WFIRST IMPipeline Updates and Wavefront Error Generation Based on Operational Scenarios

Derek Barnes

June 5, 2017

1 Introduction/Background

WFIRST, the Wide Field InfraRed Survey Telescope, is a NASA mission that aims to perform direct imaging of exoplanets and study dark energy[2]. WFIRST has a large 2.4 diameter mirror acquired from the NRO (National Reconnaissance Office) which enables direct detection of exoplanets (using a coronagraph to block out star background light)[2]. WFIRST has a design lifetime of 6 years and will be launched to Earth-Sun L2[1]. The WFIRST observatory is NASA's newest flagstone astronomy mission and is currently nearing SRR (Systems Requirement Review). The mission aims to detect exoplanets that are much closer to their parent star by achieving a high level of contrast (a goal of 1 part per billion contrast)[3]. This will allow for detection of planets similar to those in our solar system that lie within 3 to 10 AU of their parent star [3]. Figure 1 depicts simulated exoplanets that will be detectable at WFIRST's baseline contrast goal of 1 part per billion and 0.2 arcsecond star-exoplanet separation.

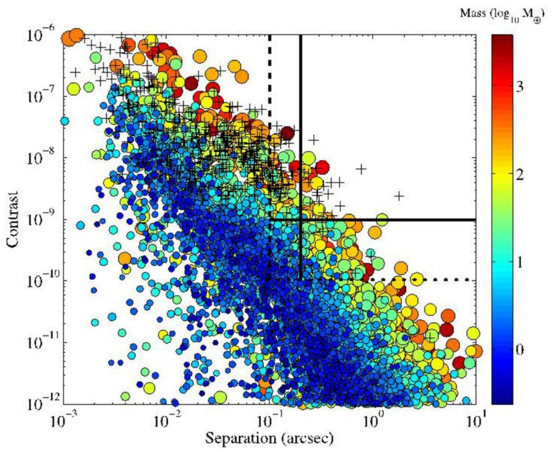

Figure 1: Detectable Planets based on WFIRST requirements. Solid black lines indicate baseline technical goals while dotted line is stretch goals. Detectable planets are above and to the right of contrast and exoplanet-star inner working angle (separation) goals. Mass of exoplanet is shown by color of marker. [3]

In order to achieve the high contrast necessary for imaging exoplanets, the

WFIRST observatory is using a coronagraph to block out background light of host stars during the search for exoplanets. Imaging of exoplanets requires precise control over optical surfaces, and precisely modeling optical surface aberrations and misalignments is required to ensure that the imaging system can meet mission requirements during all operating scenarios. The WFIRST coronagraph's performance is dependent upon the thermal environment of the observatory (which is a function of the operating scenario) and as such differing operating scenarios will have different performance capabilities. Full-scale optical and thermal testing are impractical due to the scale of the observatory and limitations of ground support equipment and testing facilities (due to gravity sag of primary mirrors and the presence of unexpected thermal disturbances) making modeling a critical method of requirement verification [4].

JPL has developed IMPipeline, an integrated structural, thermal, and optical (STOP) modeling pipeline that serves as an interface between modeling software such as thermal desktop and SigFit [1]. The IMPipeline software is currently being used (but is in a prototype phase) to generate wavefront errors based on thermal and mechanical deformations caused by WFISRT operating scenarios. Over the summer, I will support the WFIRST Coronagraph Instrument (CGI) team and generate a library of expected wavefront errors for operational scenarios and improve the IMPipeline software. This library will be used to determine baseline imaging performance of the WFIRST mission and show that it meets requirements as the design matures.

2 Objectives

I plan to support the WFIRST STOP modeling team by improving the IMPipeline software by adding data visualization during intermediate steps and generating a library of expected wavefront errors for expected operational scenarios of WFIRST. I will be using the IMPipeline to generate these libraries which will be verified by external STOP models. The addition of a data visualizer will allow for inspection of results during software operation. Both of these tasks will help the CGI team to understand the performance of the WFIRST coronagraph and define the interfaces between the coronagraph and the WFIRST observatory. The project will be considered a success if data visualization is added to the software and if a complete set of coronagraph libraries are generated.

3 Approach

In order to improve the IMPipeline software, I will first familiarize myself the IMPipeline software and run baseline analysis in order to develop proficiency with the software. I will then add in data visualization to IMPipeline intermediate steps. The block diagram seen in Figure 2 shows a high level overview of the IMPipeline software. Data visualization steps will be added after modeling output steps (blue blocks). Finally, a complete set of wavefront errors will be generated using the IMPipeline software. If the project is ahead of schedule I will improve the automation of the IMPipeline software such that it will be automatically capable of developing new libraries when instrument models change.

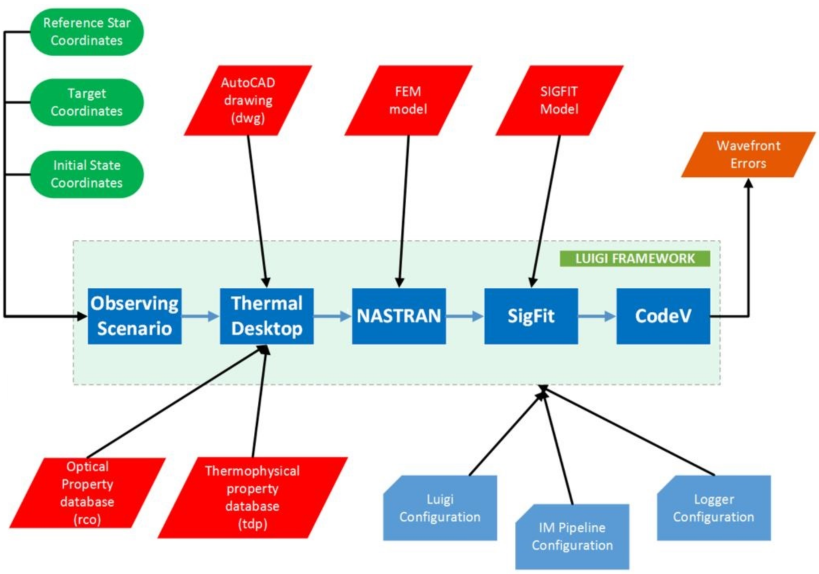

Figure 2: Block Diagram of IMPipeline software. [1]

4 Project Schedule

The schedule for the project will be as follows.

1. Weeks 1 to 2: Learn how IMPipeline software tool works
2. Week 3: Run baseline operational scenarios
3. Week 4 to 6: Develop data visualization for intermediate IMPipeline steps.
4. Week 7 to 9: Compile library of complete set of wavefront errors
5. Week 10: Improve automation of pipeline

References

[1] Navtej Saini et. all. Impipeline: An integrated stop modeling pipeline for the wfirst coronagraph.

[2] Loura Hall. Wfirst-afta: Groundbreaking space observatory to image exoplanets and tackle a universe of questions. `https://www.nasa.gov/feature/wfirst-afta-groundbreaking-space-observatory-to-image-exoplanets-and-tackle-a-universe`. Accessed: 2016-7-15.

[3] Catherine Peddie. Exoplanets - direct imaging. `https://wfirst.gsfc.nasa.gov/exoplanets_direct_imaging.html`. Accessed: 2017-5-30.

[4] Effinger Robert. Jpl summer internship. Discussions with mentor over Email.