National Aeronautics and Space Administration

Wallops Arc Second Pointer (WASP)

WASP is a NASA provided support system, developed at NASA's Wallops Flight Facility (WFF), which points science instruments on balloon gondolas at targets with arc-second accuracy and stability. WASP can support a variety of science-provided instruments and sensors, and multiple science disciplines, to meet specific mission performance requirements. Pointed masses over 600 kilograms and instrument dimensions over one meter in diameter and eight meters in length can be supported. Major components of WASP are reusable which reduces the overall costs to the BPO and to users. Collaborative design, analysis, integration and flight support services are available from WFF for proposers who want to use WASP.

Since its inaugural flight in 2011, the WASP system has been used to provide fine pointing of five unique scientific instruments during the conduct of eight balloon flights. WASP has demonstrated positional stability at sub-arc-second levels during flight. In September of 2013, WASP supported its first pointed science instrument, the HyperSpectral Imager for Climate Science (HySICS), provided by the Laboratory for Atmospheric and Space Physics (LASP), which is an institute at the University of Colorado at Boulder (CU).

Figure One - Test Flight 1 (TF1) Gondola on Launch Vehicle

The WASP system points an instrument (modeled during TF1 by a 24-ft 1500-lb steel beam) using a gondola mounted pitch/yaw articulated gimbal. The range of motion of the yaw-gimbal is purposely minimized to reduce kinematic coupling during fine pointing. Thus, the gondola itself is suspended beneath a standard NASA Rotator to provide large angle azimuth targeting and coarse azimuth stabilization.

Sub-arc-second pointing is enabled by the design of the WASP gimbal hubs. A pair of hubs on opposing sides of the gimbal is used to establish each articulated axis of rotation. Each hub uses high-precision angular contact bearings to float the rotor side and stator side of the hub on a central shaft. The central shaft in each hub is constantly rotated by a small diameter torque motor to eliminate static friction.

A large-diameter brushless DC torque motor is used to provide the torque for each control axis. The current in the three electrical phases in each of the control motors is commutated in software and set using power Op-Amps in a motor interface circuit.

Instrument attitude is computed by integrating incremental angles (delta-Theta) output from a LN251 system. While the LN251 is a fully capable GPS/INS navigation system, its use on the WASP system is limited to that of a relatively low-cost, high-quality inertial-rate-unit. Control torques are computed using a modified Proportional-Integral-Derivative control law in each axis. During the TF1 WASP demonstrated the ability to inertial pointing with sub-arc-second stability.

After the initial test flight of WASP in 2011, a number of system modifications and improvements were made that included: incorporating a Star Tracker into the control system loop, changing the mock telescope from a 24 foot steel tube to a 16 foot tube with less inertia, moving the avionics deck from the outer frame to the mock telescope, and adding angular positional encoders to the Resolver Hubs.

The third and fourth flights of WASP, which occurred in the fall of 2013 and 2014, included the HySICS science instrument provided by LASP, and successfully completed scan maneuvers of the sun and observations of the earth, moon and earth limb. This flight successfully tested several new WASP system enhancements, and demonstrated WASP's ability to be integrated with science and provide flight support.

Figure Two – WASP HySICS Integrated Gondola

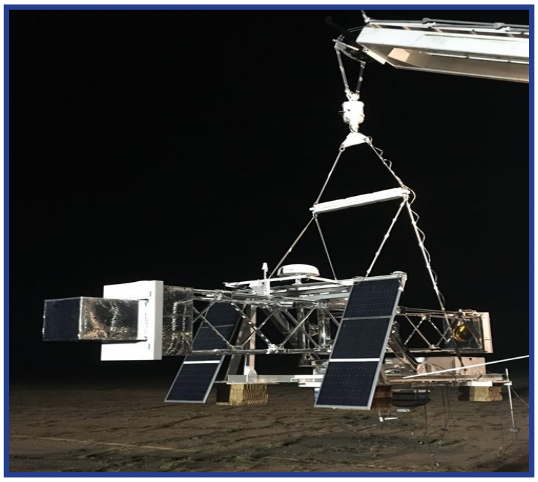

Figure Three - New Mexico WASP/X-Calibur Gondola

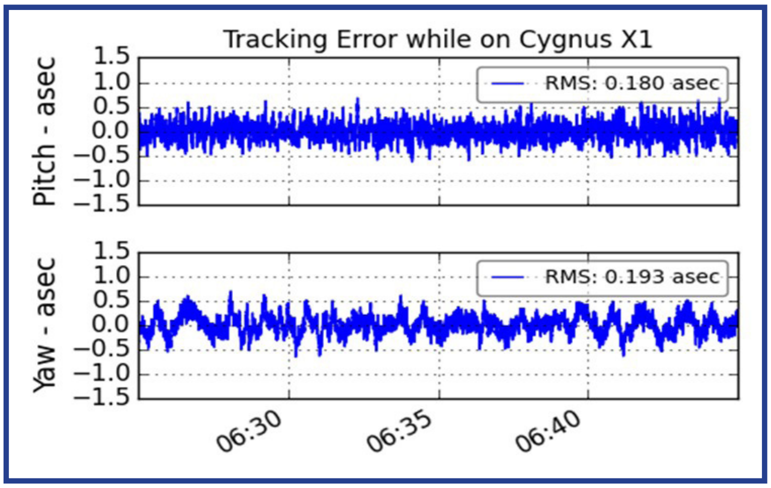

Figure Four - Tracking Error while on Cygnus X1

After multiple successful test flights, in 2016 WASP supported the first science support mission with X-Calibur from Fort Sumner, New Mexico and in 2018 supported the second flight with X-Calibur from McMurdo, Antarctica. X-Calibur, provided by Washington University at St. Louis (WUSTL), is a Hard X-Ray Polarimetry Telescope operating in the 20–60 keV energy range that observes mass accreting black holes and neutron stars. The X-Calibur missions introduced additional WASP enhancements which included a NASA Wallops developed Star Tracker with an in-flight alignment process and long duration autonomous operations.

During the 2016 WASP flight, the balloon carried the approximately 4,000lb gondola/telescope structure to over 120,000 feet altitude. WASP was successful at pointing at multiple targets including: Crab Nebula, Scorpius X-1, Cygnus X-1, and GRS1915+105.   Figure three depicts

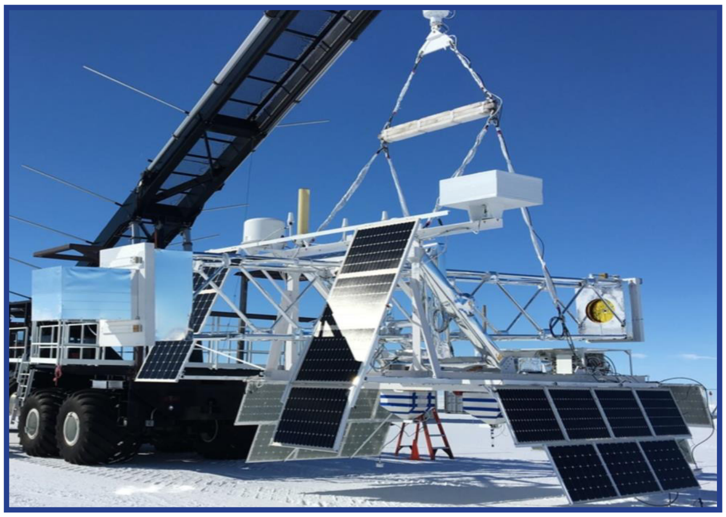

Figure Five – Antarctica WASP/X-Calibur Gondola the New Mexico WASP/X-Calibur design configuration.

For the second X-Calibur flight out of Antarctica, the primary science requirement levied on WASP was to hold the X-ray mirror axis to within 30 arc seconds of the target source during each observation. During the flight, WASP maneuvered to and acquired multiple X-ray sources and provided pointing stability between 1.0 - 3.6 arc seconds while on the source. WASP pointing was spent primarily on two targets: GX 301-2 and Vela X-1. The targets were complementary in that there were no times when both sources violated a lower or upper look elevation constraint.

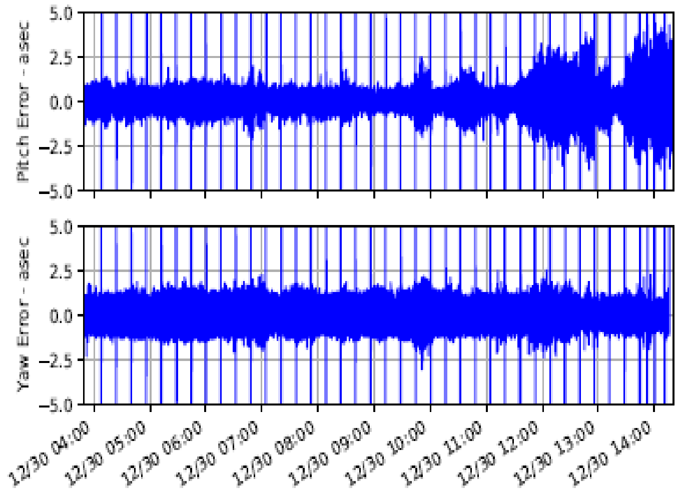

Figure Six – Raw controller errors during 1st observation GC301-2 (includes offset pointing)

In the fall of 2019 at Fort Sumner New Mexico, WASP supported two science instruments launches, the Balloon-Borne Investigation of Temperature and Speed of Electrons (BITSE) provided by Goddard Space Flight Center and the Planetary Imaging Concept Testbed Using a Recoverable Experiment Coronagraph (PICTURE-C) provided by University of Massachusetts, Lowell.

BITSE was a technology demonstration project. The long term scientific goal enabled by BITSE will be to understand the physical conditions in the solar wind acceleration region (3-10 solar radii from the Sun center). The BITSE experiment was aimed to validate the technology and performance of a new type of coronagraph to simultaneously measure electron density, velocity, and temperature. During the flight, WASP held track on the sun exhibiting the best performance seen on a WASP flight to date. The pitch and yaw pointing error RMS varied between 0.15 - 0.20 arc seconds throughout the science pointing window. During this time, the science team reported they captured over 17,000 images of the sun with their instrument.

Figure Seven – WASP/BITSE during Compatibility Testing

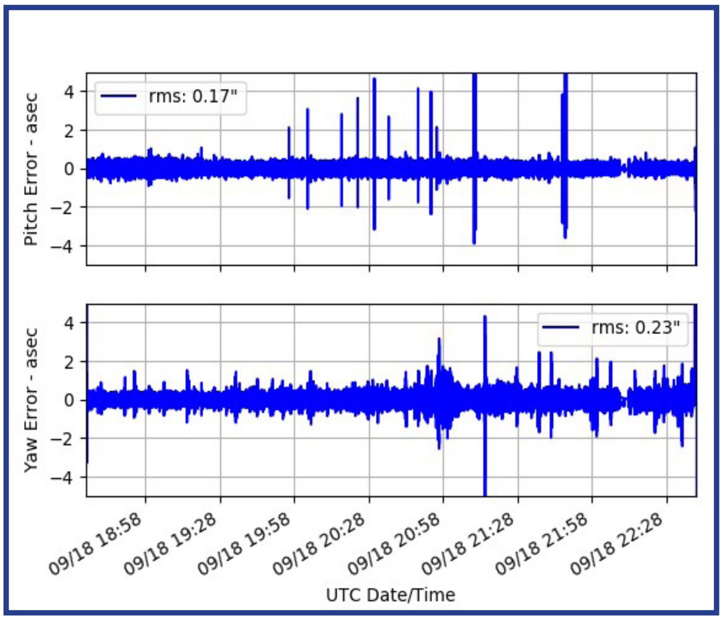

Figure Eight - BITSE Pointing Performance

PICTURE- C took the next steps along the road to characterizing Earthlike planets, in Earthlike orbits, orbiting Sunlike stars. It demonstrated with a high altitude balloon based clear aperture telescope with Low Order Wavefront Control (LOWC), provided a flight demonstration of a high performance Vector Vortex Coronagraph (VVC), and raised the TRL of an integral field detector, the Microwave Kinetic Inductance Detector (MKID). During daytime and nighttime target pointing operations, the WASP system was utilized to maneuver to, acquire, and station-keep on 4 science targets and 4 calibration targets. During target station keeping operations, WASP consistently yielded sub-arc second pointing performance with pointing RMS values that varied between 0.15” and 0.8” depending upon the controller gain settings utilized. PICTURE-C continued its efforts during a fall 2022 flight from Fort Sumner New Mexico with another successful flight. While analysis of the flight data is still ongoing, preliminary results reveal what looks like the most stable pointing performance of the WASP system to date.

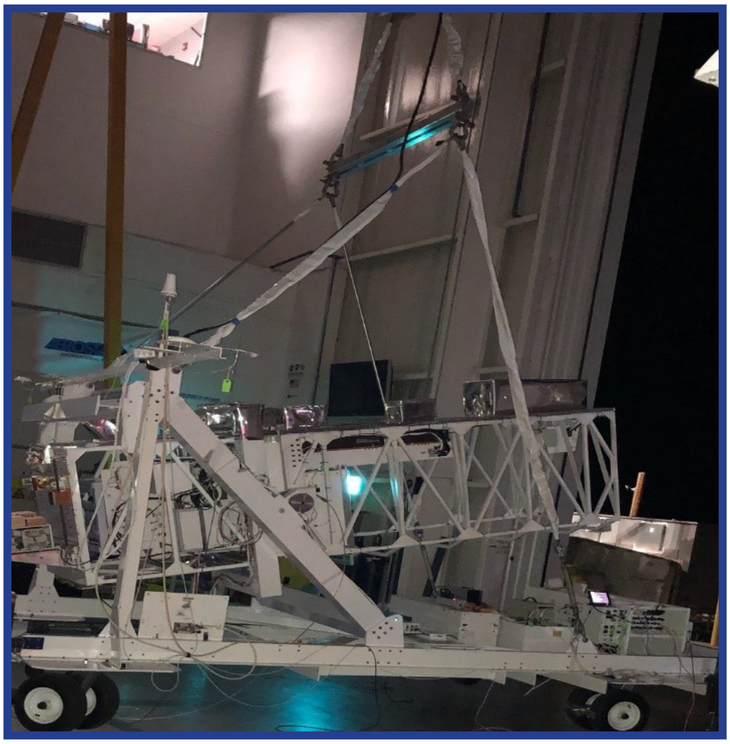

Figure Nine- PICTURE C Pointing Calibration

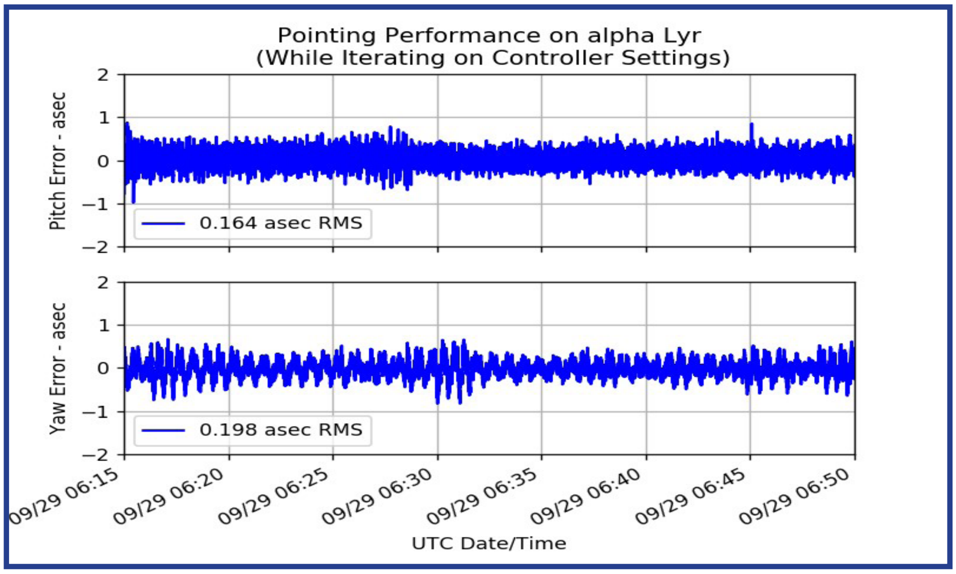

Figure 10 - PICTURE C Pointing Performance

WASP has demonstrated excellent performance during all flights and is available for science groups to propose as a solution to their fine-pointing needs. Proposals may include WFF-provided collaborative design, simulation, analysis, integration, and field support.

For more information on WASP, please contact the NASA Project Manager at WFF, Mr. Edward Udinski at edward.p.udinski@nasa.gov

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