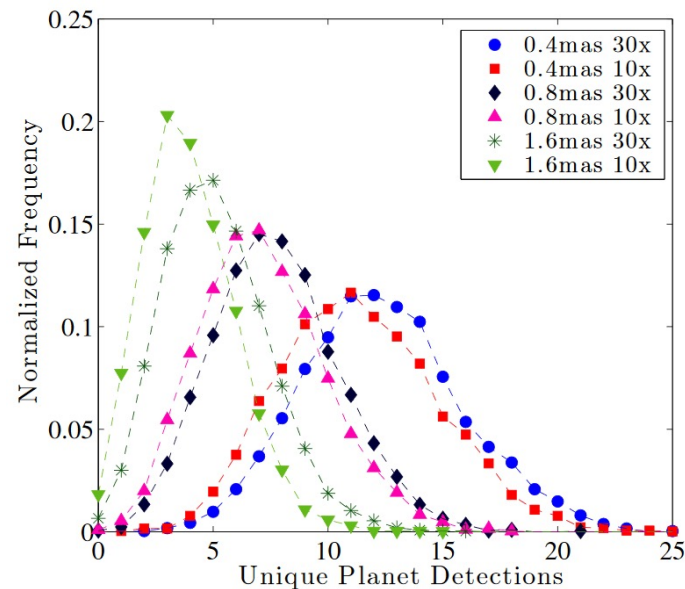
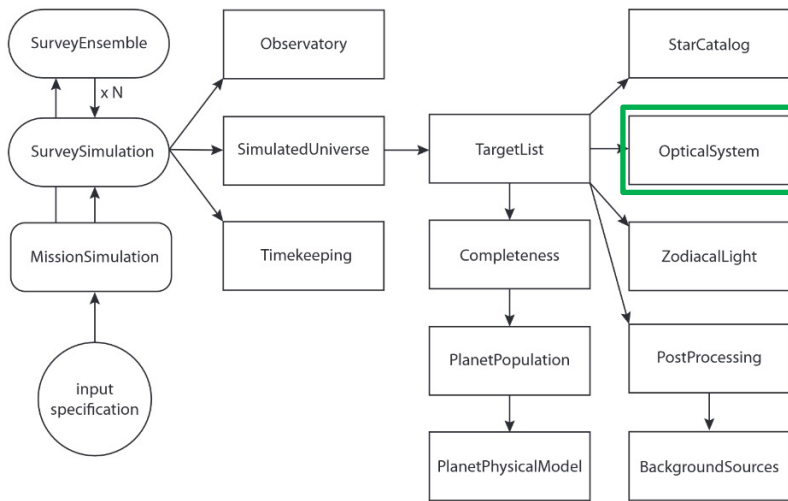
Notes Wkly Updates Scenario Error Budget DRM SNR Detector C S ...

Ready



# EXOSIMS: overview

- End-to-end simulations of space-based exoplanet imaging missions written in Python<sup>1,2,3</sup>
- Estimate detection and characterization yield by simulating hundreds of missions
- Extensible, modular, and open source



[1] Dmitry Savransky, C. Delacroix, D. Garrett (2017) [2017ascl.soft0610S](https://doi.org/10.1117/1/JATIS.6.2.027001) [2] Dean Keithly, D. Savransky, D. Garrett, C. Delacroix, G. Soto (2020) [doi:10.1117/1/JATIS.6.2.027001](https://doi.org/10.1117/1/JATIS.6.2.027001) [3] <https://github.com/dsavransky/EXOSIMS>



# CGI Perf in EXOSIMS

- Goal: Calculate exposure times quickly for a many targets and many observing scenarios
- OpticalSystem module written that can calculate the CGI Perf exposure time calculations
- Works directly from CGI Perf csv inputs
- Methods<sup>1,2,3</sup>:
  - Calculate background, speckle, and planet count rates
  - Calculate integration time
  - Calculate  $\Delta\text{mag}$  for an integration time via numerical inversion



# EXOSIMS input

- A JSON file
  - Telescope and Coronagraph information<sup>1</sup>
  - Specify which EXOSIMS modules to use
  - Hard coded parameters such as planet orbital parameter ranges
  - For each starlight suppression system we load the csv files from the CG\_Perf spreadsheet
- For more info see <https://exosims.readthedocs.io/en/latest/userparameters.html>
- To create and use planets in code, use the TargetList module
- EXOSIMS uses the TimeKeeping module to track time

[1] [https://roman.ipac.caltech.edu/sims/Param\\_db.html](https://roman.ipac.caltech.edu/sims/Param_db.html)

```
2 starlightSuppressionSystems : [  
3   { name : HLC-565 ,  
4     lam : 575,  
5     BW : 0.10,  
6     Rs : 0,  
7     IWA : 0.13049,  
8     OWA : 0.45,  
9     Nlensl : 5.0,  
10    lenslSamp : 2.0,  
11    occ_trans : $HOME/Documents/github/WFIRST-CGI-  
12    core_thruput : $HOME/Documents/github/WFIRST-C  
13    core_mean_intensity : $HOME/Documents/github/W  
14    core_area : $HOME/Documents/github/WFIRST-CGI-  
15    core_contrast : $HOME/Documents/github/WFIRST-  
16    core_platescale : 0.30,  
17    core_stability : $HOME/Documents/github/WF  
18    core_stability_setting : MCBE ,  
19    CG_Perf : $HOME/Documents/github/WFIRST-CG  
20  }  
21 ],  
22 observingModes : [  
23   { instName : imager ,  
24     systName : HLC-565 ,  
25     detectionMode : true,  
26     ContrastScenario : 2019_PDR_Update ,  
27     SNR : 5,  
28     tau_pol : 1,  
29     GCRFlux : 5,  
30     photons_per_relativistic_event : 250,  
31     luminescingOpticalArea : 0.7854,  
32     OpticalThickness : 4,  
33     luminescingOpticalDistance : 0.1,  
34     s_baffling : 0.001  
35   }  
36 ],  
37 modules : {  
38   PlanetPopulation : KnownRVPlanets ,  
39   StarCatalog : ,  
40   OpticalSystem : Nemati_2019 ,  
41   ZodiacalLight : Stark ,  
42   BackgroundSources : GalaxiesFaintStars ,  
43   PlanetPhysicalModel : ForecasterMod ,  
44   Observatory : WFIRSTObservatoryL2 ,  
45   TimeKeeping : ,  
46   PostProcessing : ,  
47   Completeness : ,  
48   TargetList : KnownRVPlanetsTargetList ,  
49   SimulatedUniverse : KnownRVPlanetsUniverse ,  
50   SurveySimulation : ,  
51   SurveyEnsemble :
```



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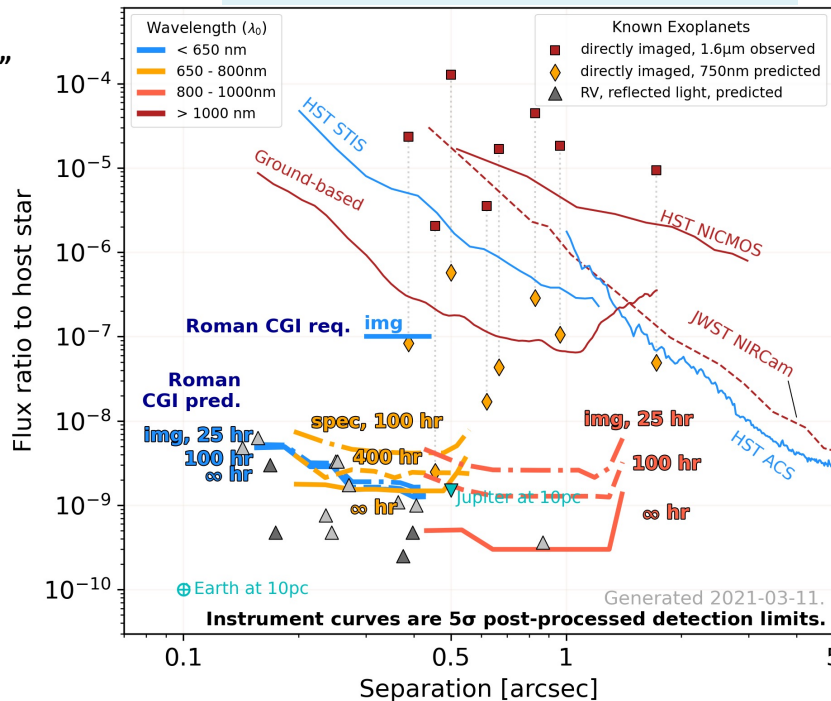
[github.com/nasavbailey/DI-flux-ratio-plot](https://github.com/nasavbailey/DI-flux-ratio-plot)

See “Observing with the Coronagraph Instrument” talk on Day 1

Predicted detection limits are strongly speckle-limited at shorter wavelengths

Based on lab demonstrations as inputs to high-fidelity, end-to-end thermal, mechanical, optical models.

Most Model Uncertainty Factors set to ~1




Brian Kern (JPL)  
John Krist (JPL)  
Bijan Nematı (UA Huntsville)  
A.J. Riggs (JPL)  
Hanying Zhou (JPL)  
Sergi Hildebrandt Rafels (JPL)

# Roman Coronagraph Exposure Time Calculator



Allows the user to derive integration times for:

- Three types of **targets**:
  - Self luminous exoplanets
  - Reflected light exoplanets
  - Exodust
- Three different **observing modes**:
  - Narrow Field of View Imager (575 nm, 10% bandwidth)
  - Single Slit, Prism-based Spectroscopy (730 nm, 15% bandwidth, R=50)
  - Wide Field of View Imager (825 nm, 10% bandwidth)
- Two Instrumental and Mission **performance** levels:
  - **Optimistic**: most model uncertainty factors are set to 1
  - **Conservative**: current best estimates of model uncertainty factors (will be updated as ground tests happen)
- Fully **documented**
- Public repository on **GitHub**
- Written in  **python**


[https://github.com/hsergi/Roman\\_Coronagraph\\_ETC](https://github.com/hsergi/Roman_Coronagraph_ETC)





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**Deep Dive Info Session on November 18, 2021, 9 am PT: [Link](#)**

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# Questions

