A COMBINED SPACECRAFT AND LAUNCH VEHICLE SYSTEMS APPROACH TO MISSION DESIGN FOR THE IRIS MISSION

Mark E. Hametz[1], **C.D. Eagle**[2], **Eric M. Haddox**[3], **Christopher M. Hoffmann**[4], **and Samuel Vaughn**[5]

[1]*a.i. solutions, Inc., Mail Code: AIS-20, KSC, FL 32899, 321-867-2595, mark.hametz@ai-solutions.com*

[2] *a.i. solutions, Inc., Mail Code: AIS-20, KSC, FL 32899, 321-867-8913, david.eagle@ai-solutions.com*

[3]*NASA Launch Services Program, Mail Code: VA-H1,KSC, FL 32899, 321-867-8949, eric.m.haddox@nasa.gov*

[4]*Lockheed Martin ATC, 3251 Hanover Street, Palo Alto, CA 94304, 650-354-5274, christopher.m.hoffmann@lmco.com*

[5]*Orbital Sciences Corporation, 45101 Warp Drive, Sterling, VA 20166, 703-406-5719, vaughn.samuel@orbital.com*

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ABSTRACT

The Interface Region Imaging Spectrograph (IRIS) mission successfully launched aboard an Orbital Sciences Pegasus XL launch vehicle on June 27, 2013 from Vandenberg Air Force Base (VAFB). IRIS is a National Aeronautics and Space Administration (NASA) Small Explorer (SMEX) mission to observe how solar material moves, gathers energy, and heats up as it passes through a little-understood region in the Sun's lower atmosphere. Observing how material and energy move through this region is a crucial part of understanding the dynamics of the Sun. It can help explain what causes the ejection of solar material that travels toward Earth and causes space weather that can disrupt human technology. The concept of operations is for IRIS to point continuously at the Sun and conduct coordinated solar observations with other satellites and ground-based observatories. To conduct science observations, the IRIS spacecraft requires periods of continuous eclipse-free viewing of the Sun. Specifically, the mission orbit must provide IRIS with a minimum of 7 months of eclipse-free time (EFT) the first year and maximize the probability of achieving 7 months per year of eclipse-free viewing averaged over the first two years, starting one month after launch.

A typical spacecraft mission will have a well-defined orbit solution early in the planning phases based on the science objectives. Therefore, the launch vehicle trajectory design will focus on either delivering the spacecraft to that mission orbit, or to an intermediate transfer orbit that is followed by spacecraft maneuvers to reach the final mission orbit. For example, a launch into a geosynchronous transfer orbit (GTO) is often optimized to minimize the spacecraft delta-V needed to achieve a geosynchronous mission orbit. For the IRIS mission, the EFT science requirements drove the mission design, but allowed for a large trade space of orbit options. In addition, the IRIS spacecraft had no propulsion system – the launch vehicle injection orbit would be the mission orbit. Consequently a unique, integrated systems analysis approach was used

over the course of the mission integration process to achieve a final mission orbit design that balanced the launch vehicle trajectory and performance with maximizing the IRIS EFT.

The first step in the mission integration process is the launch vehicle selection. NASA's Launch Services Program (LSP) selects the vehicle following a competitive bidding process for all qualified vendors on the NASA Launch Services (NLS) II contract. As part of the Task Order process, each proposal must include a mission solution that demonstrates how the mission requirements would be met. For IRIS, the core requirements were based on EFT. The calculation of this parameter involved propagating the various injection orbits and following a specific set of criteria that defines a valid EFT. The flexibility in the final orbit solution thus required some level of custom development to perform the EFT calculations as part of the proposal. Therefore, to better address this mission unique requirement and to ensure consistency from each proposal, LSP developed a tool (IRIS_EFT) that would allow users to quickly perform accurate EFT performance assessments based on an initial injection orbit. This tool was then later used in the design studies that followed.

Once the Pegasus launch vehicle was selected, an orbit trade study was conducted between LSP, the IRIS Project, and Orbital Sciences to determine an optimal mission design for IRIS as a combined spacecraft and launch vehicle system. The EFT science requirements described above were the primary driver for the mission orbit. In general, higher altitude, Sun-synchronous orbits improve EFT periods. However, the spacecraft also had radiation and orbital debris requirements that limited the available altitude range. Furthermore, since the launch vehicle injection orbit achieved on launch day would be the IRIS mission orbit, the Pegasus capabilities were included in the analyses to select the target orbit. This included the vehicle performance, orbital debris compliance, and dispersion characteristics. Additionally, the Pegasus vehicle offers multiple guidance scheme options. Therefore, a trade study was also performed to select the best guidance method that maximized the probability of meeting mission science requirements.

This paper details the results of the integrated spacecraft and launch vehicle mission design trade studies, which led to the final orbit targets and Pegasus launch vehicle guidance scheme for the IRIS mission. Following this integrated design approach, the IRIS mission was successfully launched into a nominal orbit. The resulting EFT predictions are presented which show science observations are expected to exceed the 7-month requirement not only for the baseline two-year mission, but will continue to exceed the 7-month EFT requirement an additional four years.