Exoplanet Direct Imaging Mission Simulation Code Interface Control Document

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ABSTRACT

This document describes the required input/output interfaces between each stand-alone module in the exoplanet direct imaging mission simulation code.

CONTENTS

Nomenclature

HE   Heliocentric Equatorial

ICD   Interface Control Document

MJD   Modified Julian Day

OD   Observatory Definition

OSD   Optical System Description

PP   Post-Processing

PPD   Planet Population Definition

PPM   Planet Physical Model

SC   Star Catalog

SE   Survey Ensemble

SS   Survey Simulation

SU   Simulated Universe

TL   Target List

1 Introduction

The exoplanet direct imaging simulation code generates ensembles of mission simulations for exoplanet direct imaging missions to estimate science yields. The code consists of stand-alone modules written in Python which may be modified without requiring modifications to other portions of the code. This allows the code to be easily used to investigate new designs for exoplanet direct imaging missions. This document describes the required input/output interfaces for the stand-alone modules to enable this flexibility.

1.1 Purpose

This Interface Control Document (ICD) describes the interface between modules of the code. The data inputs and outputs of each module are described. Following these guidelines will allow the code to be updated to accommodate new mission designs.

1.2 Scope

This ICD defines the interfaces between modules of the code. It does not specify the contents of the individual modules beyond a general description of what each module does.

1.3 Glossary

This section will contain definition of terms used throughout the document if needed.

2 Overview

The overall framework of the exoplanet direct imaging mission simulation code is depicted in Fig. 1. The code framework consists of stand-alone modules. The fundamental inputs of the simulation may require external data. These include the Optical System Description (OSD), Star Catalog (SC), Planet Population Definition (PPD), Planet Physical Model (PPM), Observatory Definition (OD), Rules, and Post-Processing (PP) modules. The other modules used in mission simulation require a combination of the fundamental inputs as well as modules upstream in Fig. 1. These include Target List (TL), Simulated Universe (SU), Survey Simulation (SS), and Survey Ensemble (SE) modules.

3 Global Specifications

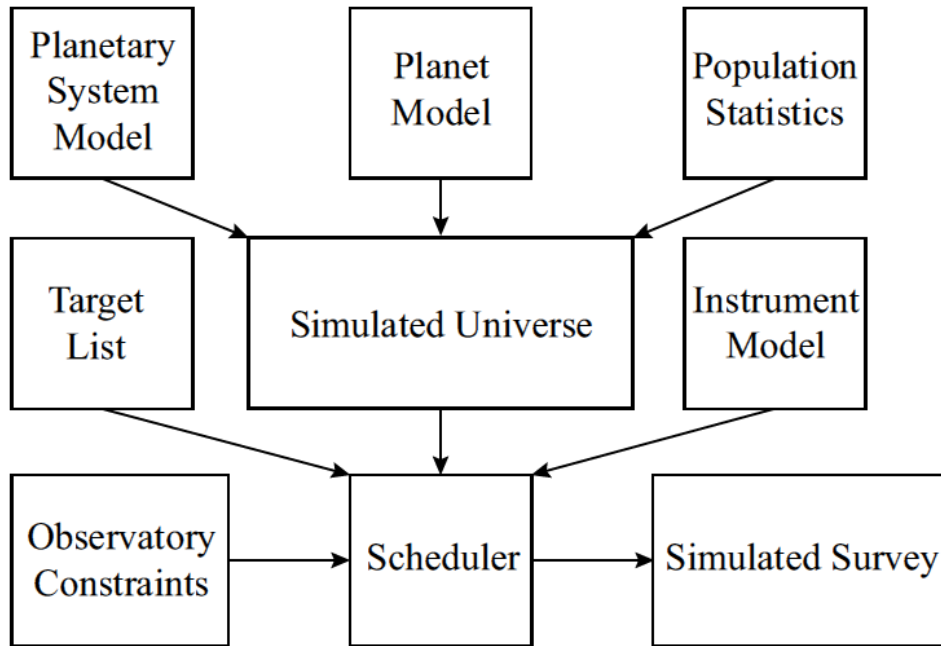This section specifies important information shared throughout the code.

Common Epoch

    J2000

Fig. 1.   Exoplanet direct imaging simulation code framework

Common Reference Frame
   Heliocentric Equatorial (HE)
Common Time
   Modified Julian Day (MJD $\triangleq$ JD - 2400000.5)

3.1   Python Packages
   The following Python packages are used for the WFIRST-specific version of exoplanet mission simulation:

astropy

   astropy.time
   astropy.units

numpy

4   Backbone
   All simulation execution will be performed by the backbone. This set of functions will have very limited built-in functionality, and will primarily be tasked with parsing the input specification described below, and then calling the specified instances of each of the framework modules, detailed in §5.

   A simulation specification is a single JSON-formatted (`http://json.org/`) file that encodes user-settable parameters and module names. The backbone will contain a reference specification with *all* parameters and modules set. In the initial parsing of the user-supplied specification, it will be merged with the reference specification such that any fields not set by the user will be assigned to their reference (default) values.

   The backbone will contain a standalone specification parser that will check specification files for internal consistency. For example, if modules carry mutual dependencies, the specification parser will return an error if these are not met for a given specification. Similarly, if modules are selected with optional top level inputs, warnings will be generated if these are not set in the same specification files.

   The backbone will contain an interactive function to help users generate specification files via a series of questions.

4.1   Specification Format
```
{
  "missionLifetime": 6,
  "missionDutyCycle": 0.24,
  "starlightSupressionSystems": [
```

```
    {
      "type": "SDO",
      "occulterDiameter": 50,
      "occulterDistance": 50000,
      "PSFfile": "/data/sdo1_psf.fits",
      "throughputFile": "/data/sdo1_thru.fits"
    },
    {
      "type": "coronagraph",
      "IWA": 3,
      "PSFfile": "/data/coron1_psf.fits",
      "throughputFile": "/data/coron1_thru.fits"
    }
  ],
  OSDmod: "hybridOSD1"
}
```

5   Modules of Fundamental Inputs

Modules containing fundamental inputs include Optical System Description (OSD), Star Catalog (SC), Planet Population Definition (PPD), Planet Physical Model (PPM), Observatory Definition (OD), Rules, and Post-Processing (PP). Much of the work of these modules will be reading external data and formatting the data for use by other modules. This section defines the input, output, and interface of each of these modules.

5.1   Optical System Description (OSD) NEEDS UPDATING

This module takes information about the optical system and formats the data into the specified outputs.

5.2   Star Catalog (SC)

This module takes information from a star catalog, such as Hipparcos, and formats the data into the specified outputs.

5.2.1   Inputs
star catalog information

Information from an external star catalog containing the target stars

5.2.2   Outputs
missionsim.starcatalog.radeg

List of target star right ascension values in degrees
missionsim.starcatalog.decdeg

List of target star declination values in degrees
missionsim.starcatalog.pmra

List of target star right ascension proper motion values in mas/yr
missionsim.starcatalog.pmdec

List of target star declination proper motion values in mas/yr
missionsim.starcatalog.rv

List of target star radial velocities in km/s
missionsim.starcatalog.parx

List of target star parallax values in mas

5.3   Planet Population Definition (PPD) NEEDS UPDATING

This module generates statistical distributions for planetary parameters.

5.4   Planet Physical Model (PPM) NEEDS UPDATING

This module generates the planet physical models needed for simulation. These include models for albedo, phase, and reflected and emitted light.

5.5 Time

This module contains all variables and functions related to global mission time and time tracking. There are two main tasks: lifetime and current mission time update.

5.5.1 Lifetime

Inputs

start
Mission start time in MJD
finish
Mission end time in MJD

Outputs

missionsim.time.start
Mission start time in MJD
missionsim.time.finish
Mission end time in MJD

5.5.2 Current Mission Time Update

Inputs

missionsim.time.currenttime
Current mission time in MJD (offset to zero at mission start)
Time Step
Time step in MJD to next mission time

Outputs

missionsim.time.currenttime
Update the mission time

5.6 Observatory Definition (OD) CURRENTLY WORKING

This module consists of three broad tasks: orbit, duty cycle, and keepout definition. The main inputs come externally and from the SC module.

5.6.1 Orbit

Inputs

Current Mission Time
Current mission time in MJD

Outputs

missionsim.observatory.r_sc
Observatory orbit position in HE reference frame at current mission time

5.6.2 Duty Cycle

Inputs

Current Mission Time
Current mission time in MJD

Outputs

missionsim.observatory.nexttime
Next available times in MJD
missionsim.observatory.nextduration
Time duration in MJD for next exoplanet detection and characterization referenced at
`missionsim.observatory.nexttime`

5.6.3 Keepout Definition

Inputs

Current Mission Time

Current mission time in MJD

missionsim.starcatalog

Output of SC module. See 5.2.2 for definitions

Outputs

missionsim.observatory.ko

List of Boolean values for each target at current mission time where true is when a target is unobstructed in the keepout zone and false is when a target cannot be observed due to obstructions in the keepout zone

5.7 Rules NEEDS UPDATING

This module contains rules governing the simulation of exoplanet imaging missions.

5.8 Post-Processing (PP) NEEDS UPDATING

This module describes the post-processing of results from the mission simulations.

6 Modules Using Internally Generated Data

Modules using data generated by the fundamental input modules include Target List (TL), Simulated Universe (SU), Survey Simulation (SS), and Survey Ensemble (SE). These modules do not take any inputs external to the code. They rely on information generated by other modules contained in the exoplanet mission simulation code.

6.1 Target List (TL) NEEDS UPDATING

This module takes inputs from the OSD, SC, PPD, and OD modules to generate target list output.

6.2 Simulated Universe (SU) NEEDS UPDATING

This module takes inputs from the TL and PPM modules to generate a simulated universe.

6.3 Survey Simulation (SS) NEEDS UPDATING

This module takes inputs from the SU, PPD, Rules, OD, OSD, PP, and PPM modules to run a survey simulation.

6.4 Survey Ensemble (SE) NEEDS UPDATING

This module takes inputs from the SS and PP modules to complete ensembles of mission simulations.