WASP is a NASA developed Fine Pointing System adaptable to a variety of Science Instruments. Standardized System with Reusable Parts to Minimize the Cost to Users and NASA. Supports Multiple Science Disciplines and a wide range of Masses and Inertias. Currently Operational and Available for Science Collaborations.
WASP Functional Overview

- Rotator provides coarse azimuth pointing of gondola (to within $\pm3^\circ$)
- Fine instrument pointing achieved using gondola mounted pitch/yaw gimbal
- Two opposing gimbal hubs per axis enable sub-arcsecond stability with a design that eliminates static friction
- Control torque for each axis provided by large diameter brushless DC torque motor
- Instrument inertial attitude integrated from LN251 Fiber Optic Gyro
- Extended Kalman Filter (EKF) used to merge unit vectors from Star Tracker and other sources (e.g. sun sensor or science target) into integrated solution
- Control torques computed from modified Proportional-Integral-Derivative (PID) compensator in each axis
• **Gimbal Frames** hold Hubs, Maintain alignment critical to minimize required torque.
• **Outer Frame** can be used as Gondola Structure.
• **Recent Developments**
  – Larger Inner Frame Provides full 1 meter clearance with existing Outer Frame
  – XL Design provides ~1.2 meter clearance and has embedded hubs to eliminate counterweights

**WASP Standard Parts**

- **X-Calibur Larger Inner Frame**
- **GHAPS XL Inner Frame**
**WASP Motor Hubs and Resolver Hubs**

- Each Axis uses One Motor Hub & One Resolver Hub.
- Constantly Rotating central shaft eliminates static friction (Stiction) when direction is reversed.
- Shaft Rotated with Electric Motor through Reduction Gear.
- Motor Hub has large diameter Torque Motor which provides the control torque.
- Resolver Hub has resolver which provides Angle Measurement between two halves of the Hub.
- Hubs support full mass of Pointed Structure and 10 G loading.
WASP Avionics Deck & Gyro

Avionics Deck
- ~21” x ~17” aluminum deck

3 Axis Fiber Optic Gyro
- Northop Grumman (NG) LN-251 Inertial Navigation System
- Used by WASP as Inertial Rate Unit (IRU).
- NG installed new firmware in 2016 reducing noise and improving pointing performance.
Dynamic Balance Trim Weights
- Three Dynamic Balance Trim Weights flown, one in each Axis.
- Commanded from Ground if needed.
- Brass Weight driven by small DC motor.

Caging Mechanism
- Linear Actuator and electric motor driven cam provide redundant methods for releasing and recaging.
- Uncage - Linear Actuator shaft retracts or motor cam pushes latch hook.
- Cage – Shaft extended, hook spring loaded or drive into place, then extend shaft.
**WASP Daytime Star Tracker**

- **CARDS – Celestial Attitude Reference and Determination System**
  - COTS camera and processor, custom light baffle
  - Low-cost system for providing attitude inputs into WASP Control System

- **Operational specifications**
  - Point Grey Camera, 100 mm Stingray Lens, RTD flight processor
  - Field of View: 5.9 x 4.4 degrees
  - Tracking solutions: 10 Hz
  - Supplies target matched unit vectors or quaternions, depending on the application, over Async Serial or Ethernet interface
WASP Test Flights

- 5 Test Flights conducted between 2011 and 2014
- All 5 from Fort Sumner, New Mexico
- Three Flights included Science Instruments
  - 2 flights with LASP Earth Science (HySICS)
  - 1 flight with GSFC Planetary and Exoplanet Science (OPIS)
- All 5 demonstrated arc-second pointing
First Science Mission with WASP

PI Henric Krawczynski, Washington University in St. Louis (WUSTL)
- Measure Linear polarization of hard X-rays in the energy range of 25-70 keV.
- 255 shell X-ray focusing mirror and a rotating Polarimeter.
- Rigid truss to maintain alignment between mirror and the detector 8 meters away

Pointing Requirements
- Compute attitude with knowledge uncertainty within 30-asec (3-sigma)
- Hold X-ray mirror boresight to target within 30-asec (3-sigma)

September 17, 2016, flight duration 24 hours and 37 minutes
- Fort Sumner, NM. Longest flight of WASP to date
X-Calibur Science Flight

X-Calibur High Elevation Pointing Test at Fort Sumner

X-Calibur on Launch Vehicle

X-Calibur Pointing during Flight
X-Calibur Pointing Performance

- Tracking errors consistent with preflight simulation and ground testing – sub-arc second.
- Star Tracker Residual provide indication of attitude estimation errors that contributes to absolute pointing error
- Roll coupling into pitch/yaw axes indicative of misalignment between Star Tracker and Inertial Rate Unit
- Able to identify misalignment by batch processing 5-10 min segments of flight data

Post Flight Improvements
- Misalignment correction technique ground tested that eliminates roll coupling.
- New centroid algorithm ground tested that improves daytime performance with high ambient background levels.
- Both to be tested on 2017 WASP Test Flight.
WASP 2017 Test Flight

- Combined with CSBF LDB Test Systems
- Includes refurbished parts of X-Calibur, OPIS, and Test Flight Two
- Evaluate daytime Star Tracker performance improvements.
- Evaluate flight prototype GHAPS Baffle for star tracker.
- Evaluate GHAPS configuration of modified WASP Avionics mounting locations.
- Sept. 2017 Fort Sumner
Current WASP Mission Support

PICTURE-C
Planetary Imaging Concept Testbed Using a Recoverable Experiment – Coronagraph
- PI Supriya Chakrabarti U Mass Lowell (UML)
- 60 cm Telescope with Coronagraph to Image Debris Disks of Nearby Systems
- Flights planned for 2018 and 2019.

GHAPS
Gondola for High Altitude Planetary Science
- NASA – GRC, MSFC, GSFC, WFF
- Developing a Reusable Gondola Platform for Planetary Science Instruments
- One Meter optical telescope, UV, IR, visible
- Initial flight planned for 2020.